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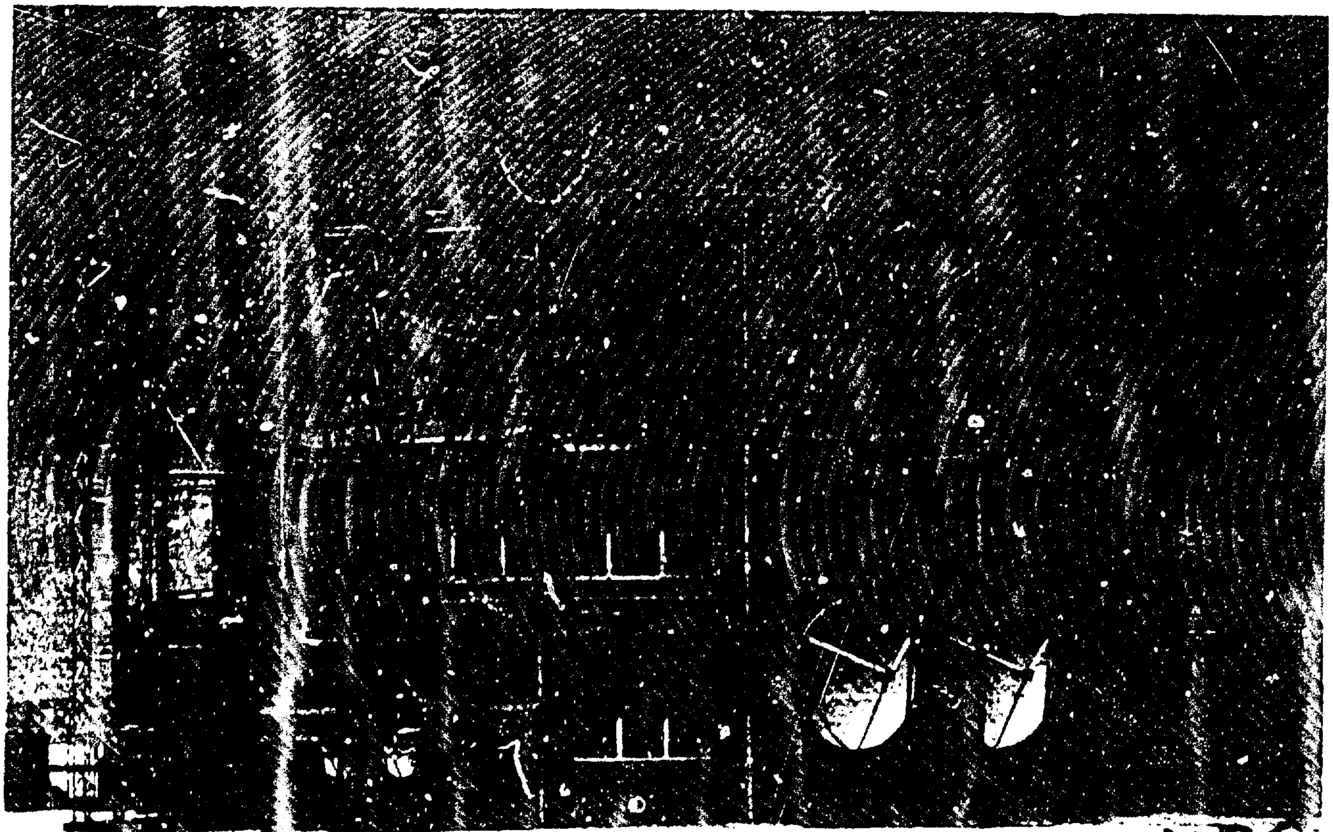
RAT SCAT

RADAR TARGET SCATTER SITE



AIR FORCE SYSTEMS COMMAND
RADAR TARGET SCATTER FACILITY
AIR FORCE MISSILE DEVELOPMENT CENTER
HOLLOMAN AIR FORCE BASE NEW MEXICO

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Attention: Chief, Radar Target Scatter Facility, (MDLRR)

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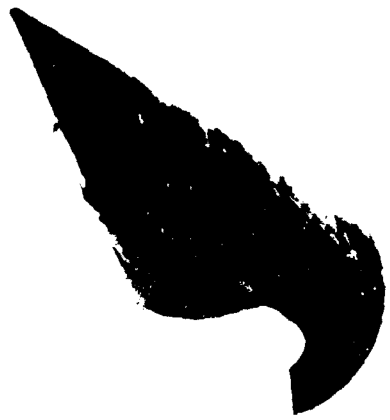
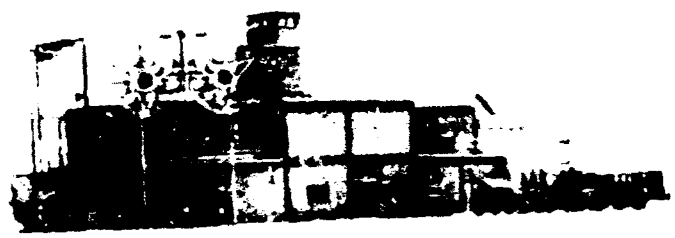




section 1

RADAR TARGET SCATTER SITE

SECTION 1

RADAR TARGET SCATTER SITE

This brochure has been prepared to acquaint potential users with the capabilities of the Radar Target Scatter Facility which will be referred to as RAT SCAT. Available for use by all government or non-government agencies, RAT SCAT is a complex of ground plane radar cross section measurement ranges which is located on the Alkali Flats near Holloman Air Force Base, New Mexico. RAT SCAT was authorized by the Department of Defense. Through FY64, the site was under the auspices of Rome Air Development Center. Effective 1 July 1964, the RAT SCAT Program, Operations and Maintenance came under the AIR FORCE MISSILE DEVELOPMENT CENTER (MDLRR), Holloman AFB, New Mexico.

The RAT SCAT complex is used to measure the static Radar Cross Section (RCS) of actual or scale models of aerospace craft such as nose cones, re-entry vehicles, decoys, satellites, etc. RAT SCAT data may then be used as criteria for increasing or decreasing the RCS of the measured vehicle. The continuing development of advanced measurement techniques and facilities can provide data which is required by the theorist and designer for evaluating both new theories and design techniques. Both experimental and theoretical work are aimed at a continuing achievement of the overall objective set for RAT SCAT, i.e., the provision of a reflectivity measurements range with "National Bureau of Standards" quality so that the standards of measurement, obtained under strict Air Force control, will be universally accepted as scientific data.

The RAT SCAT site utilizes pulsed radar, range-gated, and ground plane range techniques. Target radar cross sections between 10^{-6} and 1000 square meters were anticipated in the design of the equipment. The RAT SCAT fixed distance ranges are nominally referred to as the 500, 1200, and 2500 feet ranges. For purposes of calculations the target rotators are actually 458, 1158, and 2458 feet, respectively, from the reflector mounting points. Other range lengths are available through the use of mobile vans. Frequency coverage is continuous between 100 megacycles and 12.0 gigacycles. It is anticipated that the frequency coverage will be 30 megacycles to 12.0 gigacycles by June 1966. A minimum of 1 kilowatt power is available. Average receiver sensitivity is -100 dbm, and the linear dynamic range of the receivers is 50 db. By preceding the receiver with variable precision attenuation and by precision attenuation of the reference signal, the dynamic range may be positioned to encompass any portion of the dbsm range of the equipment (i.e., -80 to -30, -20 to +30, etc.). Bistatic as well as monostatic measurements are available as amplitude measurements. In addition to amplitude measurements, relative phase measurements and an online (real-time) vector field subtraction (VFS) technique are available. The phase measurements and the VFS techniques are direct results of the continuing program to increase the RAT SCAT capabilities. Measurements can be made using horizontal, vertical, circular or elliptical polarization. Target weights of 10,000 pounds and target lengths up to 60 feet can be accommodated. Operation of the site will meet the current and future need for making static radar cross section measurements of advanced full-scale re-entry vehicle designs and of certain other selected targets. The site represents an appreciable extension of the state of the art of radar cross section measurement.

In a ground plane range, use is made of the radar energy reflected from the earth as well as the radar energy traveling directly to the proper heights. Coherent phase addition of these electromagnetic fields enhances the loop sensitivity up to 12 db over free space conditions. On the other hand, radar returns from objects near the earth's surface are reduced; consequently, interference from such objects in the target area is also reduced. Target area interference is reduced further since target mounting platforms and rotators are located in pits below the surface of the range. A good cross section measurement range must enable the collection of data under simulated free space conditions. Background noise emanating from the range and target support structure must be reduced to only a small fraction of the energy reflected from the target. In addition, the target vehicle must be illuminated by a plane wave front of uniform intensity, and the mechanical support arrangement must permit precise and repeatable positioning of the target without alteration of the radar signature of the target.

Pulse rather than CW transmitters are used with a range-gated receiving system, which can measure radar returns from either the finite target or the range-displaced secondary standard alone. In addition, the background interference outside the target area is eliminated by range-gating. A comprehensive evaluation of each target test setup is made to insure that the target mounting techniques used will minimize the background effects on the radar signature of the target.

section 2
FACILITIES

SECTION 2

FACILITIES

The RAT SCAT site is located on the Alkali Flats near Holloman Air Force Base, New Mexico (see Figure 1). The site terrain is a flat plane composed of gypsum sand soil which is level. A square area two (2) miles by two (2) miles is assigned for site use. Almost unlimited range is available for future expansion. The facility includes a two (2)-story operations building with attached antenna towers, appropriate electronic equipment for operation over the frequency range of 100 to 12,000 megacycles, warehouses, three (3) target rotator pits, three (3) protective shelters(one (1) for each target rotator pit), monostatic and bistatic trailers with accompanying antenna towers, an electrical substation, ancillary support equipment and a bistatic road for each of the target rotator pits. The road through the dunes to reach the site is shown in Figure 2. This picture was made in November, 1962 (note the 70-foot dunes and the ground-breaking party). Over one-half million cubic yards of sand was removed in the construction of this road.

The site is laid out so that measurements can be made from the operations building at three ranges: 500 feet, 1200 feet, and 2500 feet (Figure 1). Measurements can be made at other distances by the use of mobile vans (monostatic and bistatic), and movable antenna complements which can be used with the same electronic equipment normally used in the operations building. This mobile equipment can be stationed at any position on the site, thus permitting any range length. Bistatic measurements, up to 120 degrees of bistatic angle, can be made on targets at all three (3) target rotator pits.

The operations building is the heart of the RAT SCAT site. It contains the electronic equipment (transmitters, receivers, control and data consoles, antennas and other equipment), a maintenance and radar instrumentation laboratory, a machine shop, a target preparation room, and offices. A sketch of the operations building is shown in Figure 3; the floor plan is shown in Figure 4. Antennas for each of the three (3) target ranges are attached to the outside of the building on movable racks in line with each respective target range. 2, 3, 6, 10, 16, and 30 foot antennas can be mounted on the racks for any one of the three (3) ranges and can be positioned as required.

The transmitter-receiver room is located on the first floor of the operations building immediately behind the antennas. The transmitters, monostatic receivers, and TWT power supplies are installed in this room. A portion of the equipment is illustrated on the cover picture of Section 3. All equipment racks are mounted on castered wheels so that any band of equipment can be located near the ports leading to any of the six (6) external

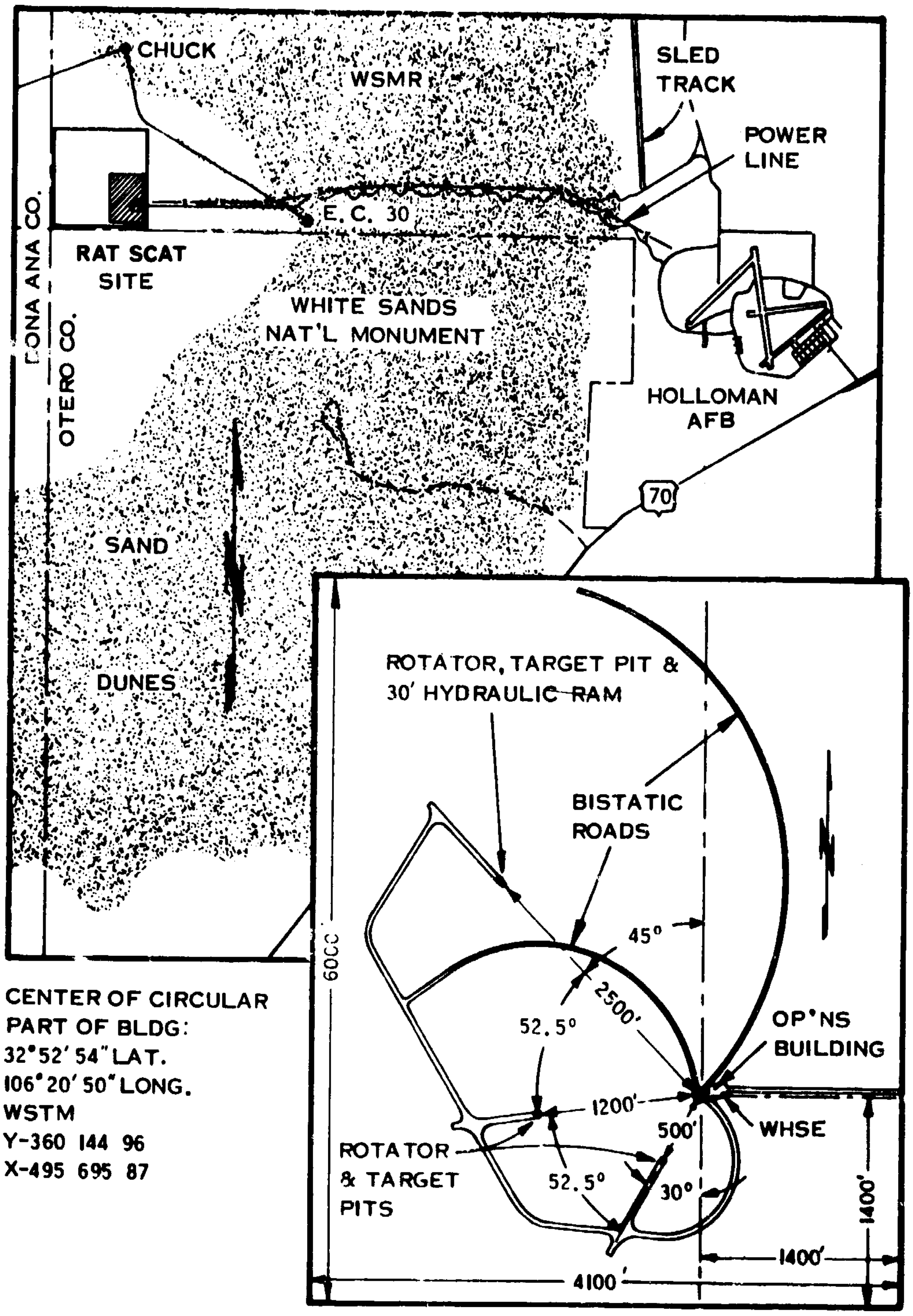


Fig. 1 MAP OF RAT SCAT SITE

Fig. 2 ROAD THROUGH DUNES

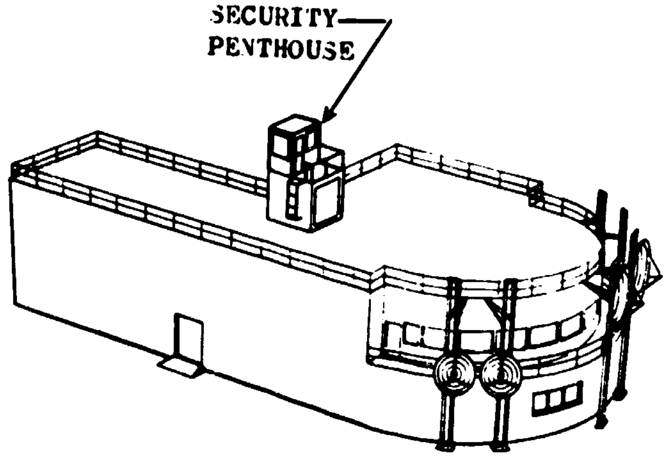


Fig. 3 OPERATIONS BUILDING

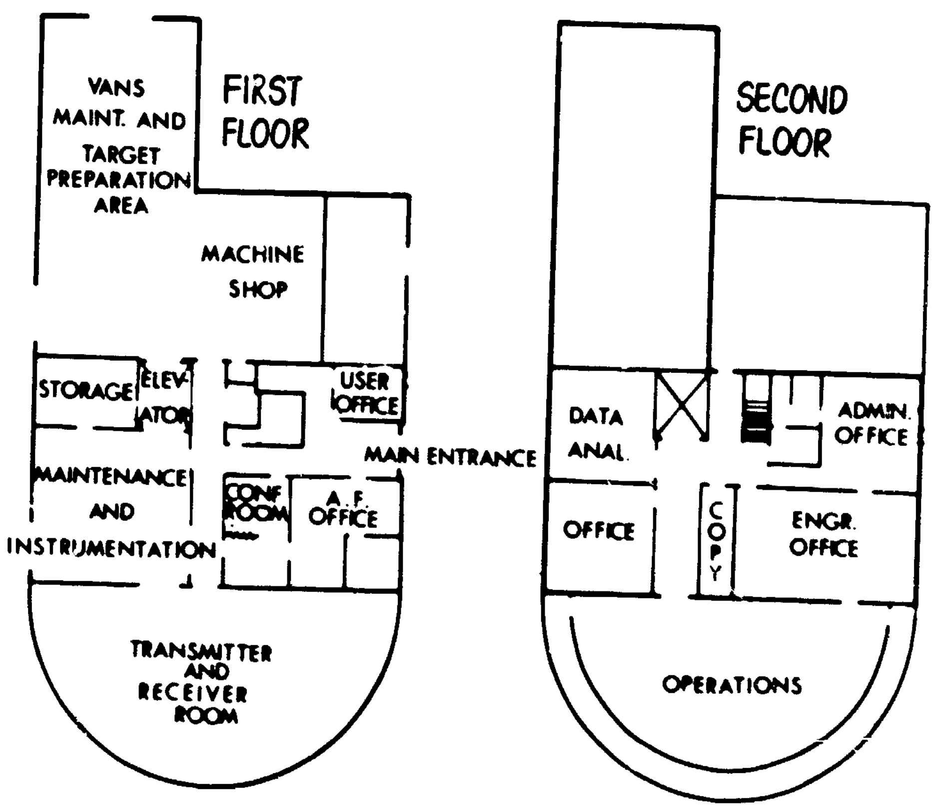


Fig. 4 FLOOR PLAN - OPERATIONS BUILDING

antennas. Mobility of the equipment also enables easy location for maintenance, calibration or installation into the mobile vans.

On the second floor, immediately above the transmitter-receiver room, is the control room which contains the control consoles, data consoles, polar recorders, computer, and distribution racks. A view of the control room is shown in Figure 5. The remainder of the second floor of the building contains rooms for engineering, data analysis, and offices.

The maintenance and instrumentation laboratory is located on the first floor, adjacent to the transmitter-receiver room. All of the specialized electronic equipment used for radar cross section measurements is subjected to periodic inspection and calibration under the supervision of Quality Control Representatives. These functions are accomplished in the Instrumentation Laboratory which is stocked with the special equipment required to achieve precise calibration alignment. A view of a portion of the laboratory is illustrated in Figures 6 and 7. The bench setup used to calibrate a precision attenuator is shown in Figure 6. Figure 7 is a photograph of the setup used for a 500-hour calibration of one of the receiver racks which has been moved into the Instrumentation Laboratory for a bench check. Trouble-shooting, repair, and maintenance can also be accomplished in the laboratory where the special equipment can be utilized. There are provisions for customer-user offices on the first floor.

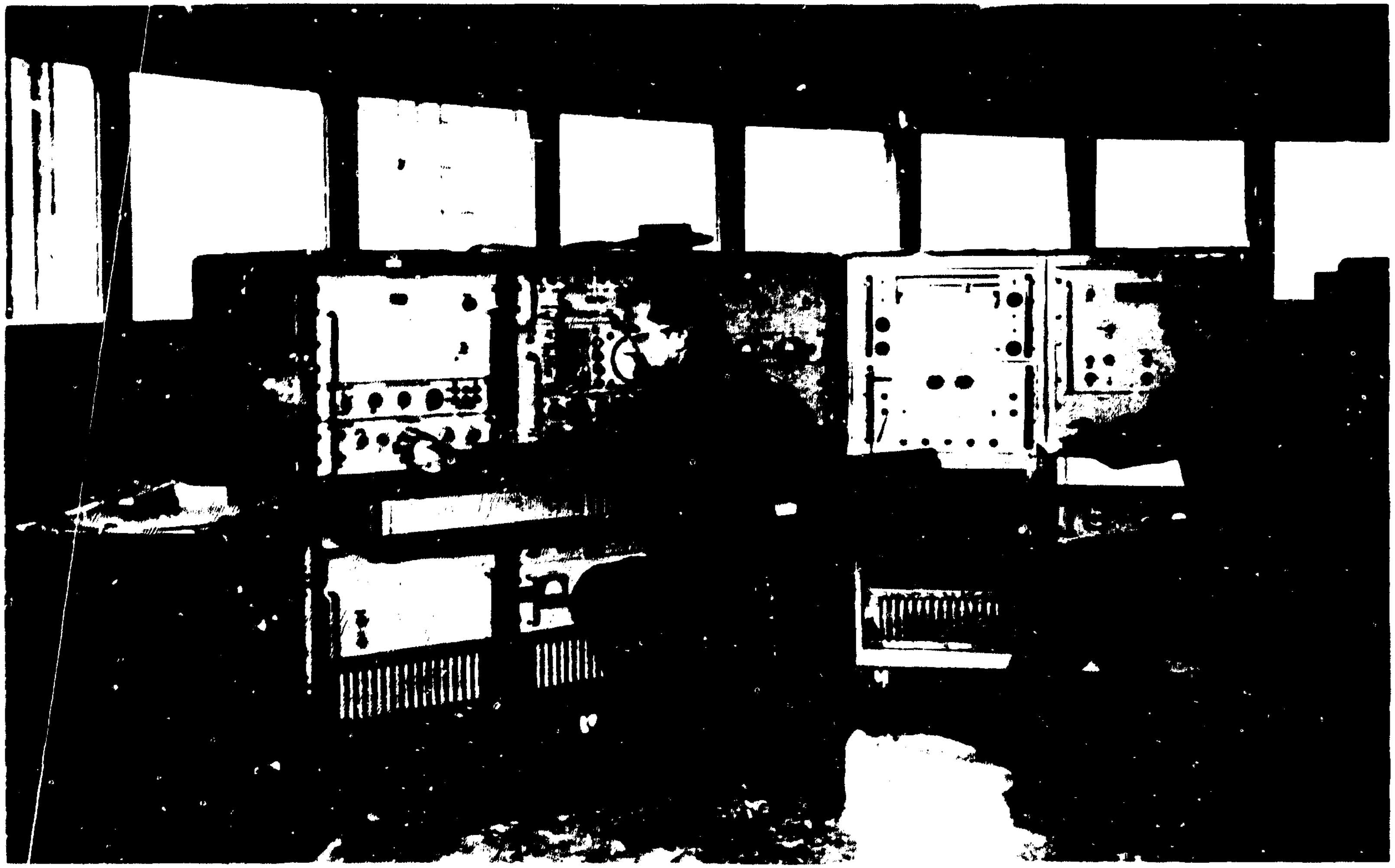


Fig. 5 CONTROL ROOM CONSOLES

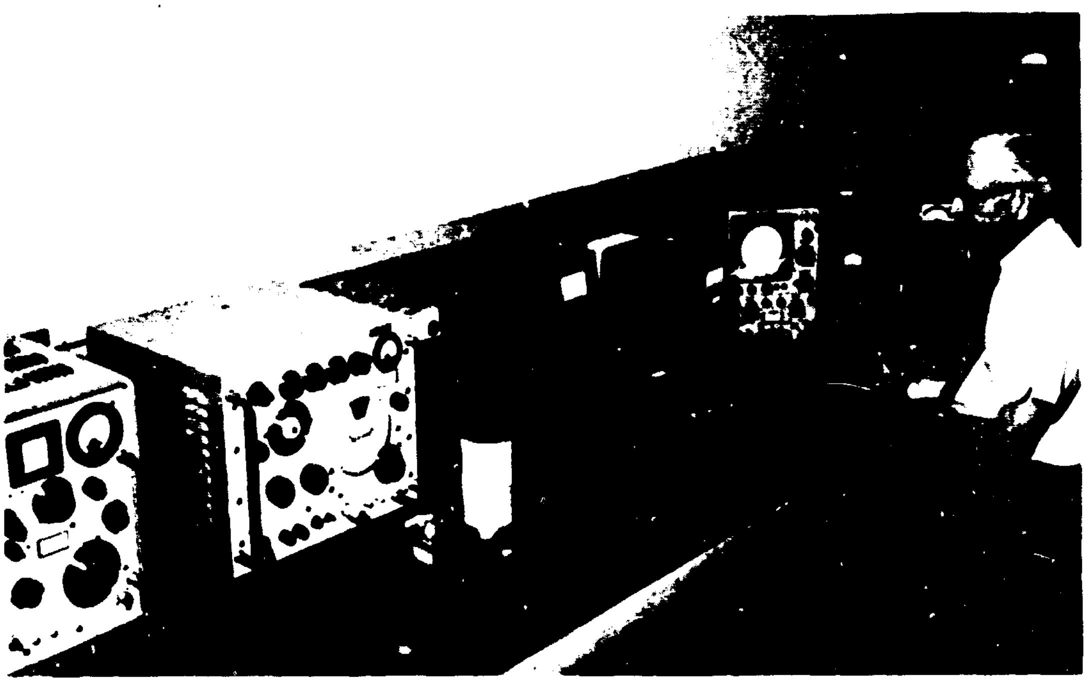


Fig. 6 CALIBRATION OF PRECISION ATTENUATOR (SECONDARY STANDARD)

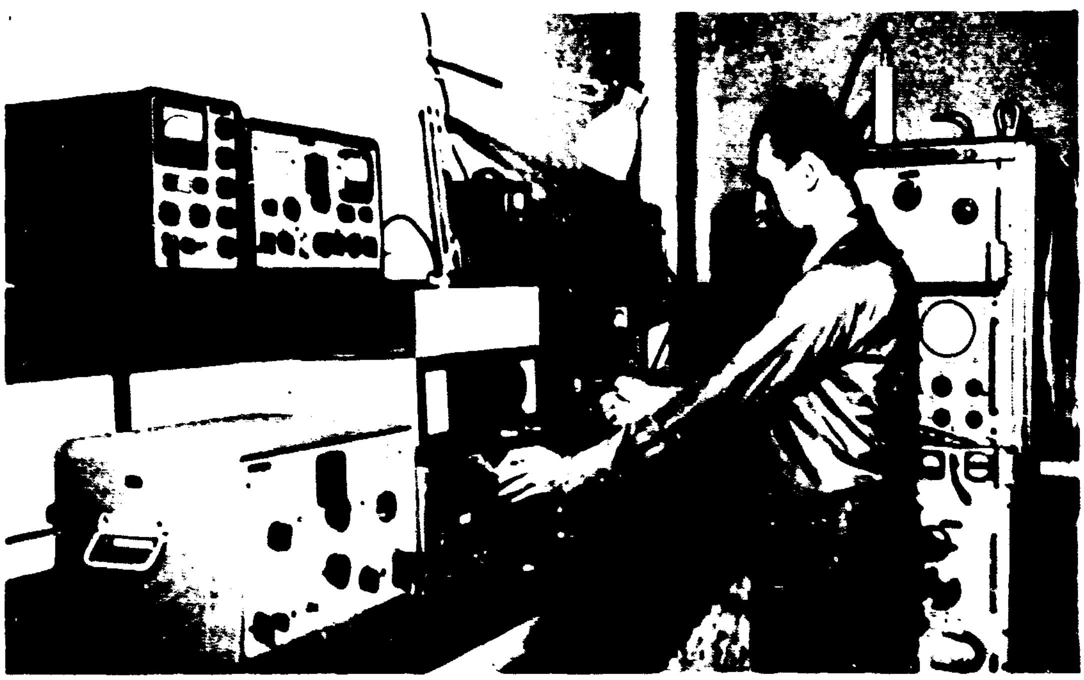
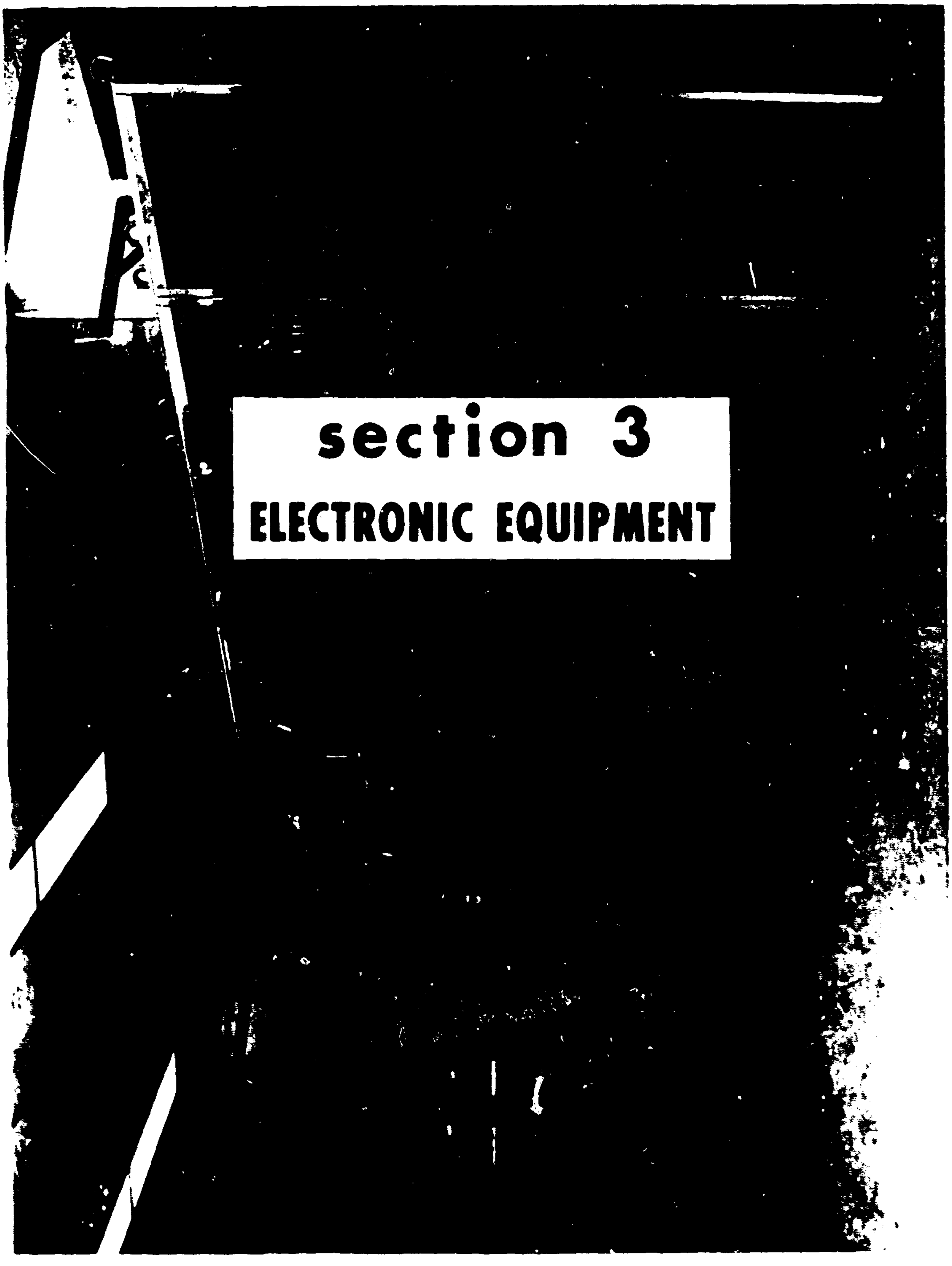


Fig. 7 CALIBRATION OF RECEIVER IN INSTRUMENTATION LABORATORY


section 3
ELECTRONIC EQUIPMENT

SECTION 3

ELECTRONIC EQUIPMENT

General

RAT SCAT electronic equipment includes the transmitters, receivers, data consoles, control consoles, antennas, and associated equipment necessary to measure radar cross section over a frequency range from 100 megacycles to 12,000 megacycles. In order to provide maximum flexibility and allow simultaneous operation at more than one frequency, the equipment has been constructed in functional blocks which are briefly described in this section. Circuitry used in a unique application for a particular frequency band has been included in the transmitters and receivers. Circuitry which is common to all frequency bands has been combined in the control consoles, data consoles, and power supplies. Seven (7) transmitters and fourteen receivers (two (2) per band) may be used in combination with other site equipment as required. Control consoles contain the equipment necessary to process receiver outputs to obtain radar cross section, rotator controls, oscilloscope monitoring, timing, and intercommunications circuits. The data consoles contain equipment necessary to record radar cross section in analog and digital form. Two (2) such consoles are provided. Each incorporates a digital capability for recording monostatic and bistatic cross section simultaneously. Mobile trailers are provided for bistatic measurements and for monostatic measurements at ranges other than the fixed ranges normally provided by operations from the operations building. A complete set of antennas and feeds, ranging from two (2) foot diameter paraboias to 30-foot paraboias are provided to cover the frequency spectrum with overlapping coverage. Representative equipment characteristics are listed in Annex 1. Seven bands of continuous pulsed coverage are provided.

Transmitters

Two types of transmitters are provided to cover the required frequency range. For frequencies from 100 to 500 megacycles pulsed oscillators (triodes) are used. TWT transmitters are used for frequencies from 500 to 12,000 megacycles. All transmitters are rated at one (1) kilowatt of peak power output and are capable of operating with pulse widths from 0.1 to 1.0 microsecond.

The TWT transmitters for bands 3, 4, 5, 6, and 7 are each housed in separate movable racks. High-voltage power supplies for the final TWT amplifiers have been separately packaged. A typical TWT transmitter, receiver, and high-voltage power supply are shown in the cover picture of this section. All equipment has been calibrated and qualified in accordance with approved Air Force test procedures.

Receivers

The RAT SCAT receiving system is basically a range-gated superheterodyne radar receiver. Two sets of receivers are provided so that monostatic and bistatic measurements may be made simultaneously. The monostatic receiver cabinets (one (1) for each band) contain the local oscillator, mixer, IF circuits and a monitoring oscilloscope. The bistatic receiver console for Bands 3 through 7 is shown in Figure 8. Range-gating and video processing signals are supplied from the control console.

The receivers are supplied with 60-megacycle IF amplifiers with a 10-megacycle bandwidth to accommodate the shortest pulses. These amplifiers are normally used in the system; the resulting typical receiver minimum detectable signal levels are shown in Figure 9. A separate selectable two (2) megacycle bandwidth IF amplifier has also been provided. This amplifier may be used in conjunction with the wider pulses and long ranges to obtain an approximate 7-db increase in Minimum Discernible Signal (MDS) while minimizing RFI problems. A steep skirt 10-megacycle bandwidth unit has also been provided as a further aid in minimizing RFI. Only minimal RFI has been experienced in three (3) years of operation because there are very strict frequency emission regulations and stringent control at the White Sands Missile Range.

Control and Data Consoles

Control of radar cross section measurements is exercised from the control console operating position shown in Figure 10. Control consoles may be installed in the operations building or the Monostatic or Bistatic van. The control consoles contain timing circuits from which main bang, range-gate, and control signals are generated. By monitoring the "A" scope video, the operator may precisely place the range-gate over the target or over the secondary standard (corner reflector or Luneberg lens). Additional control circuits incorporated in the control console include provisions for remote rotation control and intercommunications.

The energy reflected by a target is received by the receiver circuitry, a range gate is applied from the control console, and the resultant video is processed in the control console. The radar reflectivity reference servo processes the information by injecting a second signal into the IF system. This signal is derived from a constant amplitude reference oscillator and is modified by a precision attenuator. The servo acts to balance the amplitude of the echo and reference signals so that linear operation is obtained over the dynamic range of the system. The radar reflectivity can be recorded in 50 db dynamic range increments from 10^{+4} square meters to 10^{-12} square meter.

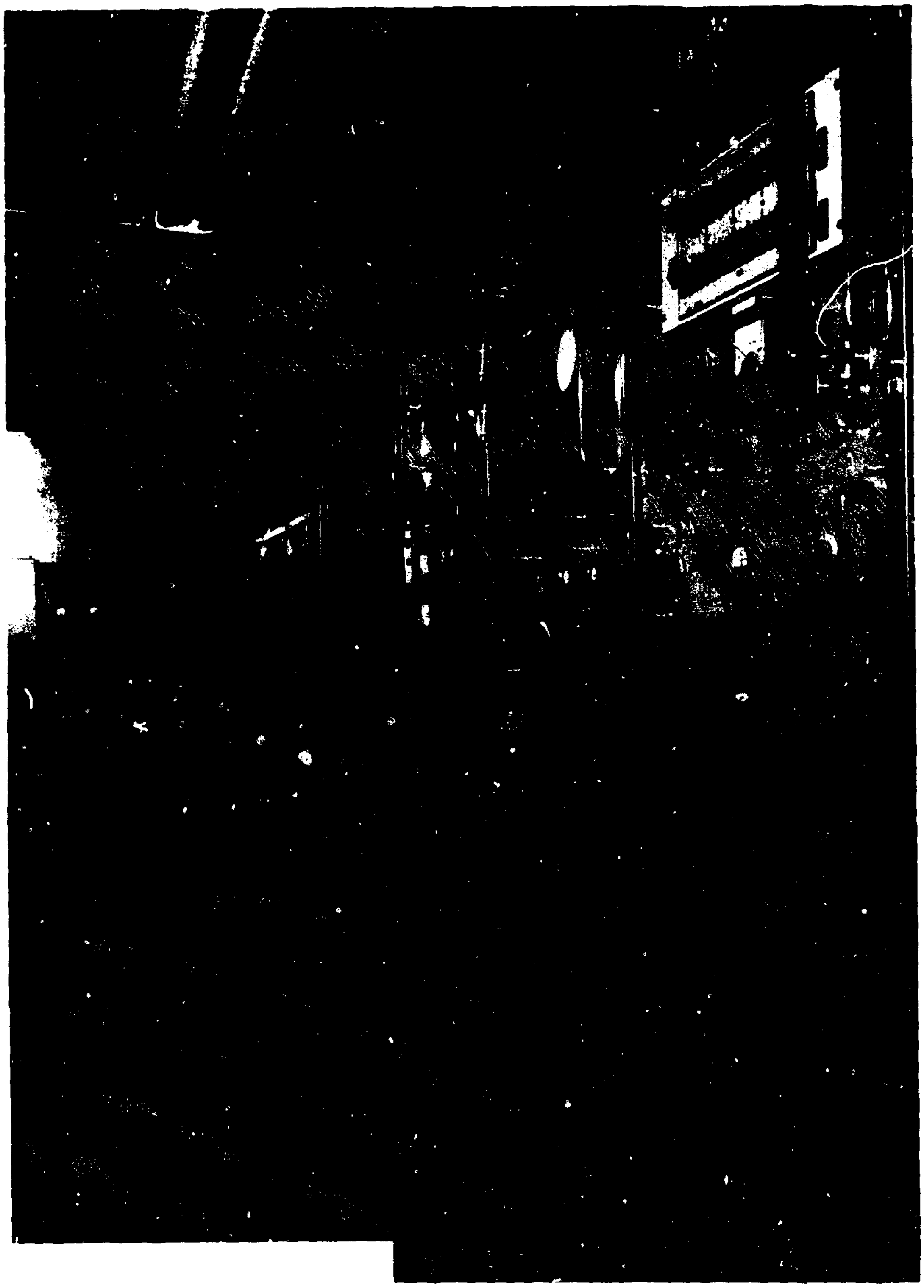


Fig. 8 INSIDE BISTATIC VAN

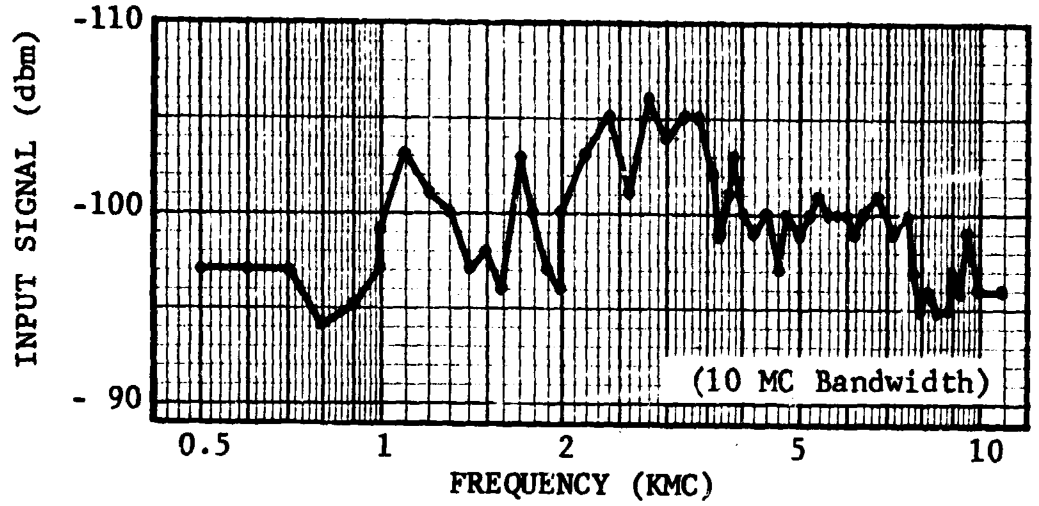


Fig. 9 MINIMUM DETECTABLE SIGNAL LEVELS

Data consoles are provided as part of the RAT SCAT equipment complement. A rectilinear analog recorder is installed in each of the data consoles to record cross section as a function of azimuth angle in analog form. Binary digital information is also punched and visually displayed in the Data Console. The main function of the data consoles is to provide digital recording facilities. Digital information is punched on paper tape in teletype format. Digital data blocks are generated at discrete azimuth intervals. Intervals of 0.1, 0.2, 0.4, 1.0, 2.0, and 4.0 degrees may be selected. A digital data block consists of 4 digits for azimuth (0 through 360.0 degrees); 3 digits for monostatic cross section (0 through 99.9 db of which only 50 db is used); and 3 digits for bistatic cross section or monostatic phase (0 through 99.9 db or 0 through 360 degrees). On the light table shown in Figure 11 are samples of the RAT SCAT data records, i.e., rectilinear analog, polar analog, and punched digital tape. All of the information is recorded as a function of azimuth angle.

Phase Measurement Equipment

Equipment is provided to measure the phase angle of the signal reflected from the target over a portion of the available frequencies. The same basic principle is used in the operation of this equipment as that used in the operation of the amplitude measurement system. The target echo signal is compared to a reference signal injected into the receiving system at a time when no normal echoes are present. A servo system operates on any phase error between reference and echo signals in such a way as to cause a reference phase shifter to position itself so that the reference phase approaches the target phase. The position of the phase

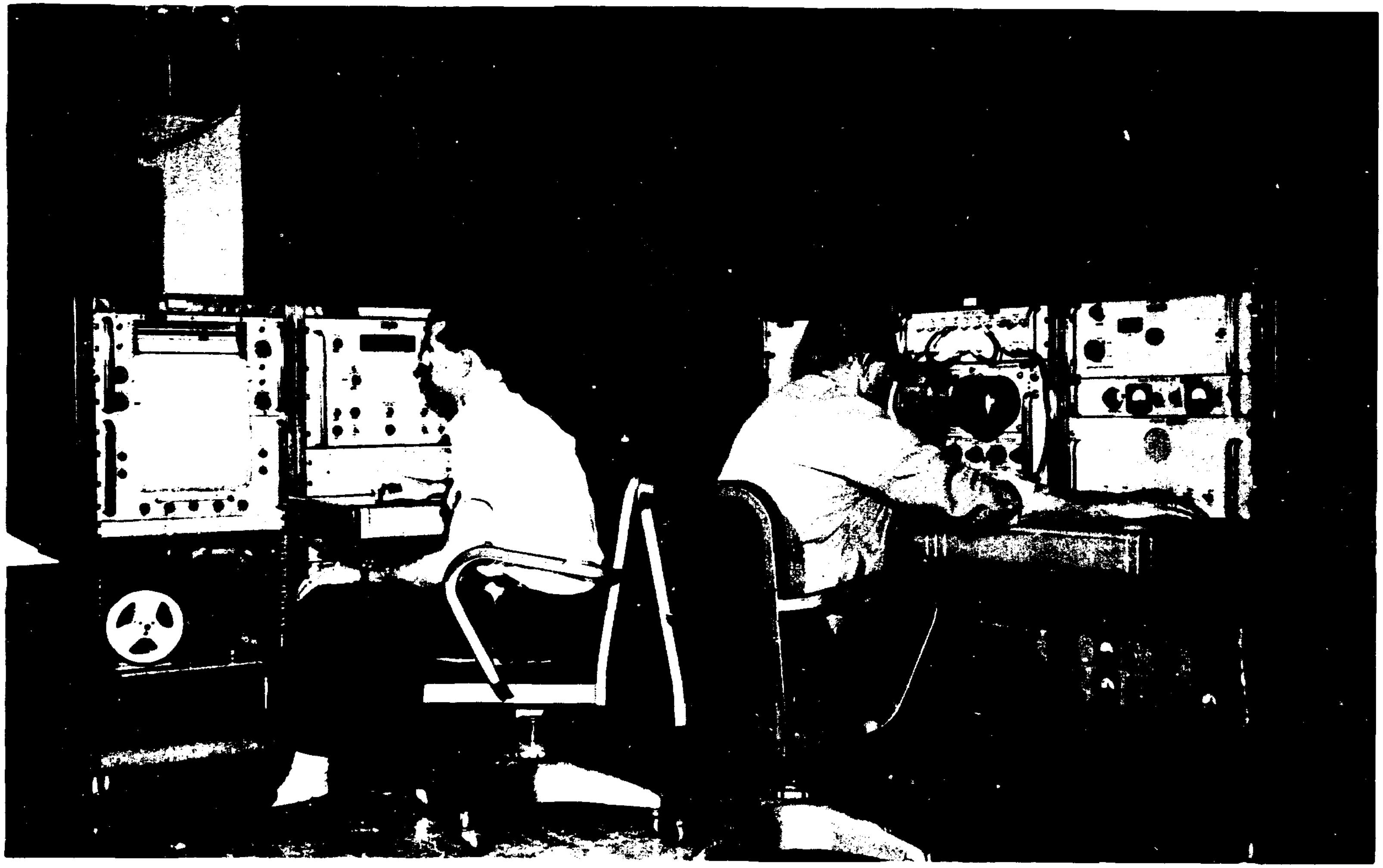


Fig. 10 CONTROL ROOM CONSOLES

Fig. 11 ENGINEERS EVALUATING VARIOUS RAT SCAT DATA

shifter is read out by use of potentiometers and a digital shaft encoder. The closed loop design of the equipment is such that the new output indication is linearly related to phase, and phase shifts in the IF system are automatically compensated. A picture of the phase measuring console is shown in Figure 12.

In order to measure the phase angle, a high degree of transmitter frequency stability is required. A frequency stabilizing rack is used in conjunction with existing transmitters so that the frequency of the transmitted signal is phase locked to a crystal oscillator. Frequency stability in the order of one part in 10^8 may thus be realized.

Vector Field Subtraction

The vector field subtraction (data extraction) system makes use of amplitude and phase information to subtract out the effects of background. The extraction system will be used by making two sets of measurements: (1) background, and (2) background plus target. If both amplitude and phase are known, the background may be subtracted from the background plus target to determine the cross section of the target alone. Typical results of vector field subtraction are shown in Figure 43. A Packard-Bell PB 250 computer is used to make either "on-line" or "off-line" computations. The normal procedure is to perform the computation "on-line." This method provides a real time computed output which can be recorded directly in the same coordinate system as the measurement data. Thus, the second data run may result in obtaining four records: measured amplitude, measured phase, computed amplitude, and computed phase.

Mobile Vans

An interior view of the monostatic van is shown in Figure 13. Portable antenna towers (Figure 14) are used in conjunction with this van. The van is equipped with a control console, a rectilinear recorder, a polar recorder, a TWT power supply, a transmitter and a receiver. The van may be moved anywhere on the range.

The bistatic van, illustrated in Figure 15, is physically similar to the monostatic van. It is equipped with a control console, a recorder, and receivers for all bands. The van is deployed along the bistatic roads specifically provided for this purpose.

Antennas

The antenna system consists of parabolic dishes with interchangeable feeds to cover the required frequency range. Antennas incorporating 2, 3, 6, 10, 16, and 30 foot dishes have been provided. Three (3) sets of each size are available to enable simultaneous transmission, monostatic

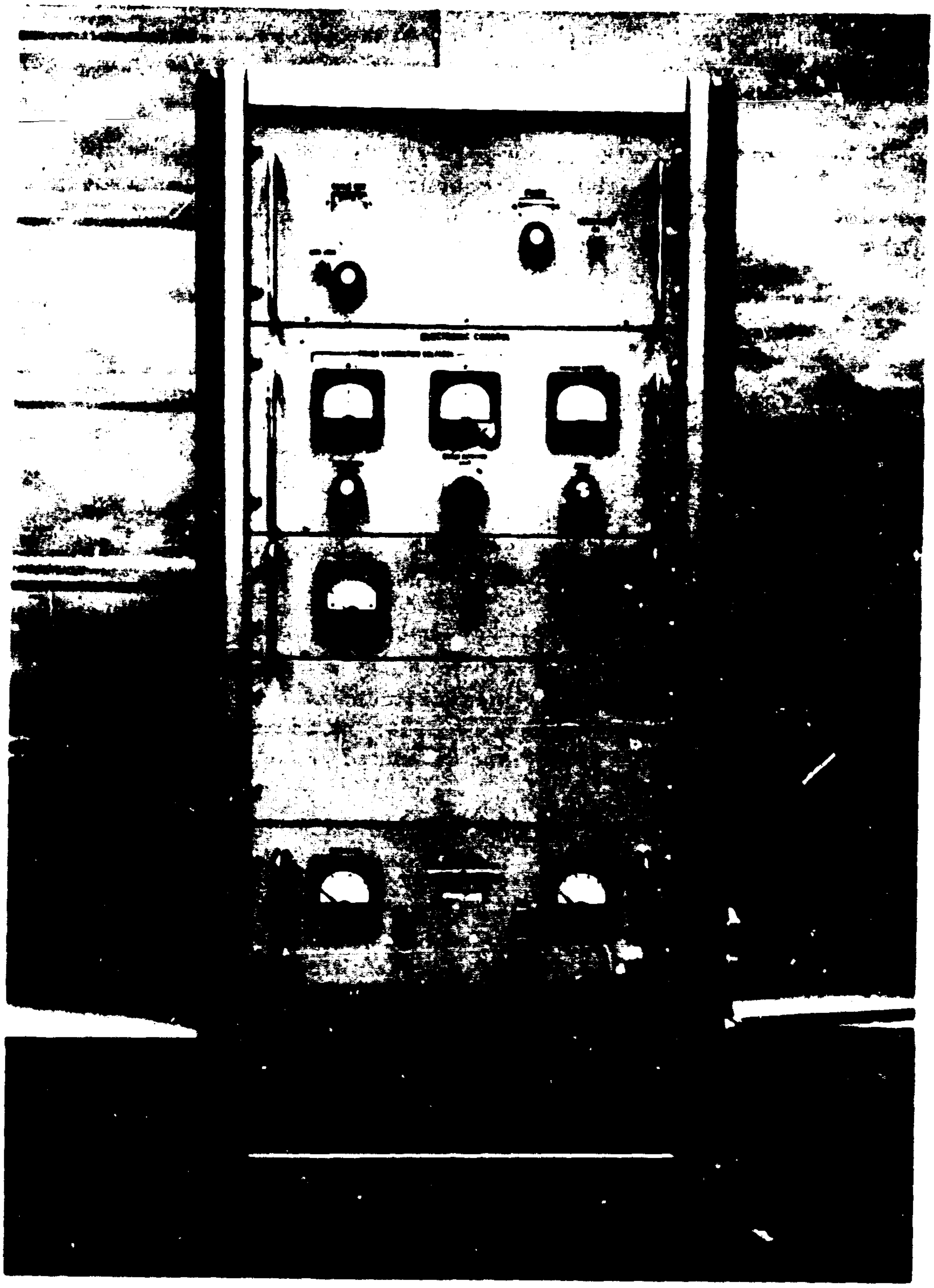


Fig. 12 PHASE MEASUREMENT RACK

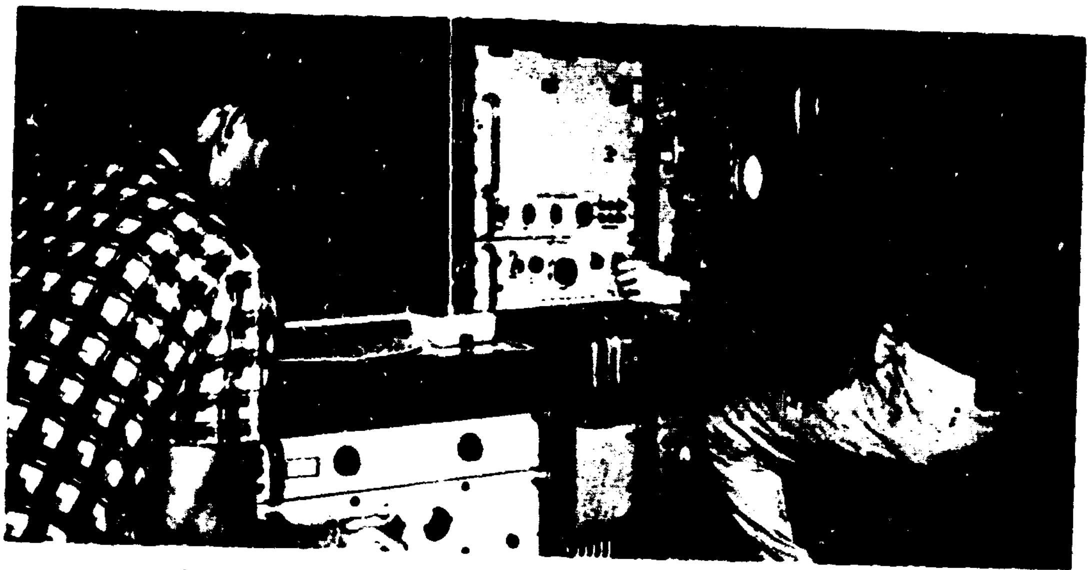


Fig. 13 MONOSTATIC VAN - INSIDE VIEW

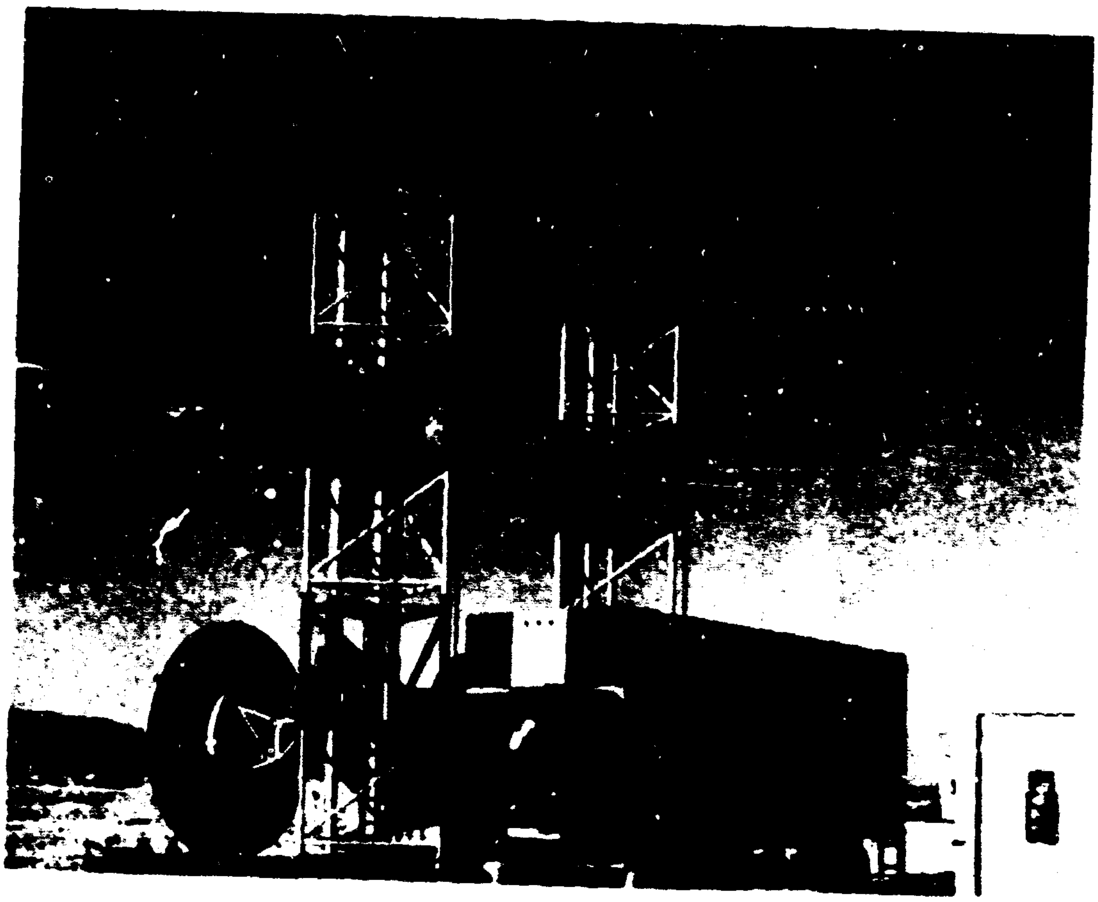


Fig. 14 MONOSTATIC VAN - EXTERNAL VIEW

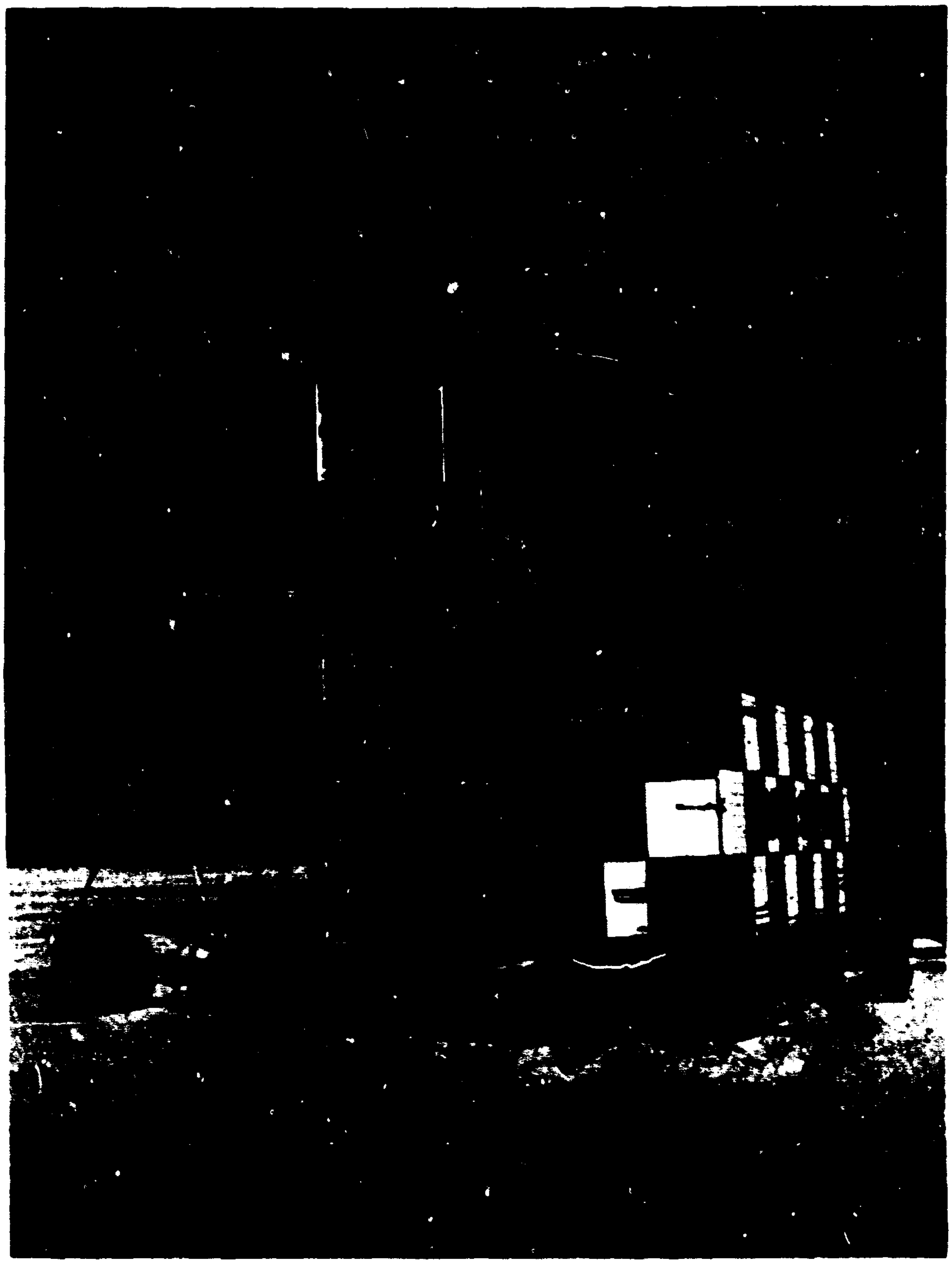


Fig. 15 BISTATIC VAN - EXTERNAL VIEW

reception and bistatic reception. Figure 16 is a picture of the 16 foot, Band 3, log periodic fed dishes mounted for the 500 foot range.

The antenna feed assemblies are constructed so that horizontal, vertical, and left or right circular polarization may be transmitted and received. Varying degrees of ellipticity may also be introduced. The low power feeds are front fed type and the high power feeds are Cassegrain type. Two different feeds are shown in Figure 17; one a log periodic L-band feed and the other a waveguide X-band feed.

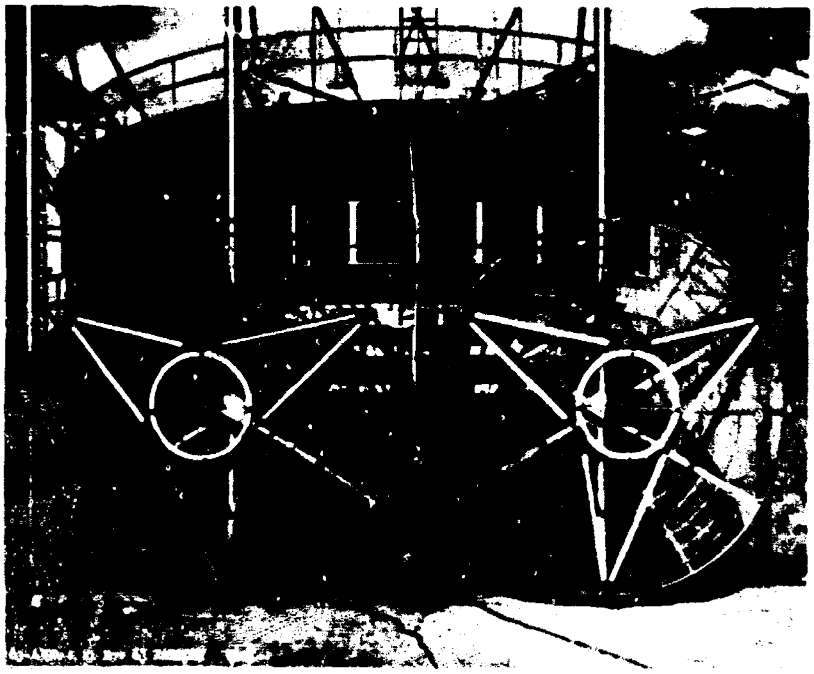


Fig. 16 SIXTEEN FOOT DISHES, LOG PERIODIC UHF FEEDS

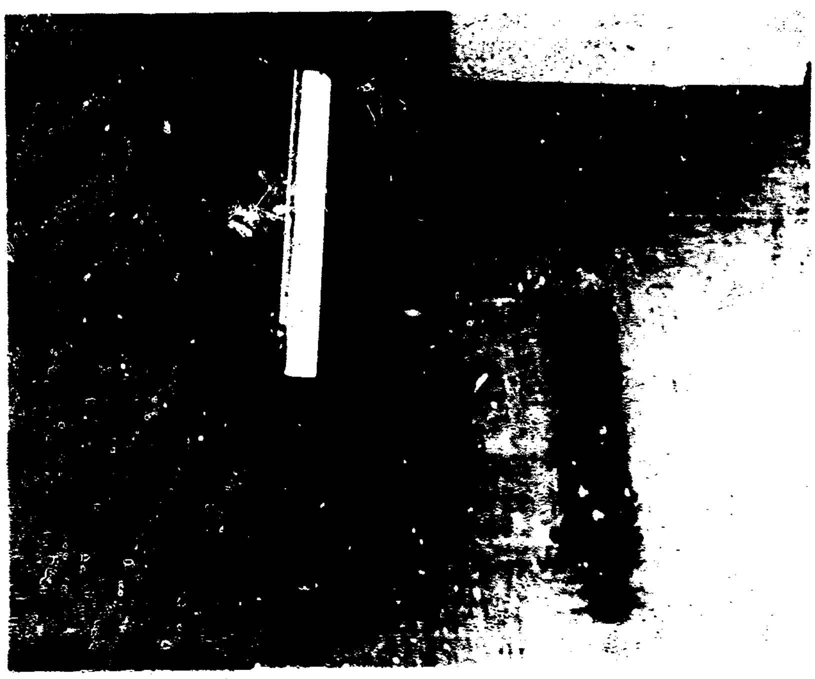


Fig. 17 L-BAND LOG PERIODIC FEED AND X-BAND WAVE-GUIDE HORN FEED


section 4
SUPPORT EQUIPMENT

SECTION 4

SUPPORT EQUIPMENT

Target Handling

Storage for targets on site is available. Armed guard service is provided for the classified models. The high-bay area in the operations building is utilized for the storage and preparation of the target for measurements. The adjacent machine shop can be used to effect most changes desired in the configuration of the target. Styrofoam transitions or saddles are used between the target and the Styrofoam support columns. These are fabricated and tailored to meet the requirements for each individual target. Electronic and mechanical requirements are rigidly enforced to insure the tuning of the saddle and target support for minimum radar cross section, so that the true target radar cross section will predominate.

The target to be measured is usually supported above the rotator table by use of a Styrofoam column or columns. The Styrofoam is turned down to the proper size and shape by the use of one of several lathes specifically adapted for turning Styrofoam. A hot wire rough cut and a special high speed router finish cut is used for cutting as the Styrofoam log is turned by the lathe. The horizontal lathe shown in Figure 18 is used for fabricating target supports up to ten (10) feet in length. A vertical lathe, shown in the cover picture of Section 4, is available for producing target supports of greater length, and a smaller lathe is available for shaping Styrofoam transitions or saddles.

Rotators and Ram

The rotators used for the three (3) target ranges are identical. The rotators are each installed in a 10 foot deep, 25 foot octagonal-shaped pit. The rotators are 17+ feet in diameter, and can be operated with the table flush with the ground level or down to 6 feet below the ground level. The assembly is raised and lowered by means of an eight (8) inch hydraulic ram. In order to support some types of targets whose lengths are in excess of 50 feet, the table diameter can be increased to 30 feet. In this configuration the table top is flush with the ground. The table is capable of continuous rotation at any speed between 0.1 and 1.0 revolution per minute. The plane of the rotator table can be tilted up to 15 degrees, and the axis of tilt is manually adjustable. Figure 19 is a photograph of the Polaris vehicle mounted on dual tripod supports. Note that both the table top and the pit walls have been lined with radar absorber in order to obtain a low background level.

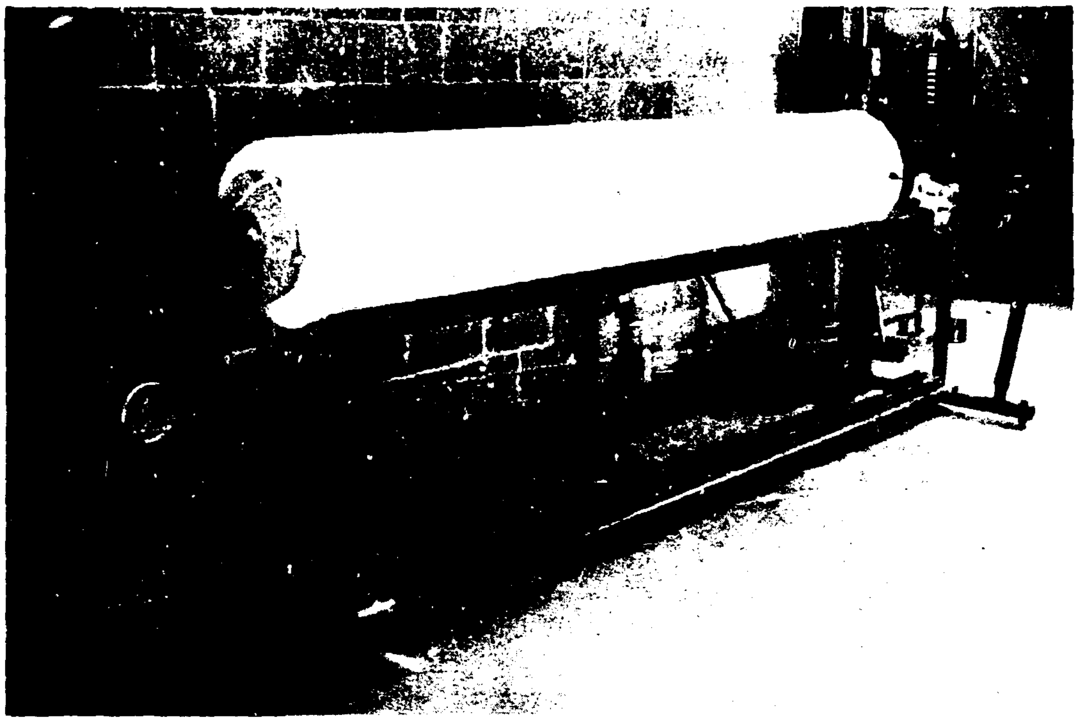


Fig. 18 HORIZONTAL POLYSTYRENE LATHE

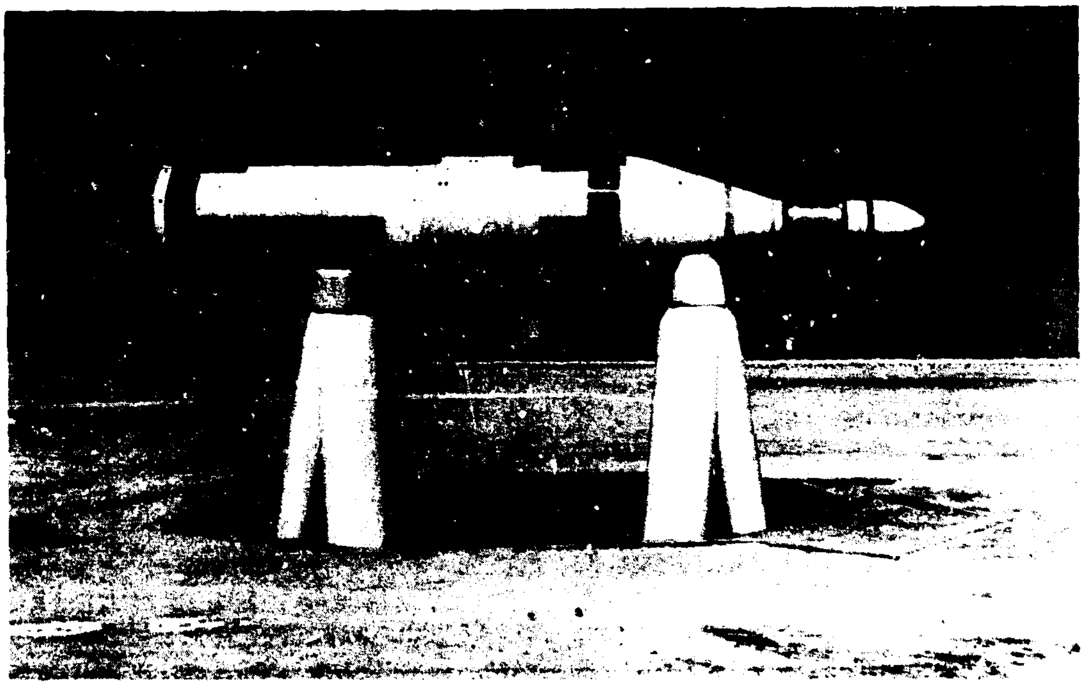


Fig. 19 DUAL TRIPOD MOUNTING OF THE POLARIS VEHICLE

A retractable hydraulic ram 30 feet tall has also been installed near the 2500 foot pit as a target support device. It is capable of supporting an 8000 pound target. A 30 foot high air bag is also available for low-frequency measurement.

Mobile Target Shelters

Mobile target shelters, illustrated in Figures 20, 21, 22, and 23 have been provided for each of the target pits. Each 35 by 30 foot shelter is constructed of aluminum and steel and is propelled by a TT-11 tug. During measurement operations, the shelter is moved down range out of the range-gate of the radar. The shelter is also used as an aid in target handling by using the installed hoists for target lifting and the independently suspended catwalks which provide access to the target. Figure 20 is a photograph of the Polaris vehicle being placed upon the dual tripods and associated transitions. Figures 21, 22, and 23 show different views of the shelter. The shelter is also configured so that hydraulic cylinders will lower it to the ground off its eight (8) wheels to provide weather protection.

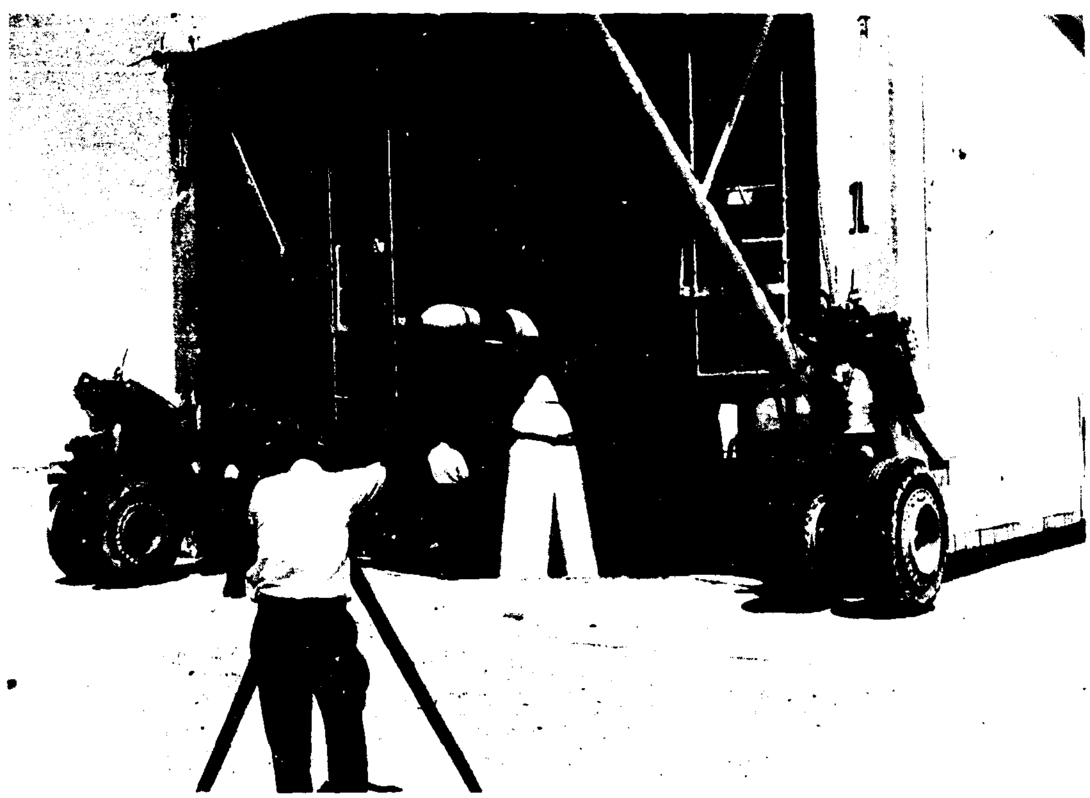


Fig. 20 SHELTER BEING USED TO MOUNT THE POLARIS VEHICLE

Fig. 21 SHELTER UNDER TOW BY TT-11 TUG

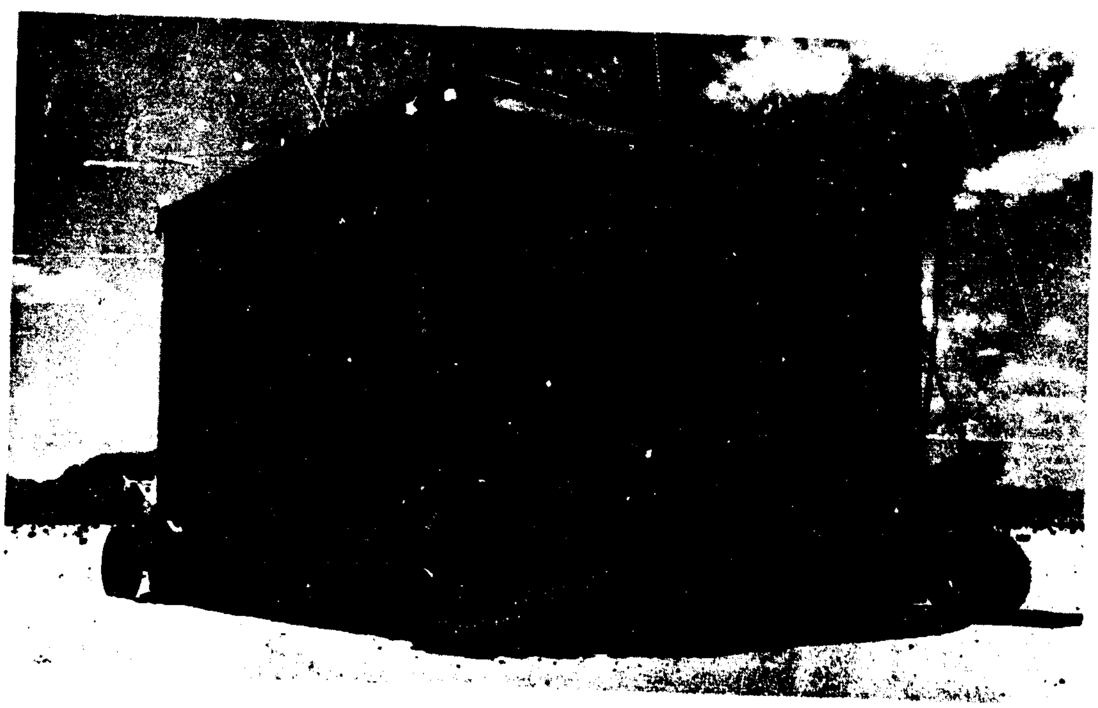


Fig. 22 SHELTER ROLL-UP DOOR END

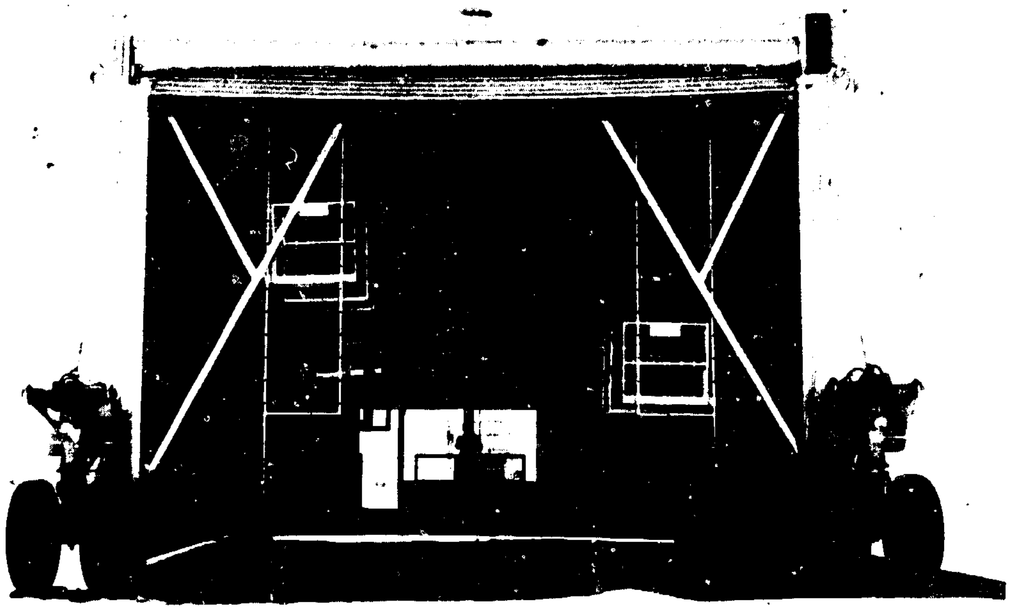
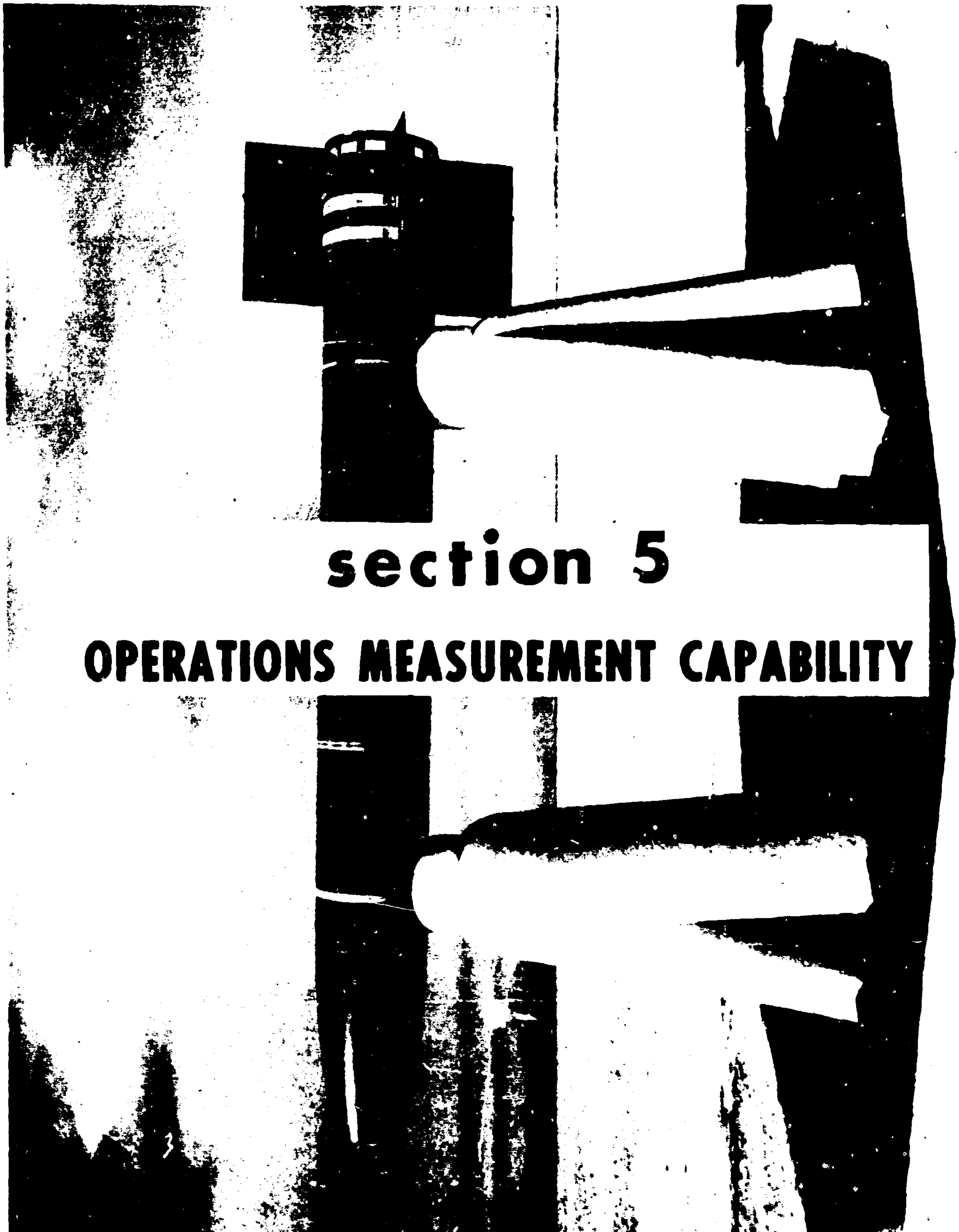


Fig. 23 SHELTER DOOR UP - READY TO ROLL

Other Vehicles

A 10 ton, 35 foot boom crane is available for loading targets on their supports. There are also chain hoists in each of the mobile target shelters which can be used for this purpose. Three (3) special truck-mounted aerostands, illustrated in Figure 24, are available for mounting small targets and for quick access to large targets mounted on the target supports on the rotator. A special trailer is available for transporting large but delicate vehicles. Each wheel is separately mounted and sprung to permit travel over the terrain without disturbing the vehicle axis. The vehicle is mounted on wooden blocks placed at the vehicle hard points.

Fig. 24 AEROSTAND TRUCK



section 5

OPERATIONS MEASUREMENT CAPABILITY

SECTION 5

OPERATIONS MEASUREMENT CAPABILITY

Accuracy Criteria

In order to fulfill the role of a high quality Radar Cross Section Measurement Facility, emphasis at RAT SCAT has been placed on the accuracy and repeatability of the measurements. To provide the RAT SCAT facility with high quality, scientific data, and measurement standards, a rigorous analysis of sources of measurement errors has been made. More important, an extensive measurement program has been undertaken to establish an empirical correlation with theoretical analysis. Without such substantiation, any claims to measurement accuracy and quality cannot be recognized as valid. In view of the rigorous, scientific approach taken in assessing the measurements, the RAT SCAT claim of measurement capability is considered to be conservative. RAT SCAT can presently demonstrate a measurement capability without peer. Background cross section of less than -80 dbsm has been obtained, targets of -60 dbsm or less can be measured, target weights of 10,000 pounds can be accommodated, and target sizes to 56 feet in length have been measured. To equate these capabilities to operational measurement requirements, certain criteria must be established and demonstrated. Some of the more important of these areas are discussed in the following pages.

Equipment Performance

Power

An illustration of the power effect with pulsed systems, from interfering background, is shown in Figure 25 as a function of range for a given transmitter power level. Except for beamwidth effects, the background on a pulsed range essentially exhibits a fixed geometrical size. An increase in transmitter power will be required to operate at the same received power level return if the target range is increased, or conversely, if the transmitter power is fixed, an equivalent decrease in background sensitivity will be experienced if the range is increased. A comparison of pulse versus CW approach is also shown in Figure 25. The upper two curves illustrate the effects of available power levels associated with CW equipment. Note that the CW approach must necessarily move closer in range to obtain minimal backgrounds and very significantly sacrifices accuracy due to violation of the far field criteria.

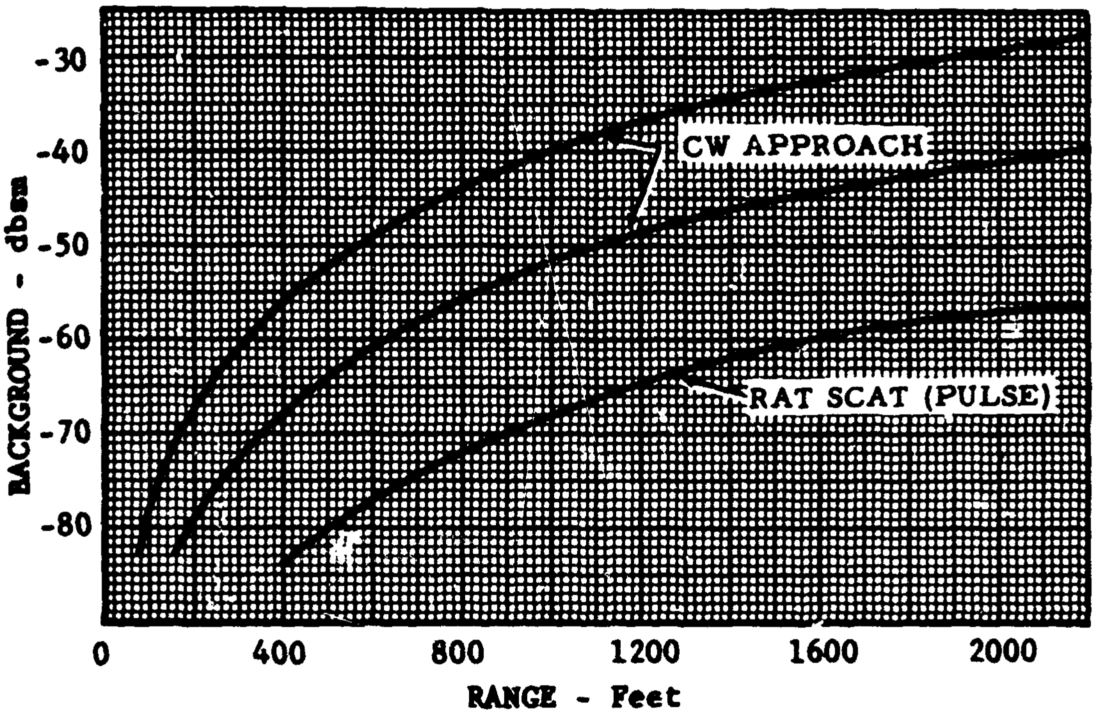


Fig. 25 BACKGROUND SENSITIVITY CHART

Receiver Sensitivity

The sensitivity of the present RAT SCAT receivers is shown in Figure 26 as a function of frequency. These sensitivities are maintained to meet Air Force requirement levels by periodic calibration under the cognizance of quality control engineers. Reduction or degradation in receiver sensitivity produces the same degradation

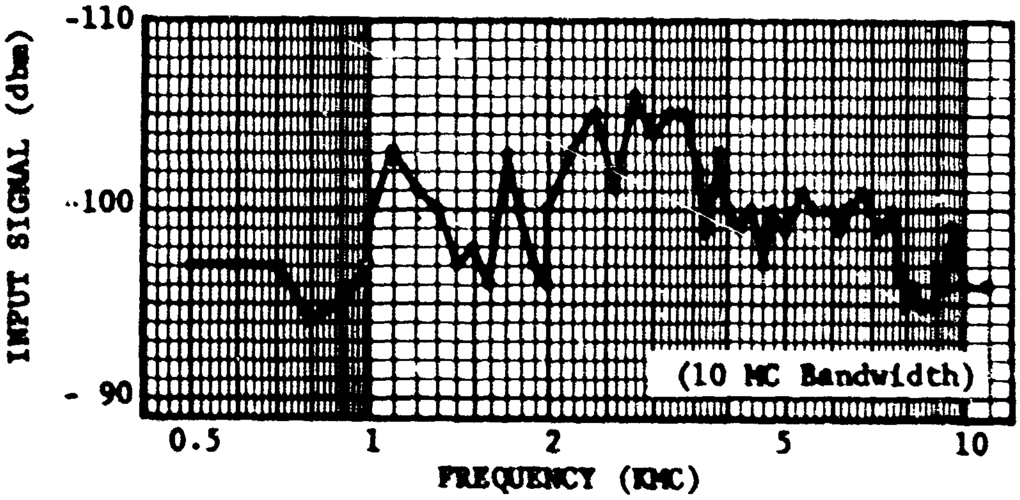


Fig. 26 RECEIVER SENSITIVITY CHART

effect on equipment measurement performance as the reduction or degradation of power. Thus, strict Air Force quality control will assure the best quality for RAT SCAT.

Equipment Linearity

A significant factor in radar cross section measurement accuracy is equipment linearity. Measurement accuracy cannot be guaranteed to any better accuracy than the linearity stability of the system. Cross section ranges are plagued with linearity problems when the conventional AGC voltage reference is used as a measurement reference. Either complex circuitry with inherent reliability problems is employed to compensate for such non-linearity or the error is accepted. In most cases it is accepted and ignored.

In the RAT SCAT equipment, passive elements are used as a reference in conjunction with a uniquely designed sigma servo. The system linearity is shown in Figure 27 in the form of results constantly obtained in a typical quality control linearity check on the RAT SCAT systems. Significant performance results include (1) linearity maintained over a 50-db dynamic range and (2) average linearity maintained over weeks of operation within 0.2 db.

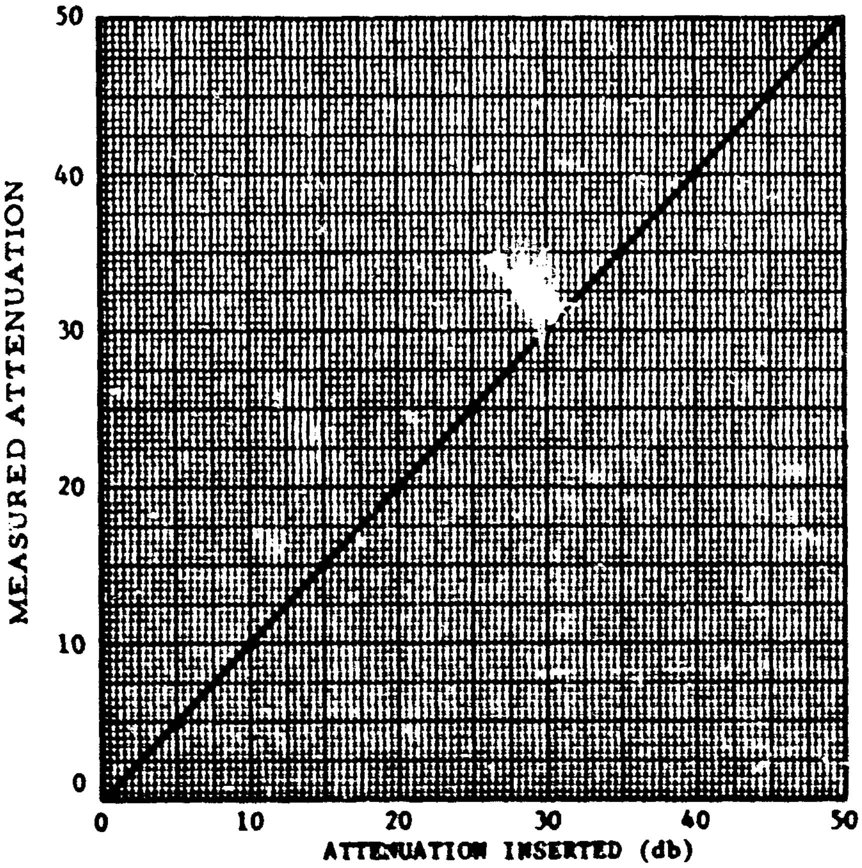


Fig. 27 LINEARITY DYNAMIC RANGE

Range Performance

Phase Front Curvature

Phase front curvature is a variation of the electromagnetic field in the target area (see Figure 28) from that of free space. Consequently, this variation must be considered in an assessment of the accuracy of radar cross section measurements. To minimize this error, long ranges are needed, especially when high frequency measurements are undertaken. Long ranges are readily available at RAT SCAT. Normally the following criterion is used at RAT SCAT to establish the minimum range length:

$$R = \frac{1.5\, D_A^2}{\lambda} + \frac{2\, D_T^2}{\lambda}$$

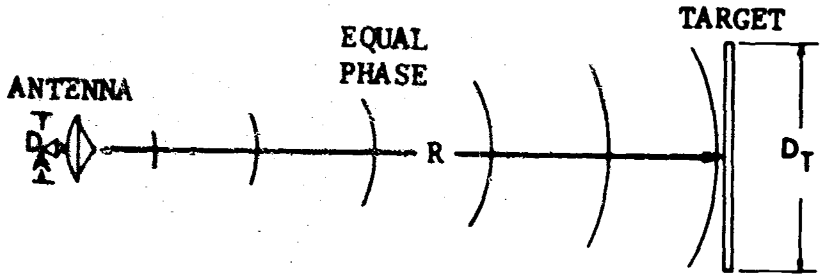


Fig. 28 PHASE FRONT CURVATURE

The range requirement due to phase front curvature is $R = K_1 D_A^2/\lambda + K_2 D_T^2/\lambda$ where K is a function of the allowable error and D_A and D_T are antenna and target dimensions respectively. In those cases where degradation in accuracy can be tolerated (broadside, maximum target dimension), smaller values can be used for K in the above formula. This will not affect the overall characteristic signature but only the depths of the nulls.

Extraneous Illumination

Extraneous illumination, such as the rotator reflections illustrated by the dashed lines in Figure 29, can result in a serious error contribution if not properly controlled. Conventional background cancellation techniques are not effective in suppressing this phenomenon. This situation could affect the measurement results. The data in Figure 30 represent the result of such an extraneous illumination test made at RAT SCAT by using the Operational RAT SCAT rotator configuration and techniques. The average error from this test was 0.1 db. Here again, strict AF control and quality control at RAT SCAT and the use of appropriate radar absorber materials has resulted in minimizing this possible source for large errors.

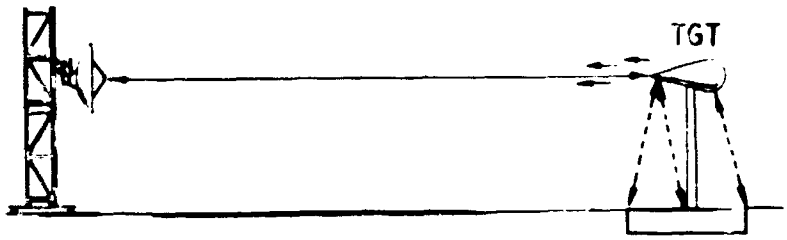


Fig. 29 EXTRANEOUS ILLUMINATION

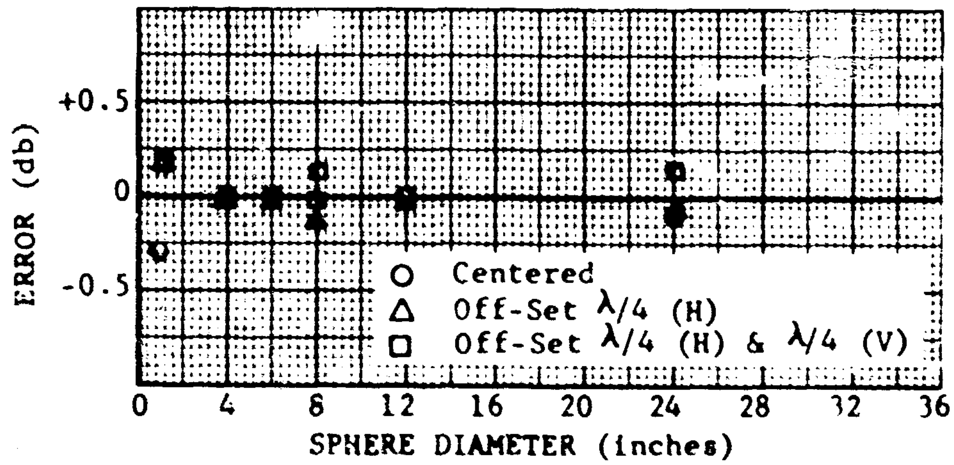


Fig. 30 EXTRANEOUS ILLUMINATION TEST RESULTS

Target Dimensions

As indicated earlier in the discussions under phase front curvature, RAT SCAT provides an exceptional capability for handling large, heavy, full-scale aerospace vehicles. In addition, the mobile vans can be used to satisfy requirements for a longer range or other pits can be added to meet predictable future requirements. In both cases, the available flat RAT SCAT space and the present equipment are compatible with either type of increased capability.

Cross Section Background

The ability to cope with interfering background signals is an important aspect of the target measurement capability of a radar cross section range. It should be carefully noted, as discussed under the preceding sections, that it is only one of the criteria required for accurate measurement.

It is emphasized that the test conditions play a vital role in terms of the results obtained. For example, doubling the antenna diameter or halving the range length will lower the equipment background level 12 db. Obviously, it is mandatory that all pertinent parameters and conditions be accurately specified when evaluation or comparison of equipment capabilities is undertaken.

Target Supports

The magnitude of the cross section of target supports, which represent an interfering signal in vehicle measurements, is determined by the vehicle weight. In the case of large, heavy, full-scale vehicles, large diameter supports are required. The return from these supports can be categorized as (1) coherent returns and (2) noncoherent returns. The coherent returns are amenable to cancellation and/or discrimination. Figure 31 is a picture of a typical Styrofoam target support. The data in Figure 32 represent the results to date of Styrofoam target supports capable of supporting 250 pounds.

Experimental and theoretical investigations conducted by RAT SCAT personnel have resulted in the creation of a technique which can be used to achieve low returns from Styrofoam columns heretofore unattainable. The technique consists of "tuning" a vertically mounted cylindrical column by selecting precise diameter-to-wavelength ratios.

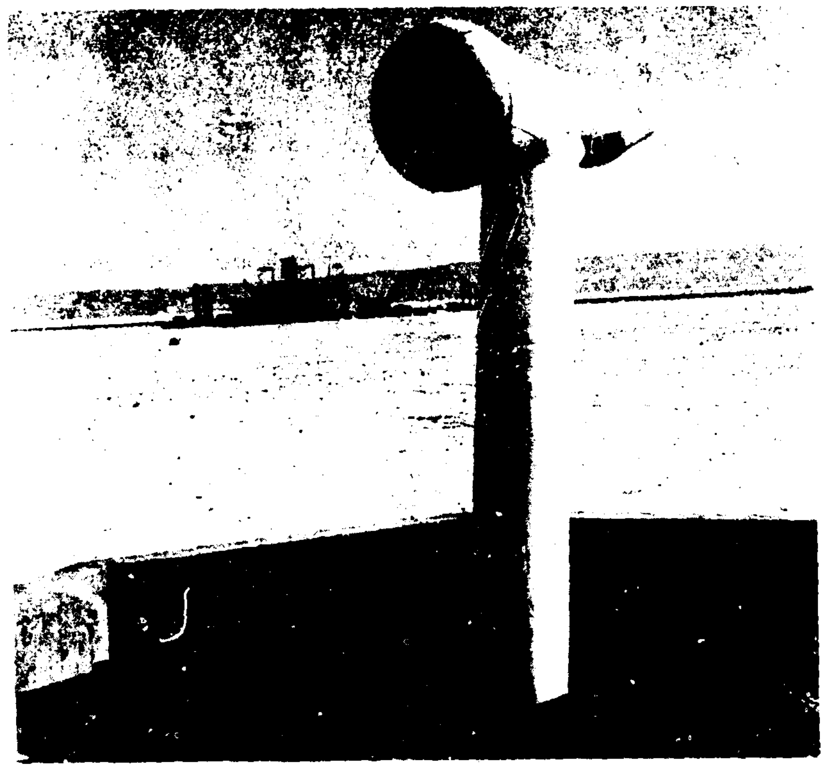


Fig. 31 TYPICAL POLYSTYRENE SUPPORT

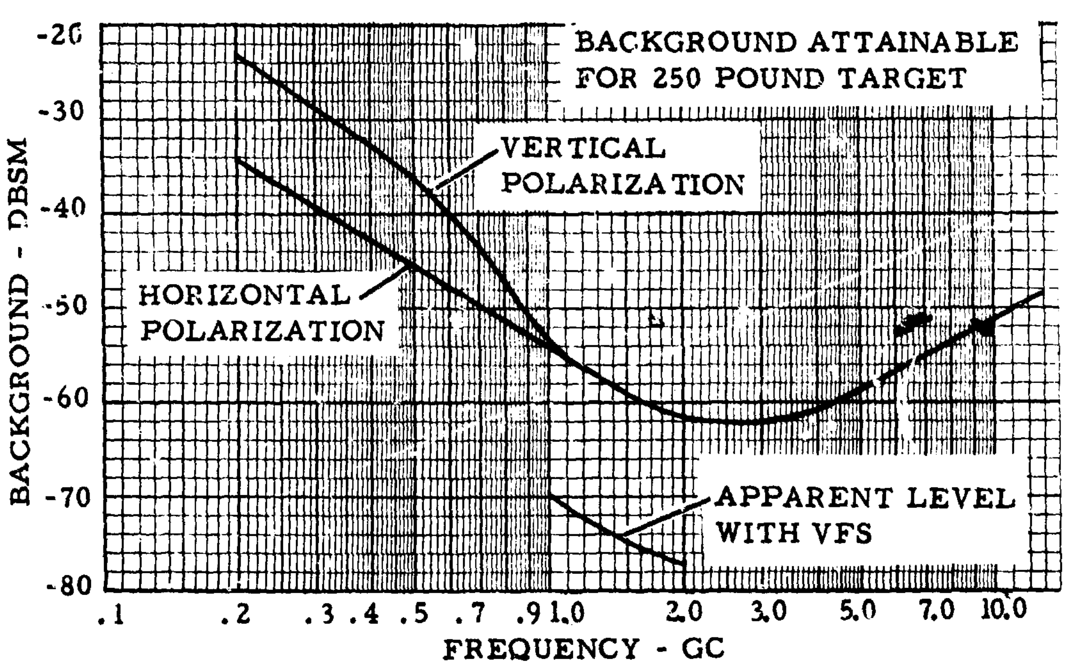


Fig. 32 RANGE BACKGROUND

Experimental data obtained by the University of Michigan under a RAT SCAT R&D subcontract is illustrated in Figure 33. Note the deep nulls at two frequencies. These nulls appear at periodic intervals throughout the spectrum for a given diameter column. Columns are selected so that the null in the column return coincides with the operating frequency. RAT SCAT personnel have derived formulas which have been checked empirically, and have developed curves, such as those reproduced in Figure 34, to aid in tuning columns. Use of this technique has resulted in improvements of up to 20 db over measurements attainable without column tuning.

A typical example of a target multiple support mount is shown in Figure 35. This type of support is used in measuring large, heavy models of considerable cross section. Cancellation of returns from these mounts is complicated by a ducting phenomenon which was identified in early developmental measurements.

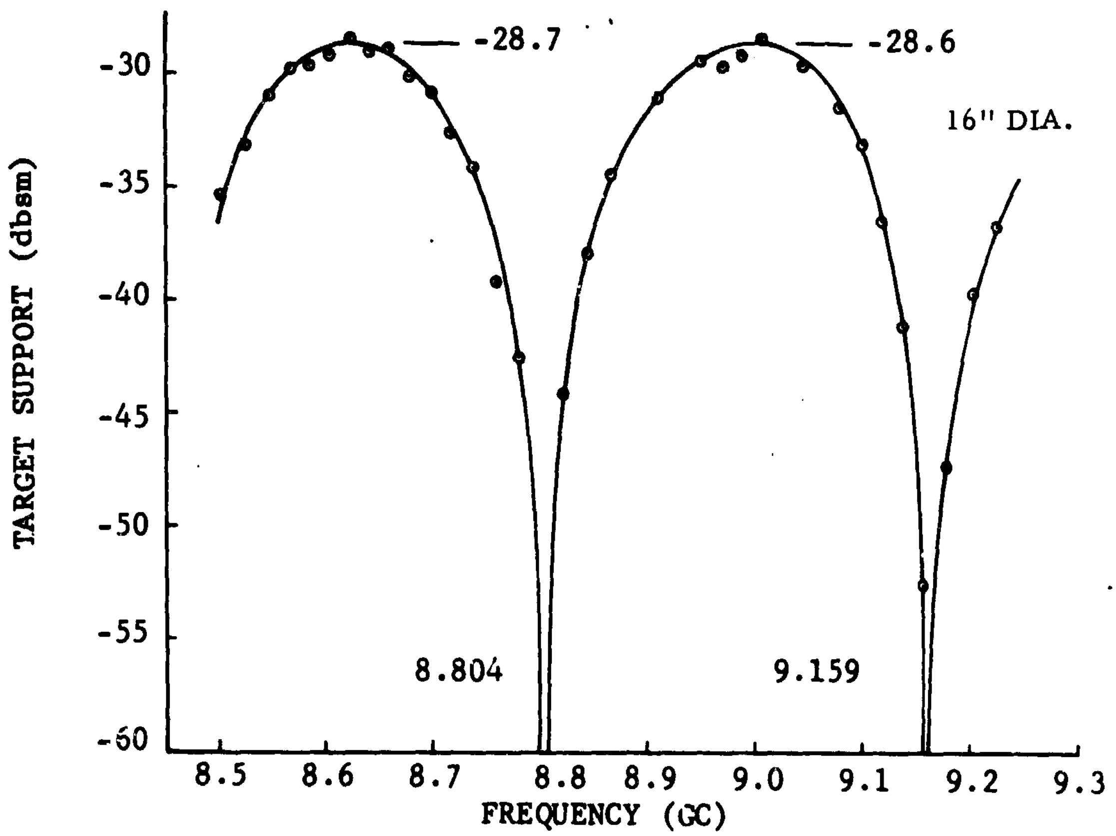


Fig. 33 EFFECTS OF TUNING COLUMN

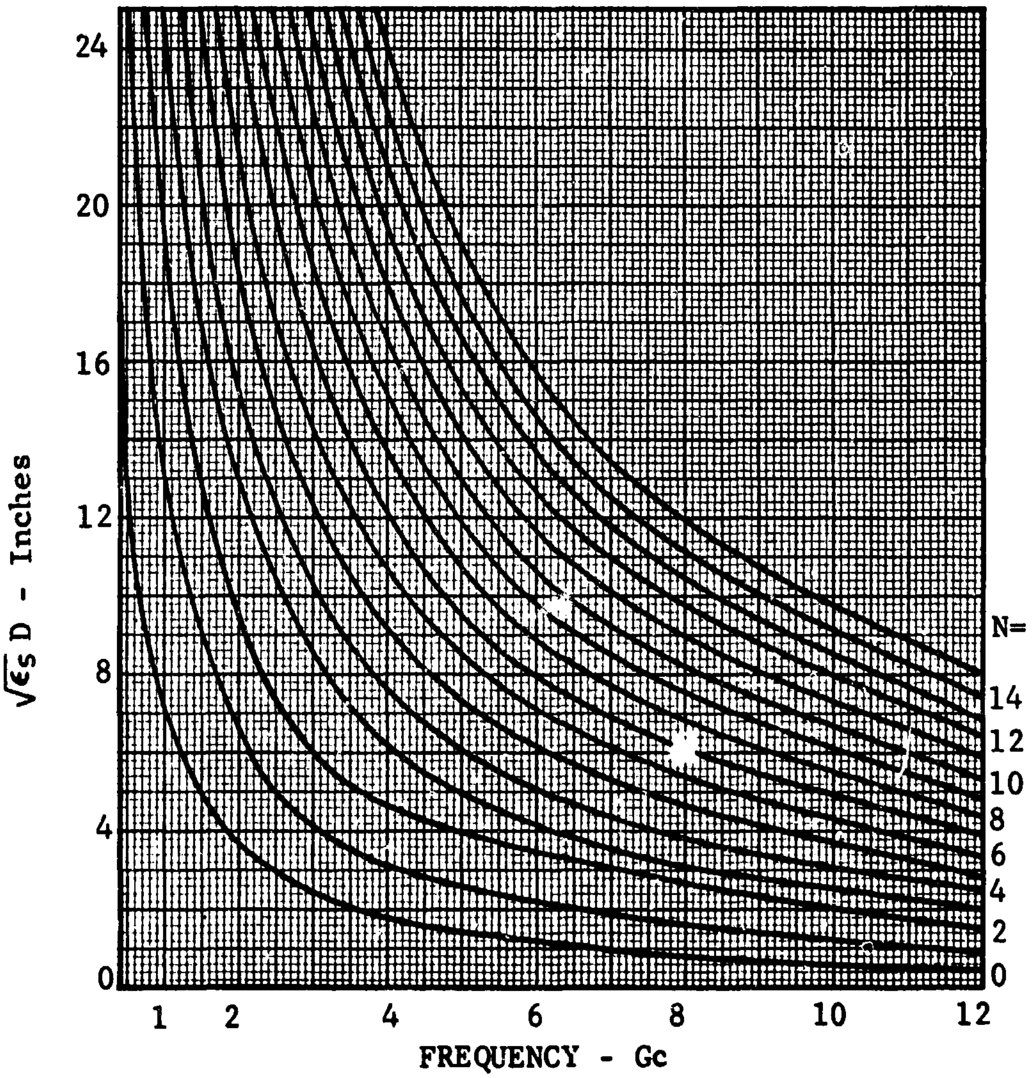


Fig. 34 RAT SCAT TUNED COLUMN CURVES

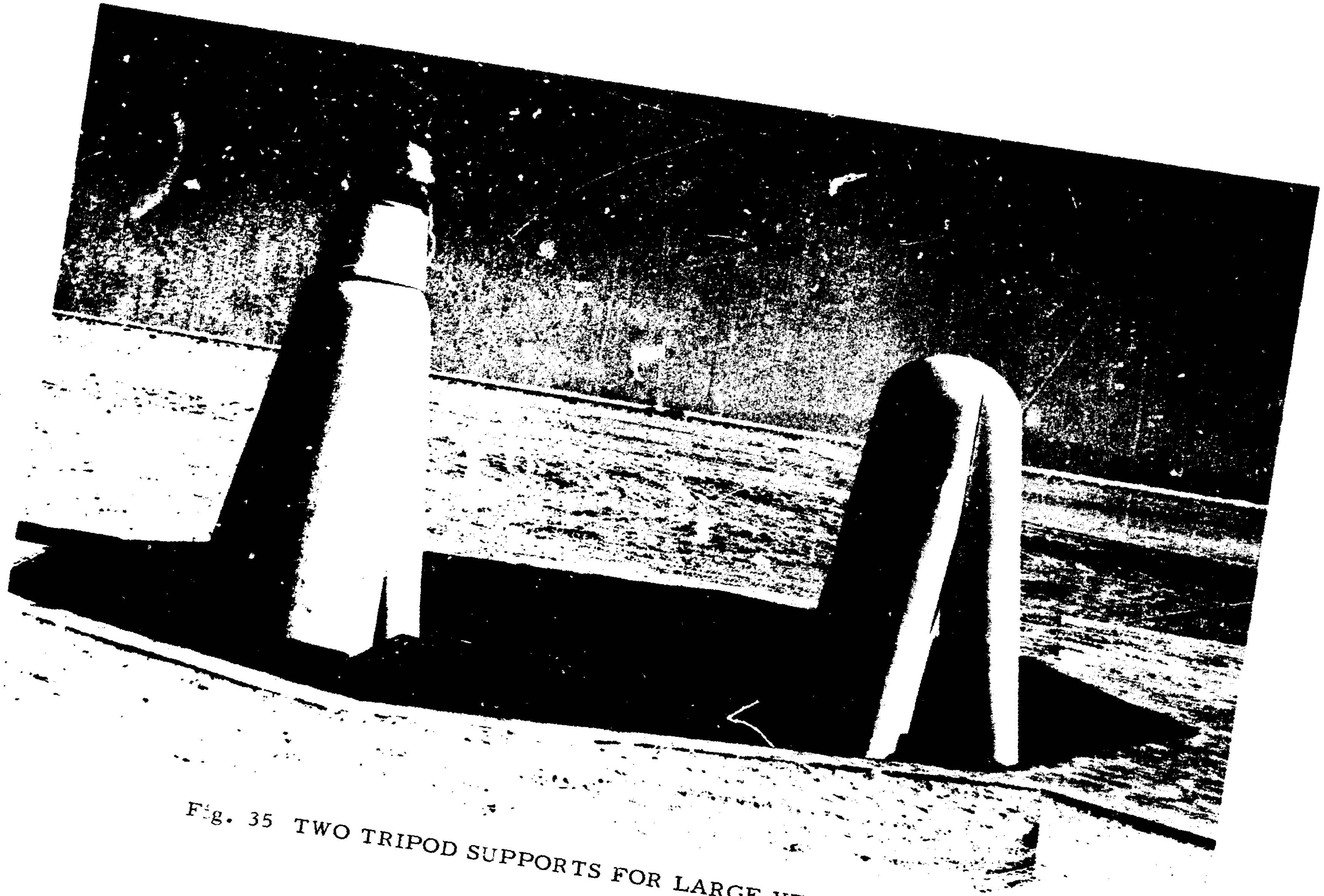


Fig. 35 TWO TRIPOD SUPPORTS FOR LARGE VEHICLES

section 6

CROSS SECTION MEASUREMENTS

SECTION 6

CROSS SECTION MEASUREMENTS

Measurements Summary

Past users of the site include BSD, RADC, AFMDC, Army, ARPA, Navy/ARPA, Lincoln Labs, AFSWC, Navy BuWeps, ASD, SSD, and others. Over 10,000 measurements of quality RAT SCAT scientific data have already been made. Vehicles of a length up to 55 feet and significant weights have been measured; a Polaris vehicle, weighing approximately 6000 pounds, has been measured. In addition, the satisfaction of contractual obligations has resulted in many other measurements for the purposes of (1) assuring quality measurements, (2) performing product improvement tasks, and (3) conducting qualification and acceptance tests to provide compliance with the specification. As more equipment has become operational and as experience has been gained in working with the equipment, the overall measurement capability has been considerably increased.

Special Measurements

To evaluate and confirm the capability of RAT SCAT, special tests have been devised and performed. Scientific measurement criteria have been specified for these tests in order to isolate specific system errors. The results of the more important of these tests are discussed in the following paragraphs.

Sphere Measurements

The sphere is a geometrical body for which accurate theoretical calculations can be made without the use of approximations. For this reason, precision spheres are utilized at RAT SCAT for primary standards. Comprehensive sphere tests have been made over Bands 1 through 7. A typical plot of results obtained from such tests is shown in Figure 36. It is apparent that extremely close correlation between theory and tests has been obtained.

Another proof of the accuracy obtained at RAT SCAT is the correlation between theoretical results and measured results shown in Figure 37. The test values shown in this figure, obtained from Band 6 tests, are typical of the accuracy obtained at RAT SCAT. The

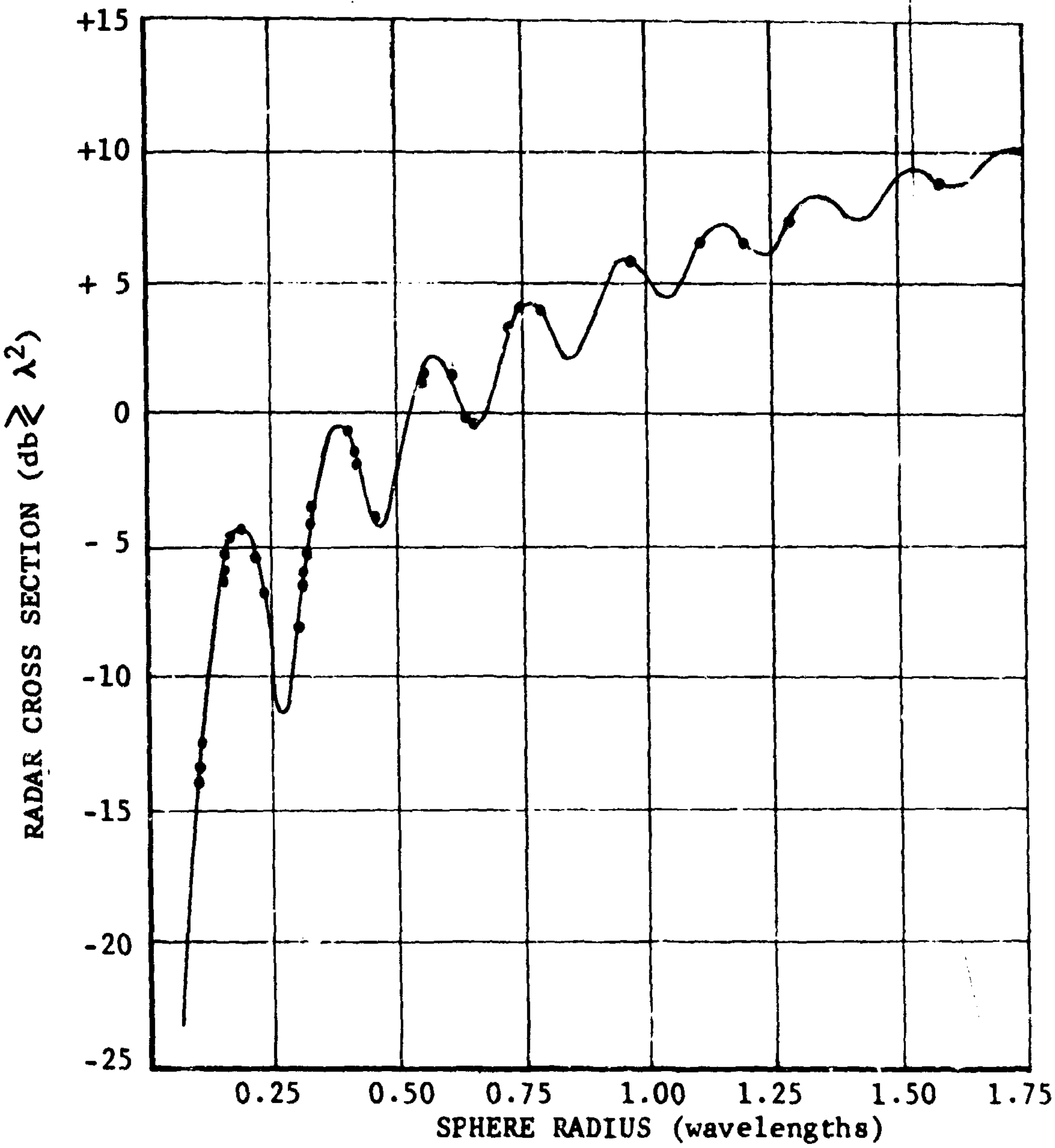


Fig. 36 COMPARISON OF MEASURED AND THEORETICAL SPHERES

limit lines represent the specification requirement for the equipment under the specified test condition. Analysis of these data shows that the accuracy obtained is significantly better than specified. From results such as these, it can be stated with complete confidence that measurements at RAT SCAT can be made to less than 1 db of error. In fact, errors of less than 0.5 db are normally obtained during operational measurements.

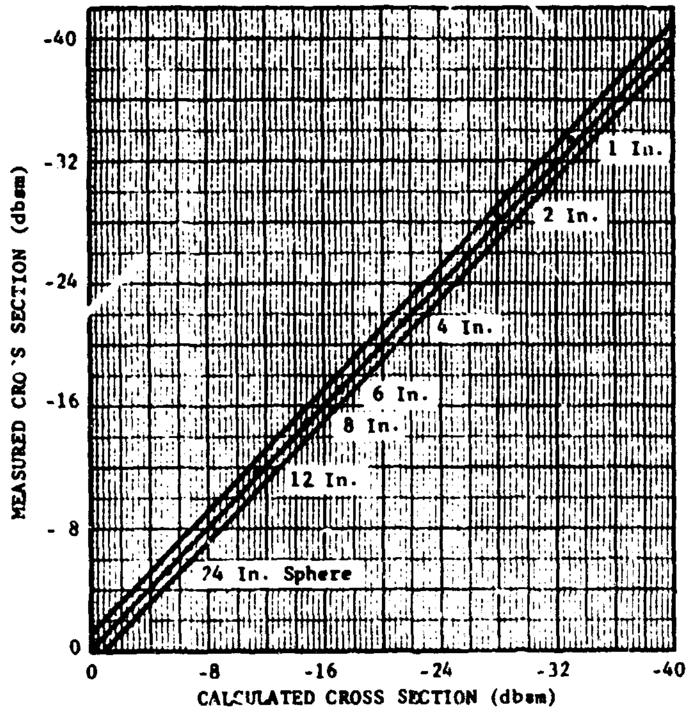


Fig. 37 MEASUREMENT ACCURACY TEST

Cone Measurements

The sphere test results, shown in the preceding discussion, are excellent devices for accuracy measurements; however, they cannot be used to demonstrate the dynamic range of equipment. More suitable vehicles for such testing are sphere-cones; models of these vehicles are shown in Figure 38. Figure 39 illustrates the mounting technique which was used.

Fig. 38 SPHERE CONE MODELS (DIME)

Fig. 39 SPHERE CONE MOUNT (NICKEL)

Test results obtained from measurements made on the cone vehicle are shown in Figure 40. Radar cross section measurements of this vehicle show a minimum cross section of -53.5 dbsm and a dynamic range of 31 db. As another indication of equipment accuracy, it should be noted that at the 180 degree lines, the normal starting and stopping reference for RAT SCAT measurements, both ends of the plot close exactly.

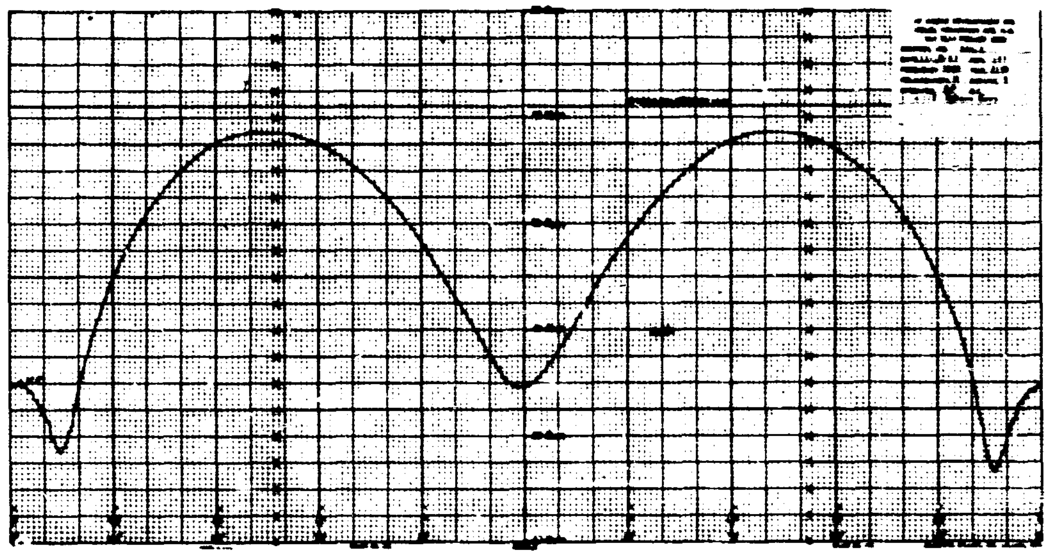


Fig. 40 CONE CROSS SECTION

Bistatic

A bistatic operational capability exists at RAT SCAT for measuring all bistatic angles between 0 and 120 degrees. A description of the bistatic equipment and trailer has been previously presented. The installation of a horn at the bistatic trailer for receiving a reference signal from the main building is shown in Figure 41.

The results of bistatic qualification tests made at bistatic angles of 0, 30, and 120 degrees on a flat plate are shown in Figure 42. The computed bistatic cross section of a sphere is used for calibration, but there is no single transfer standard which is suitable for all bistatic angles. Suitable transfer standards or transfer techniques have been and are being developed at RAT SCAT.

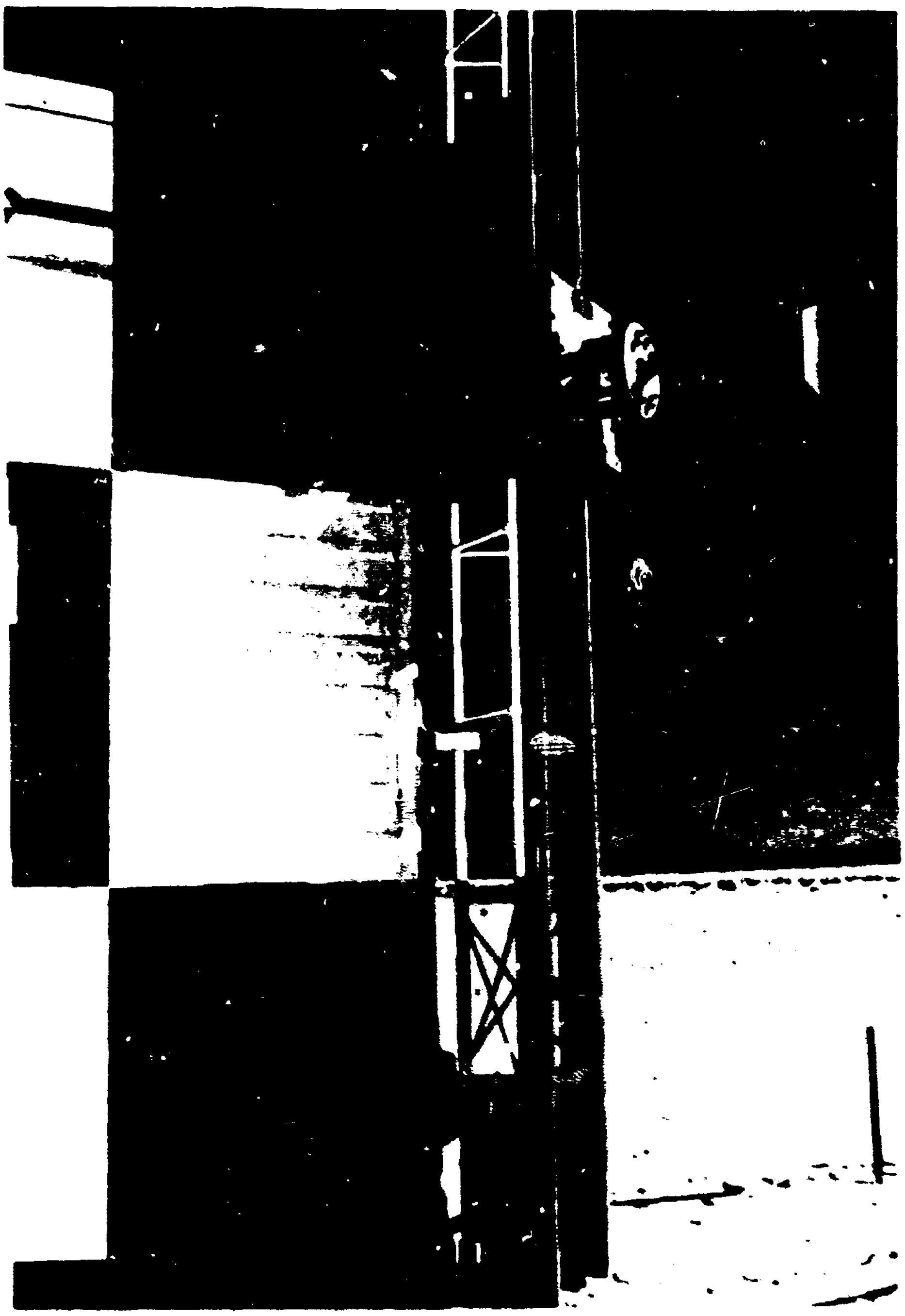


Fig. 41 BISTATIC SAMPLE HORN

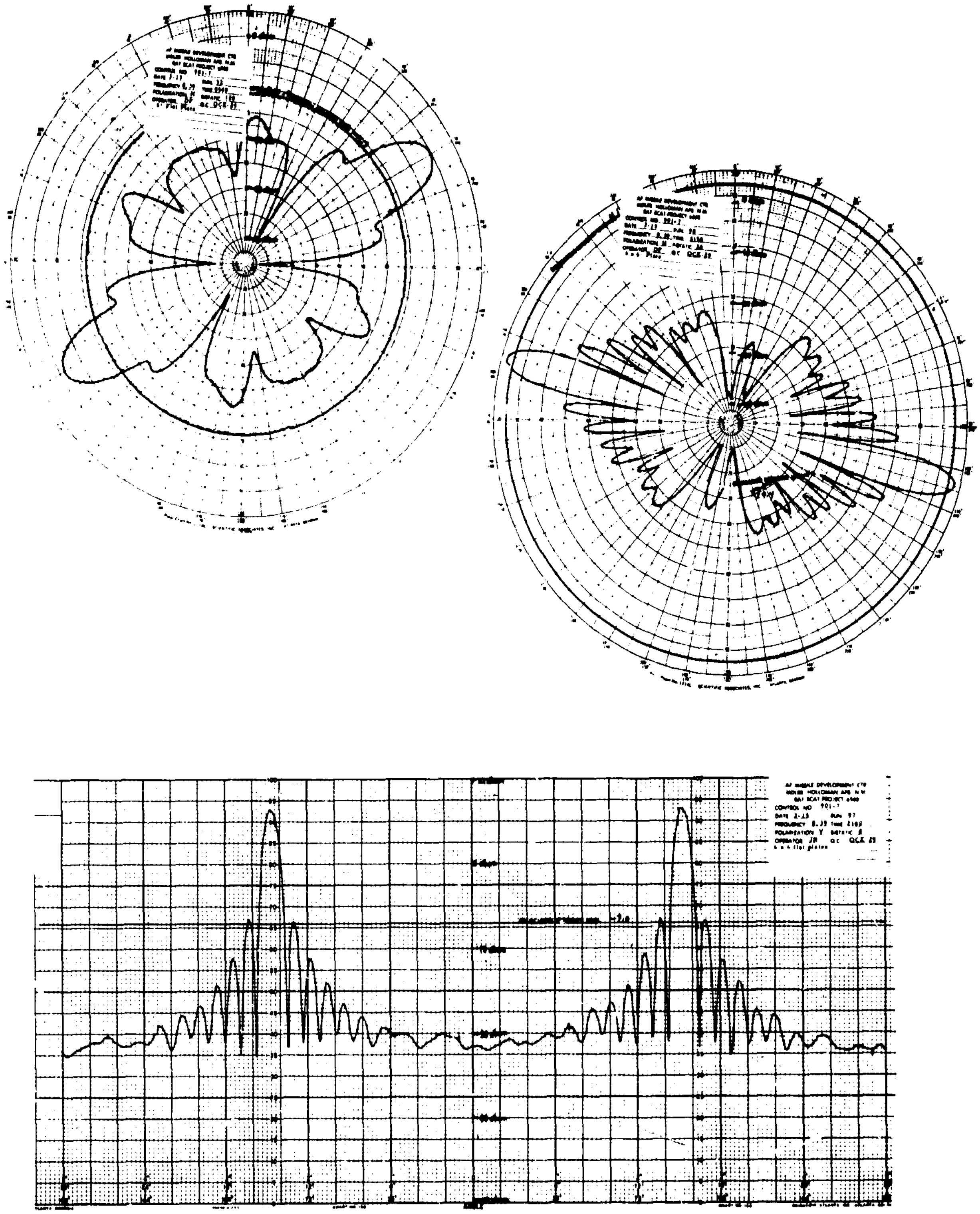


Fig. 42 BISTATIC TEST RESULTS

Vector Field Subtraction (VFS)

An extensive series of VFS measurements was conducted on the Lincoln Laboratory "Texas Foxtrot" program. In order to demonstrate system accuracy, measurements were made of a one-inch diameter sphere. The results are illustrated in Figure 43. The theoretical cross section of the sphere was -46.5 dbsm.

Operational Measurements

A number of measurement programs have been conducted at RAT SCAT on a variety of user vehicles, some on a high priority basis. A few of the vehicles measured are shown in the following figures.

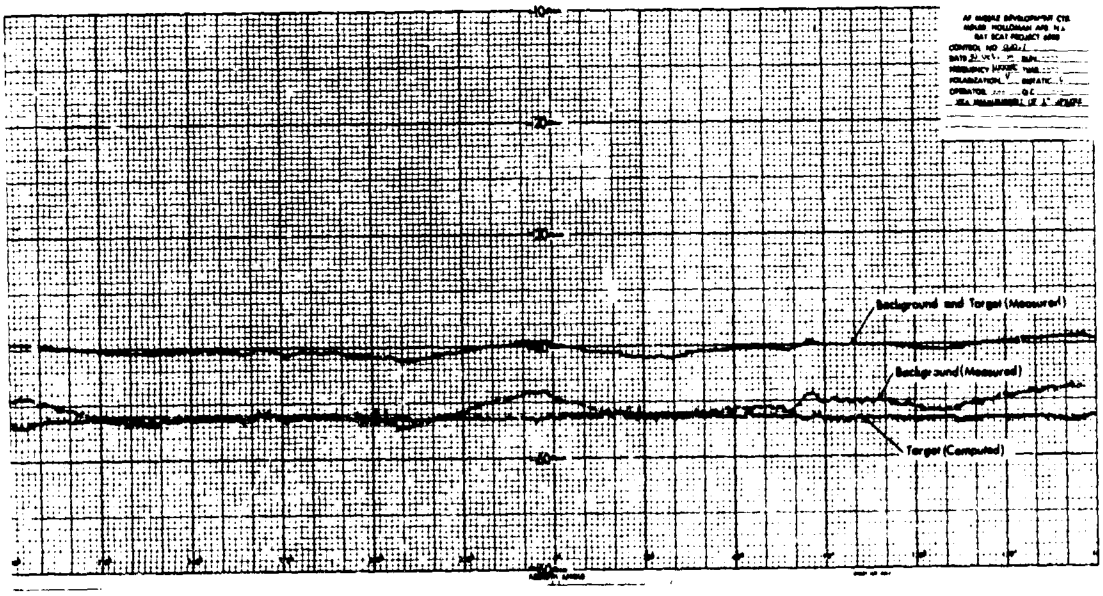


Fig. 43 VFS MEASUREMENT DATA

Figure 44 is a picture of a Polaris first stage, installed in the 2500 foot pit and ready to be measured. The bottoms of the saddles or transitions used are spherical hollows that mate with and bind the three (3) parts of the tripods together. Mating spherical surfaces are incorporated on the tops of each of the legs in the tripod. Note there are no flat surfaces on the mating of the three (3) logs into a tripod.

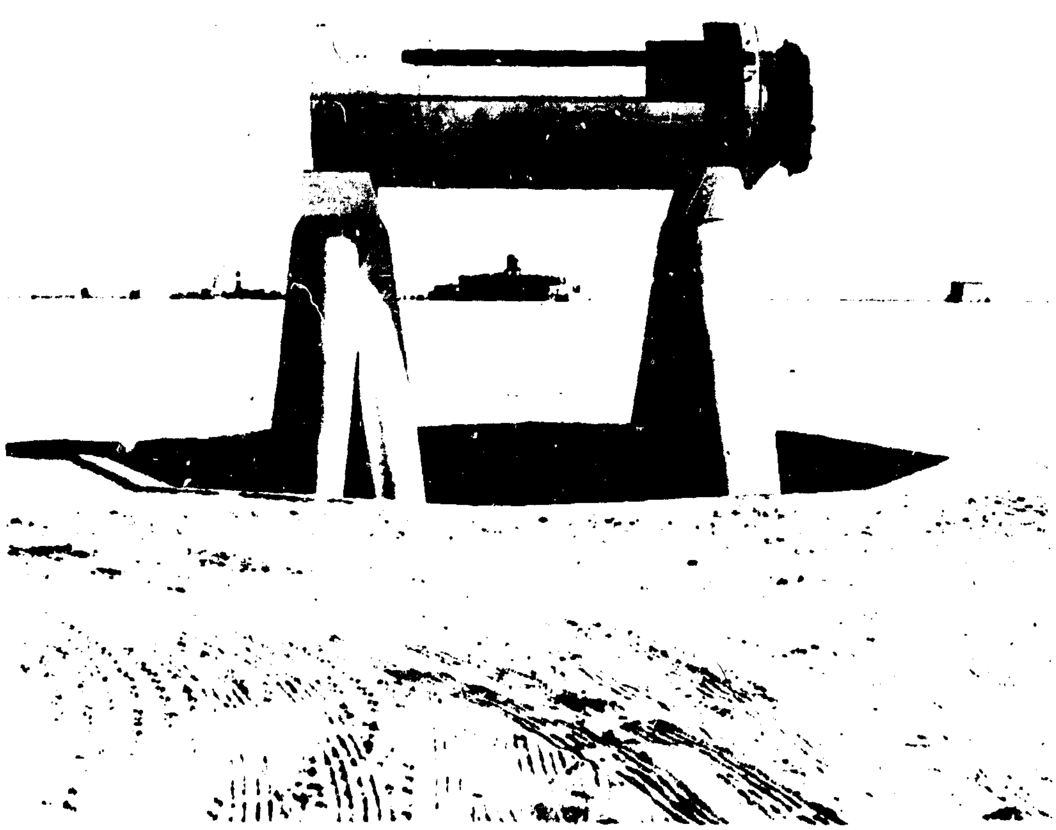


Fig. 44 POLARIS FIRST STAGE

Figure 45 is a photograph of the Mark 11 Re-entry Vehicle (R/V) mounted in the 1200 foot pit on a 19 inch Styrofoam vertical column. The operations building can be seen in the background. In this view, the antenna towers of the three pits are visible. Visible on the table rotator are pads of Goodrich VHP absorber which is used to absorb higher frequency signals.

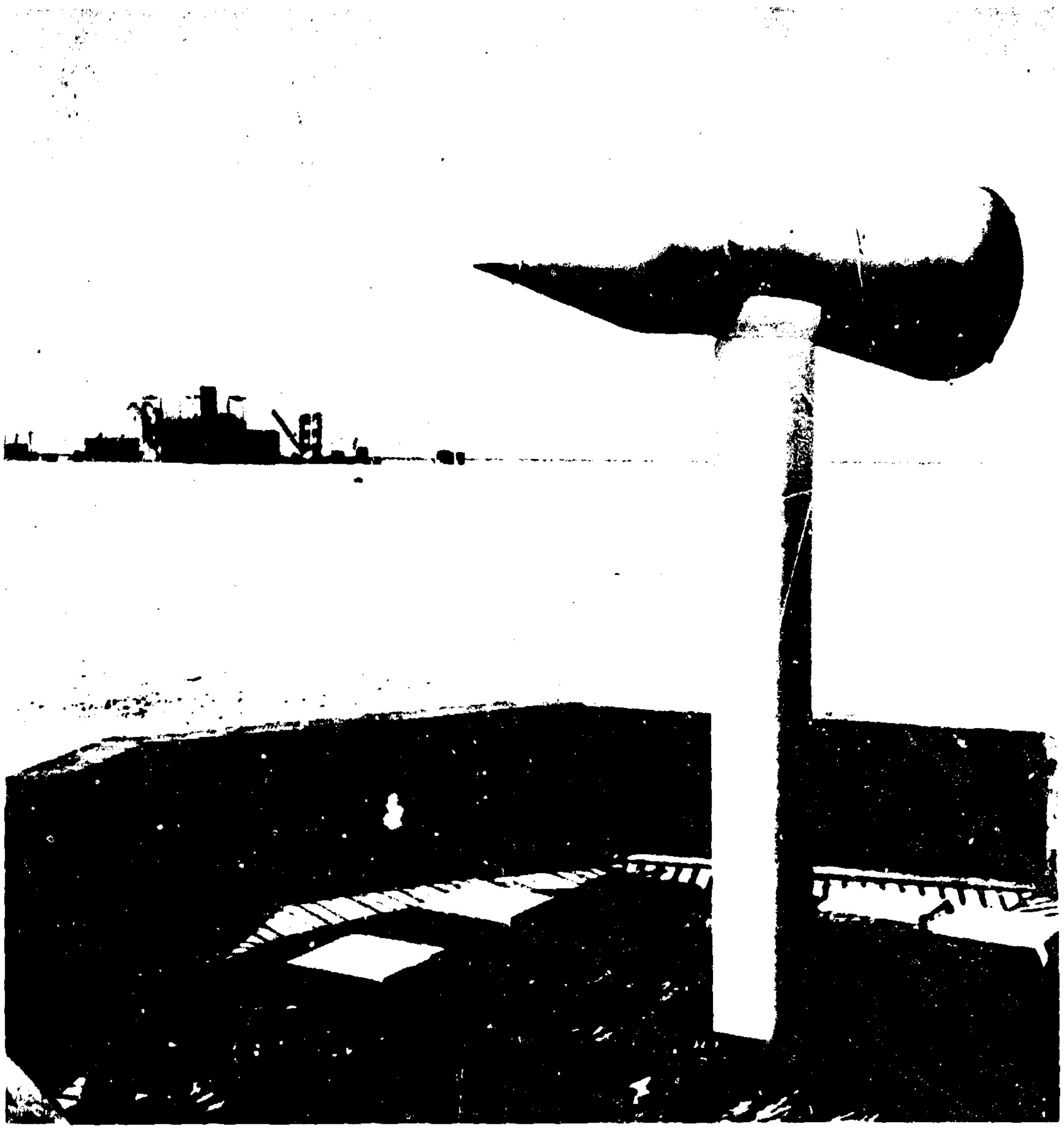


Fig. 45 MARK 11 RE-ENTRY VEHICLE

Figure 46 is a night photograph of the Mark 11 vehicle mounted in the 2500 foot pit on a special saddle or transition. Eccosorb and Goodrich VHP practically cover the complete pit area. This Mark 11 is being measured by using the RAT SCAT Frequency Stepping technique to isolate the significant individual cross section specular contributions to the total radar signature.

Fig. 46 MARK 11 FREQUENCY STEPPING MEASUREMENT

A Nike Apache vehicle, part of the BSD ABRES program, is illustrated in Figure 47. This vehicle was measured for ABRES in order to provide tracking radars with radar signature information to assist in tracking and target definition as well as acquisition. The 500 foot target pit is in the foreground. In the background, two 10 foot parabolic antenna dishes are being fed by log periodic feeds. Also visible are two 6 foot antenna dishes, mounted on the second set antenna tower, and directed at the 1200 foot target pit.

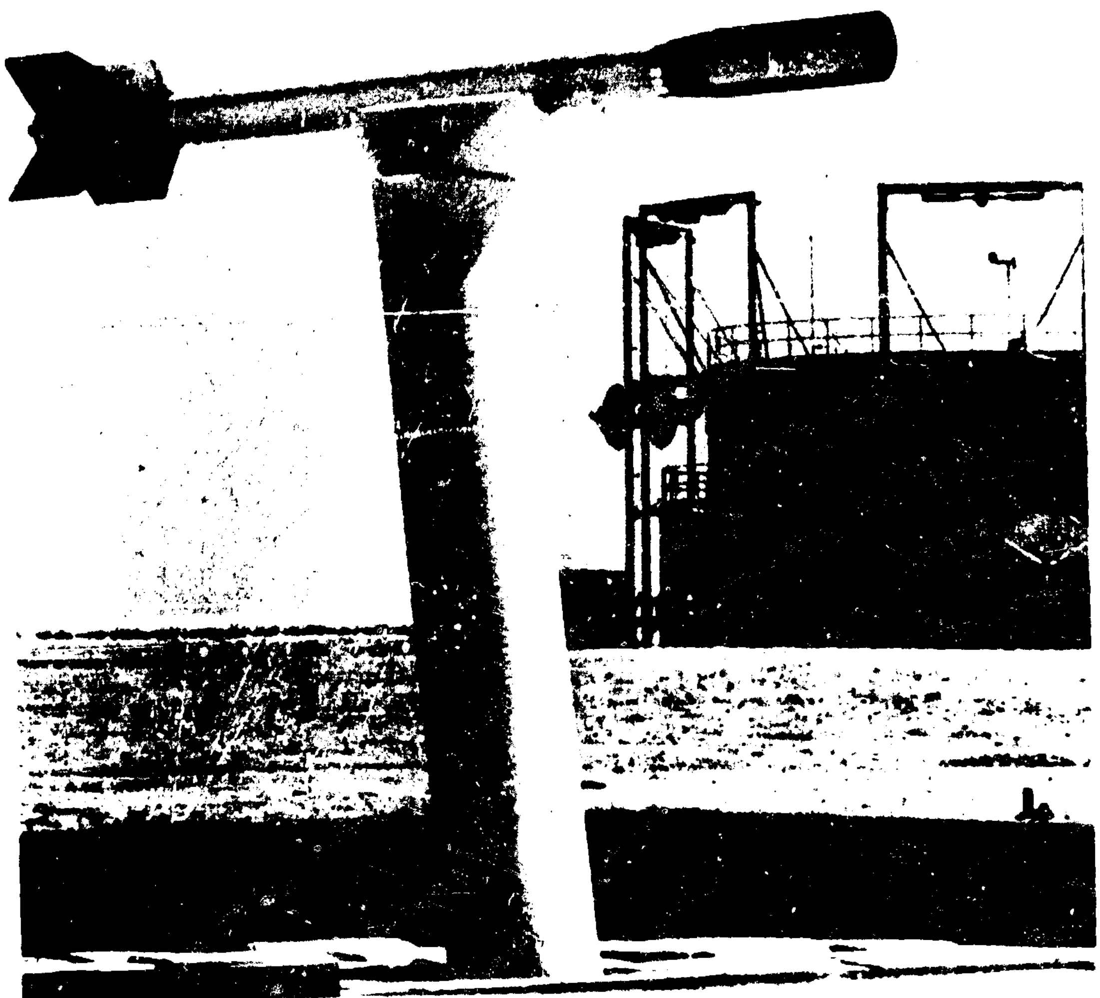


Fig. 47 NIKE APACHE

A side view of an Athena booster is illustrated in Figure 48. The booster is shown supported by a tapered column which is mounted on the rotator of the 1200 foot range.

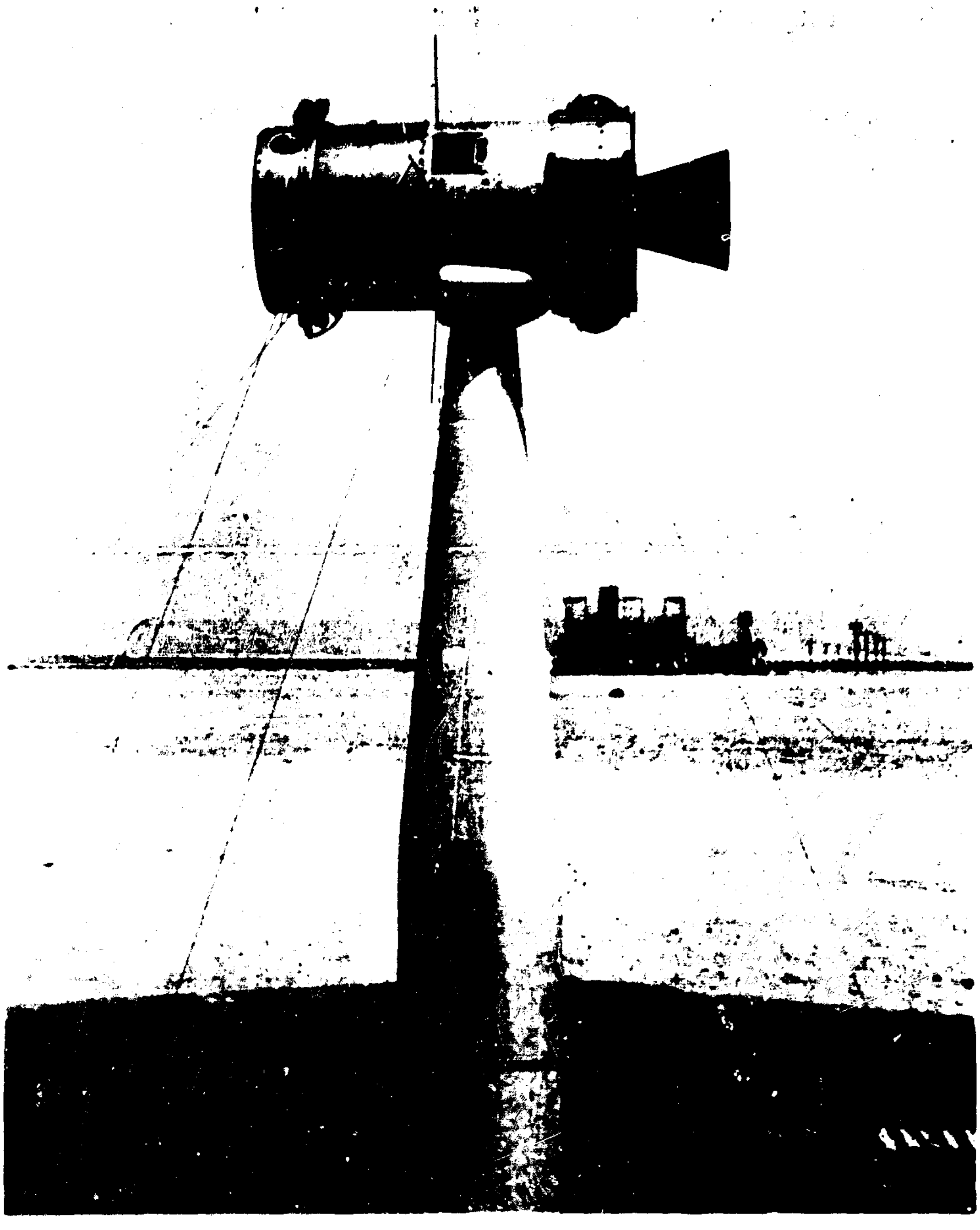


Fig. 48 SIDE VIEW OF ATHENA BOOSTER WITHOUT MOTOR

A photograph of Lincoln Laboratory's "Texas Foxtrot" is reproduced in Figure 49. This photograph was taken with the mobile shelter still protecting the pit. VFS measurements were made of this vehicle at Band 4.

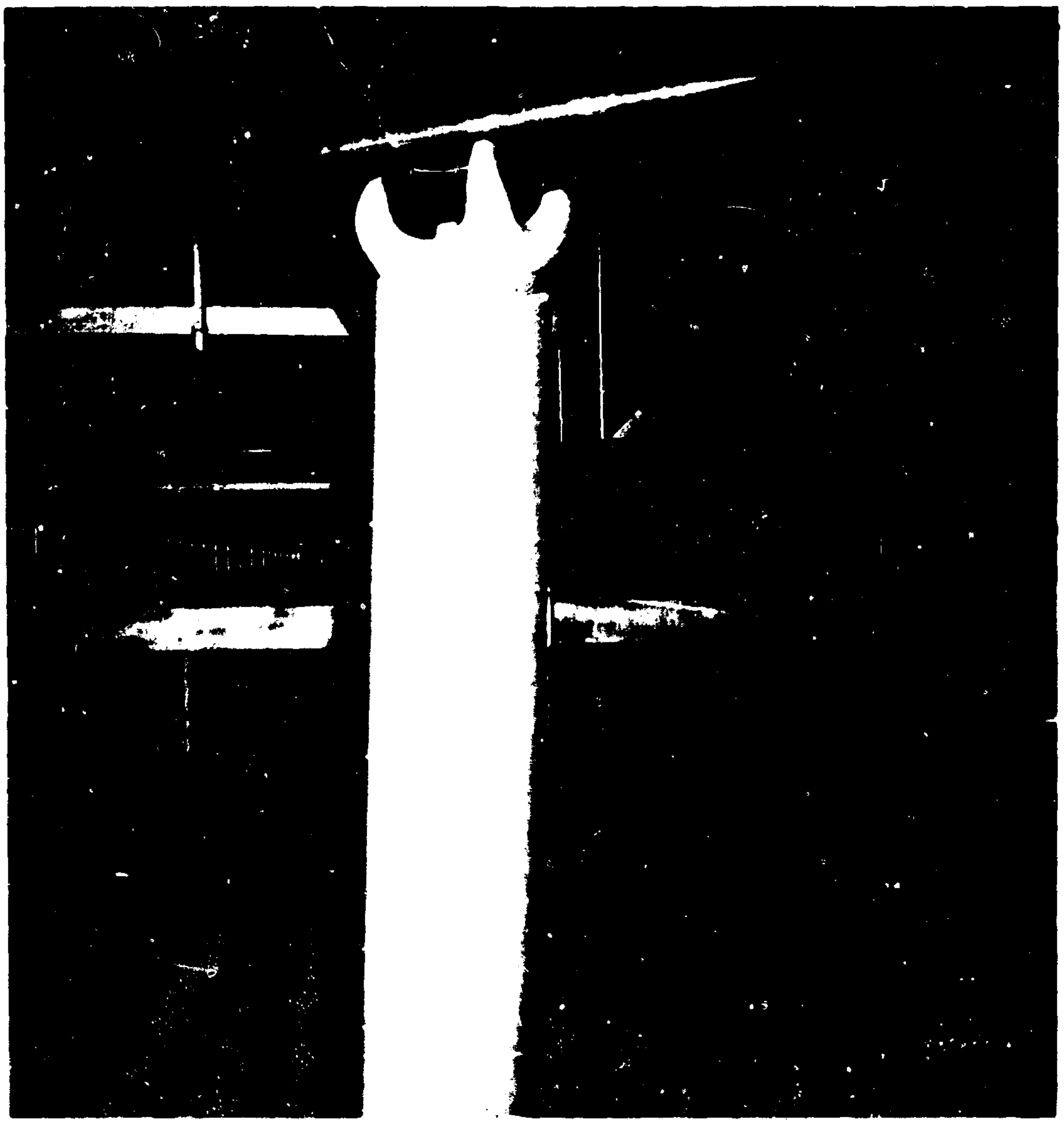


Fig. 49 TEXAS FOXTROT

The Lincoln Lab models "Oboe," "Quebec," and "Peter" are shown in Figures 50, 51, and 52 respectively. The mounting technique is typical for small targets.

Fig. 50 LINCOLN LABS "OBOE"

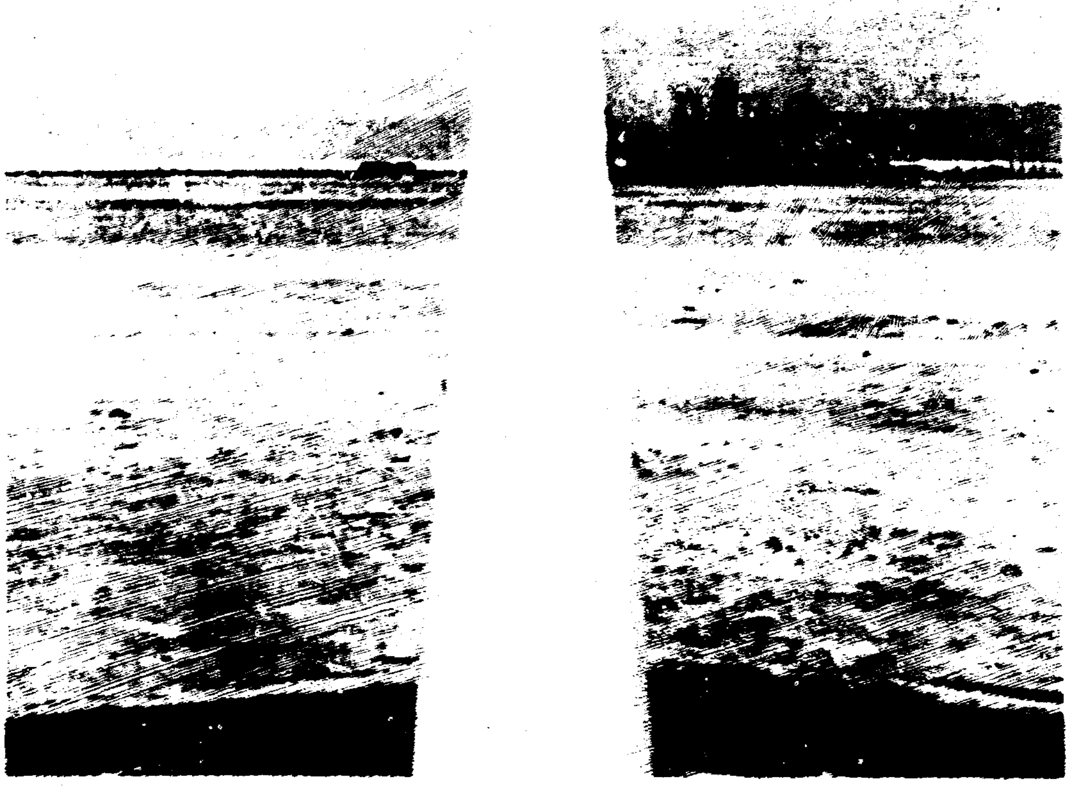


Fig. 51 LINCOLN LABS "QUEBEC"

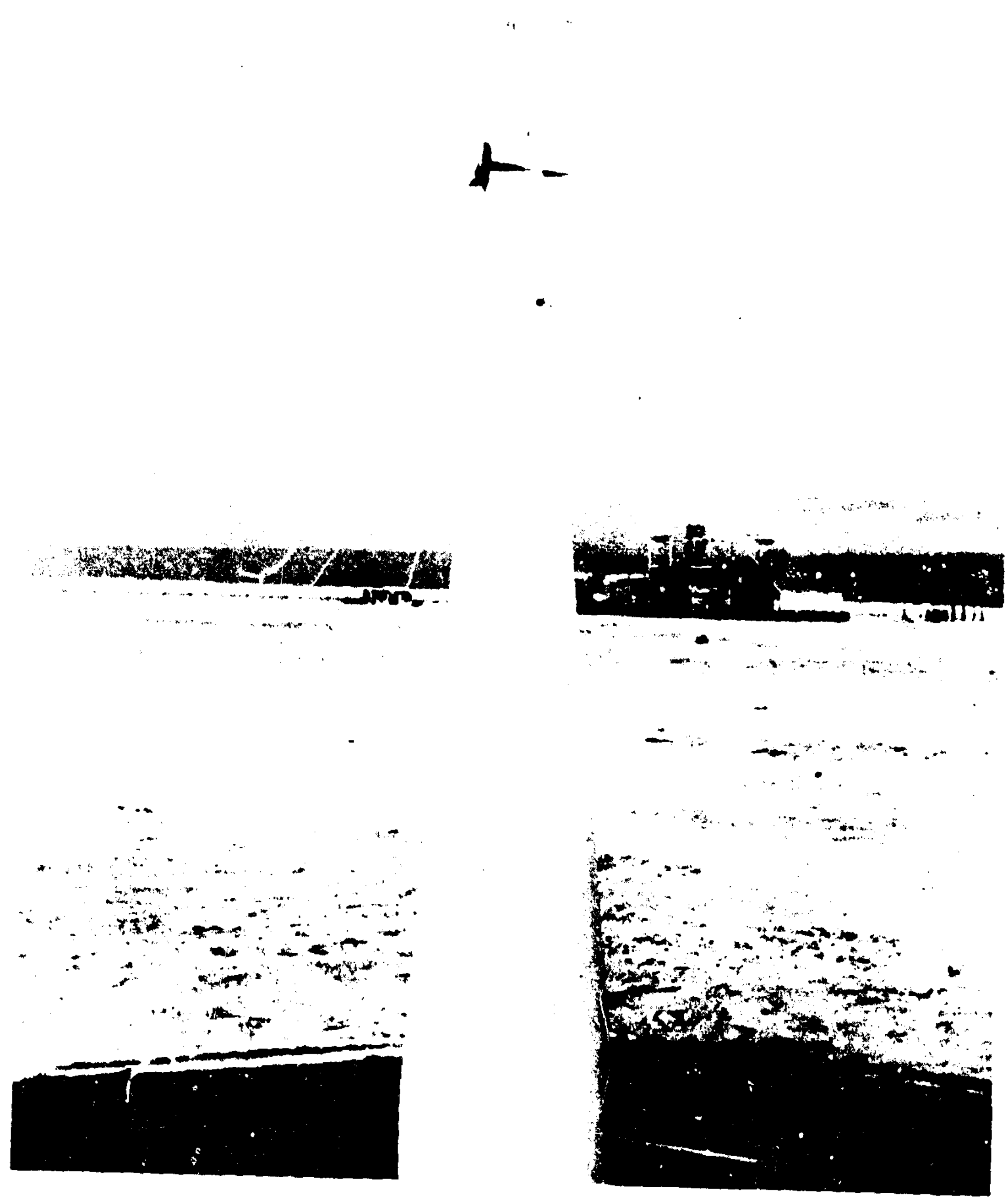


Fig. 52 LINCOLN LABS "PETER"

Figure 53 is a photograph of contractor vehicle 009-1 "REX." This vehicle is shown mounted on the rotator of the 500 foot range. Note the difference in the typical mounting technique used for REX and that of the Pershing Nose Cone as shown in Figures 54 and 55.

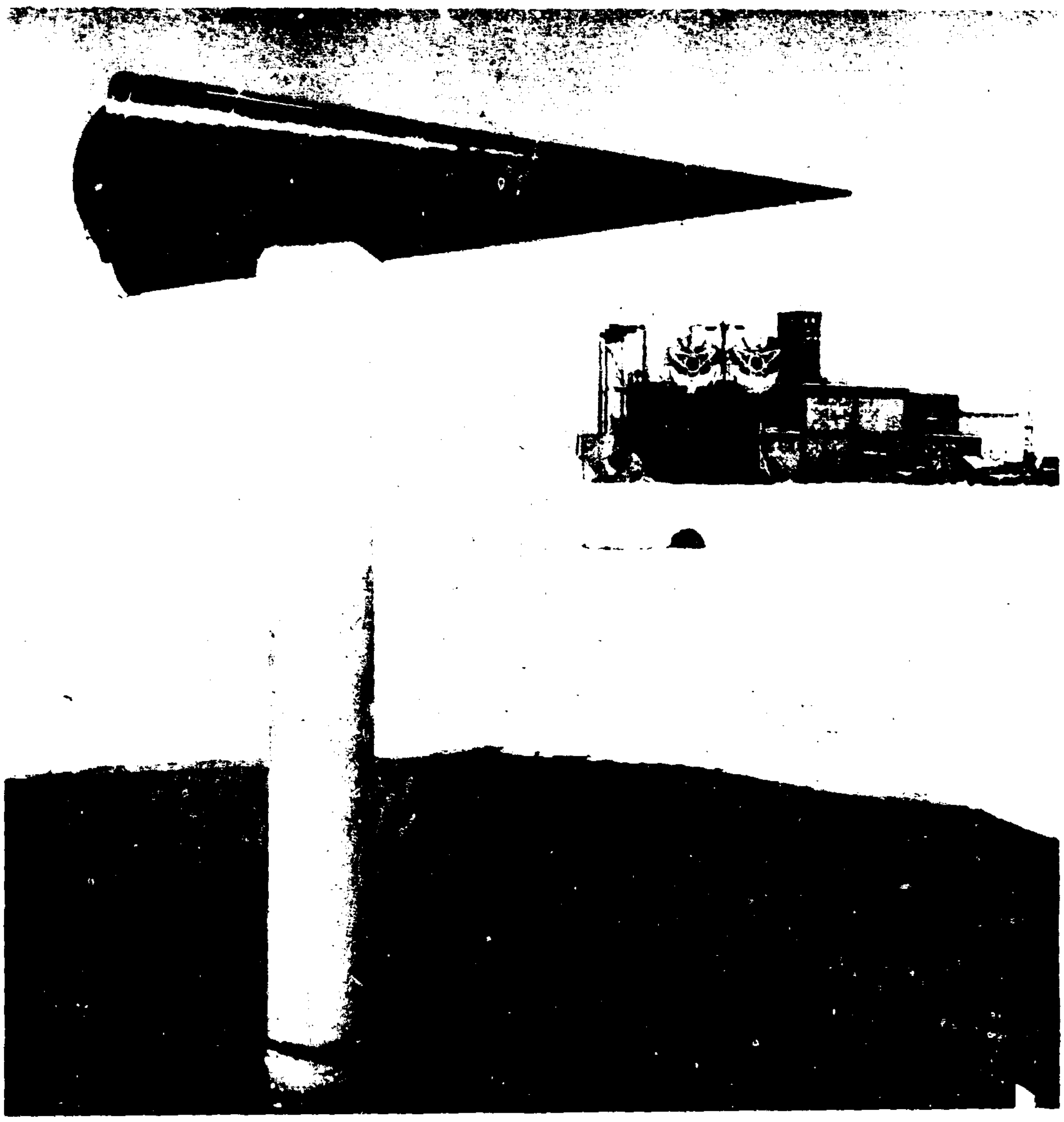


Fig. 53 REX VEHICLE

The Pershing Nose Cone, illustrated in Figure 54, was measured for the Army. These measurement data were also used by BSD for the ABRES program to assist in acquisition and tracking by WSMR Megawatt radars.

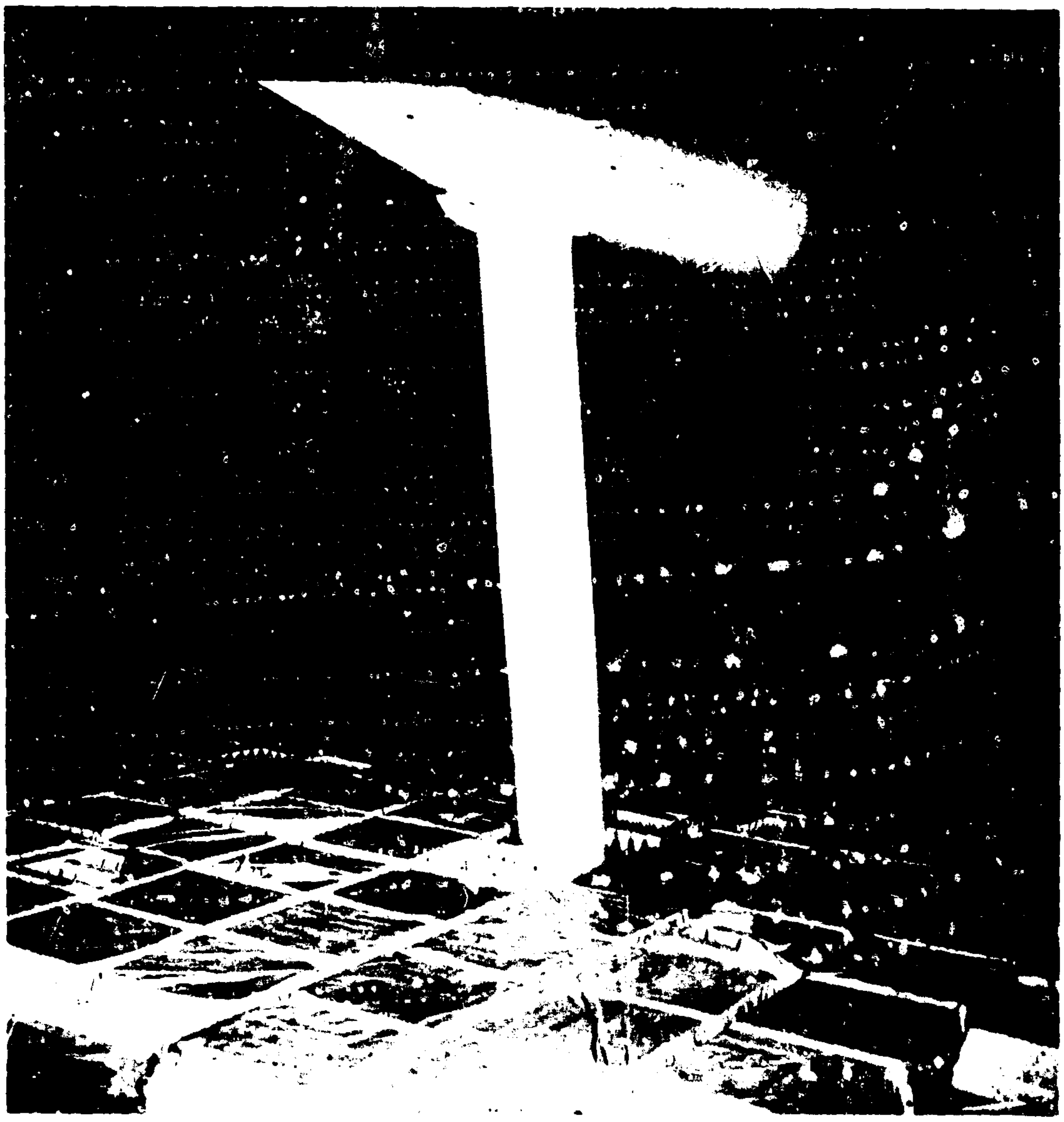


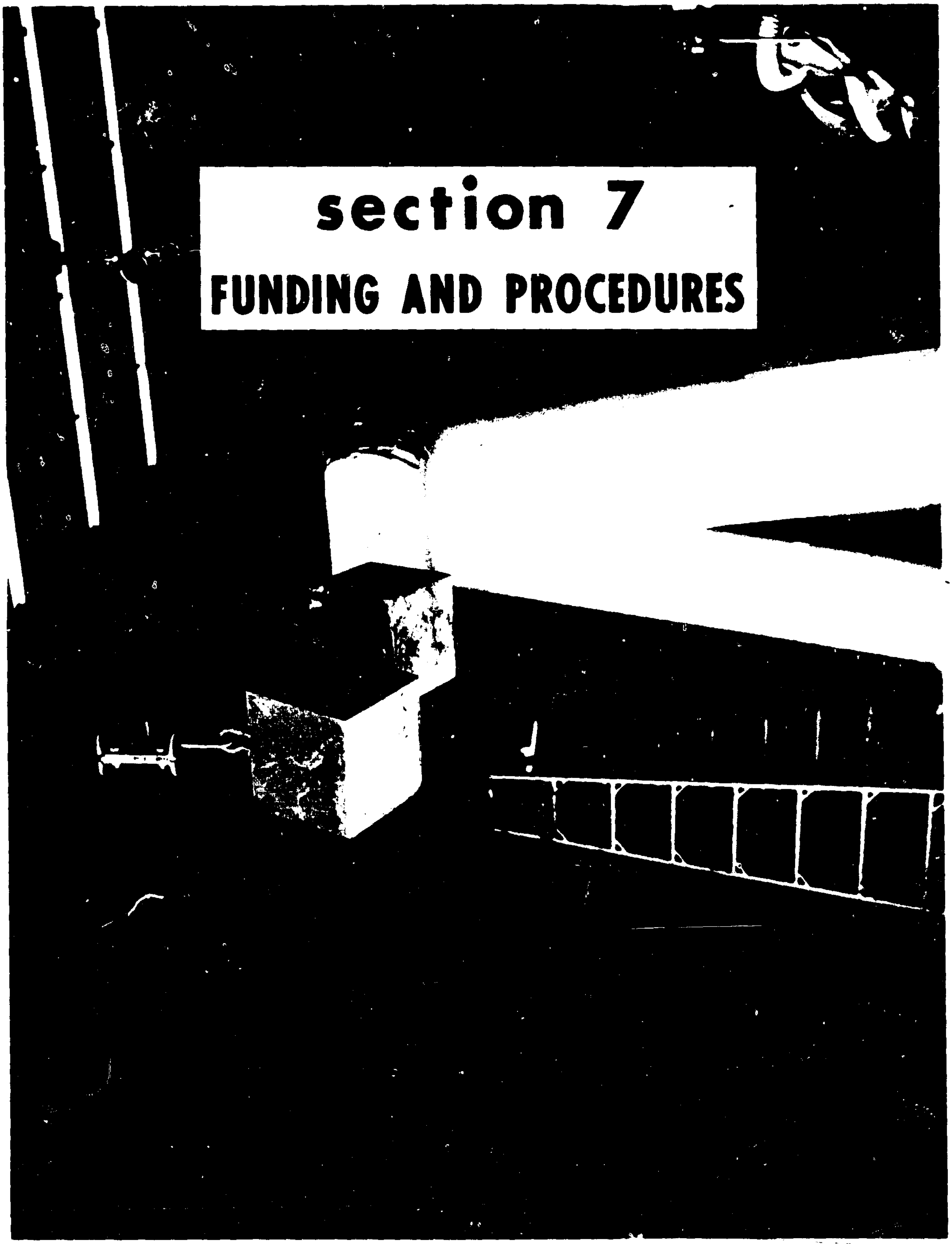
Fig. 54 PERSHING NOSE CONE (1/4 VIEW)

Another view of the Army Pershing Nose Cone is shown in Figure 55. The non-symmetrical mounting was required because of the forward location of the target center of gravity and because of prime interest in the nose on aspect angles.

Fig. 55 PERSHING NOSE CONE (SIDE VIEW)

section 7

FUNDING AND PROCEDURES



SECTION 7

FUNDING AND PROCEDURES

Funding and Services

General

A measuring series is initiated when a potential user contacts the Air Force Missile Development Center (MDOPT and MDLRR) and the user requirements are outlined. A Request For Static Radar Measurements (REFSRAM) is then completed to provide the necessary information to operations personnel. The user will formally submit a letter request to MDOP info MDLRR with three copies of the completed, signed REFSRAM. Acceptance of the test requirements for the Commander, AFMDC, is based upon this documentation. Major changes to the project scope must be formalized by the user and accepted by AFMDC documentation. The REFSRAM (Annex 2) includes information on test frequencies, target orientation, target configurations, bistatic angles, target size, weight and special handling requirements, security classification, special diagnostic test requirements, and type of data desired.

The RAT SCAT test plan and range configuration is established to provide optimum satisfaction of the user's REFSRAM requirements. The range length, target supports, and transitions or saddles are fabricated. Preliminary tests are conducted to establish the fact that the desired flat electromagnetic field (wavefront) exists at the target area and that the entire system is properly calibrated. Each test receives individual supervision; an assigned Data Analyst designs the test parameters, oversees the complete setup, observes the data collection, and subsequently writes the report.

All operations are under the surveillance of the Government quality control and engineering personnel to assure that valid data is obtained. User representatives may monitor test activities if they desire; however, the quality of tests is certified by the Air Force.

Data obtained from the tests is recorded in the form of rectilinear analog plots, polar analog plots, and digital punched paper tapes. A report is prepared for the user containing the test procedures and conditions encountered with an explanation of standardized RAT SCAT procedures, such as target orientation angular references. In conjunction with the data, the report enables the user to make a complete evaluation of the results of the tests. The user can also be supplied a copy of the rectilinear analog plots as "quick-look" data within 24 hours after the data is obtained.

Office space is available in the operations building for the convenience of users who may want to monitor the execution of tests which are being undertaken in response to their requests (on site visitor user phone number is Area Code 505, GR 3-6511, Extension 679-7222). The RAT SCAT facility has been cleared to handle classified material up to and including SECRET. Special arrangements can be implemented by the Facility Chief through military channels to provide guard services, adequate security measures, and strict enforcement of need-to-know requirements. Proprietary information is also provided adequate safeguards.

Funding

Reimbursement will be required for projects conducted at RAT SCAT according to the details established below. The costs involved depend upon the total time in "Pit Hours" required to conduct measurements.

A "Pit Hour" contains many variables and incorporates all incident costs to make the measurements. The RAT SCAT AFMDC facility is the only agency which can estimate the number of Pit Hours required for each task. The formula used is complex but fair to all users. It is

$$\text{Pit Hour/Freq} = 8\ TMF + 1/2\ TN + 1\ AS + K$$

where

T is a measurement difficulty factor proportional to measurements such as Monostatic, Bistatic, Phase, Frequency Step, Polarization or Non-Conventional

M is a measurement difficulty factor proportional to the Radar Cross Section

F is a frequency difficulty factor

N is number of measurements per frequency (360° rotation in azimuth, 1 polarization, 1 roll angle and 1 pitch angle)

A is the number of vehicle alignments or orientation changes

S is a vehicle size difficulty factor

K is a factor for predictable delays (reconfiguration of RV)

The following reimbursement policy is stated:

- USAF Activities	Workload programmed in time for inclusion in support estimates = non-reimbursable
- USAF Activities	Unprogrammed workload = peculiar costs in accordance with Par 3C of AFSCR 172-2
- DOD Agencies	(Army, Navy, ARPA, etc.) will be charged at a predetermined rate per pit hour of $155.00 plus project peculiar items
- Other U.S. Govt. Agencies	Will be charged at a rate commensurate with the scope and magnitude of the specific project
- Authorized Non-Govt Agencies	Will be charged for all government resources expended on their particular project.

Appropriation reimbursement is a payment or repayment to a specific AF appropriation (57X3600 RDT&E) from some source outside the appropriation for services, supplies, etc., rendered and properly chargeable. Examples are: Reimbursements between AF appropriations (57X3010 to 57X3600), from other DOD appropriations (Navy, Army, ARPA), from other governmental agencies (NASA), or outside agencies or activities (contractors, foreign government, etc.). Monies for projects or tasks to be accomplished on a reimbursable basis are obtained by direct fund authorizations. Such documents may be, but are not limited to, the following examples:

- Funded Purchase Request (PR)	Gov't Non-military Agency
- Military Interdepartmental Purchase Request (MIPR)	Military Agency
- Procurement Directive (PD)	AFSC Divisions
- Advice of Allotment (AA)	Air Force
- Obligation Authority (OA)	Air Force
- Military Assistance Sales Case (MAS)	Foreign Governments through AFSC Hqtrs
- Purchase Order - Include Letters of Authority (PO)	Contractors

Fund reimbursement should be made to AFMDC; Attention: COMPTROLLER (MDBCB) and identified as to the named project support. The basis for establishing an accepted RAT SCAT workload occurs when MDBCB receives and accepts a formal funding document as reimbursement.

Procedures

Range Selection

In general, high-frequency measurements are conducted on the 2500 foot range, moderate-frequency measurements on the 1200 foot range, and low-frequency measurements on the 500 foot range. Far field criteria, in conjunction with associated relations concerning antenna dish diameter, target dimensions and frequency, antenna height and target height requirements imposed by a ground plane operations, govern the choice of range according to the formula (Figure 56)

$$h_a h_t = \lambda R/4$$

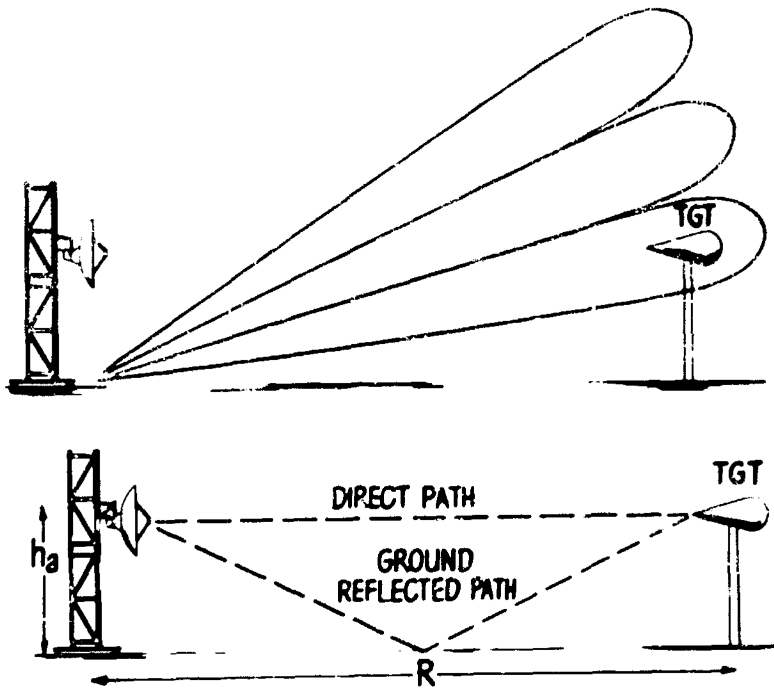
where h_a is the height of the transmitting antenna, h_t is the height of the target, λ is the wavelength, R is the range and all measurements are in feet.

Target Supports

Unless target weight or target height requirements prohibit the use of Styrofoam columns (cylindrical or tapered), advantage is taken of the inherent low radar cross section of these columns. Load testing is shown in the cover photograph for this section. Optimum results can be achieved by "tuning" the column (i.e., varying the diameter to obtain a minimum return) to the test frequency or by shaping columns of appropriate size, or by the use of combinations of these techniques.

The phase measuring capability, in conjunction with the use of associated equipment, can be used to subtract background returns from target-plus-background data and thereby obtain low-level target returns. Phase measurements are also used in scattering matrix applications.

A close-up photograph of the Lincoln Laboratory's "Texas Foxtrot" is shown in Figure 57. This transition (The Bear Cub) is a good example of what can be done with Styrofoam when low cross section targets are to be measured. This transition was fabricated to provide good target stability with a minimum amount of Styrofoam in contact with the vehicle.



Constructive and destructive interference between direct path and ground reflected energy produce a lobe structure in the radiation pattern of the source. The target is located on the first lobe when $h_a h_t = \lambda R/4$

Fig. 56 RANGE SELECTION

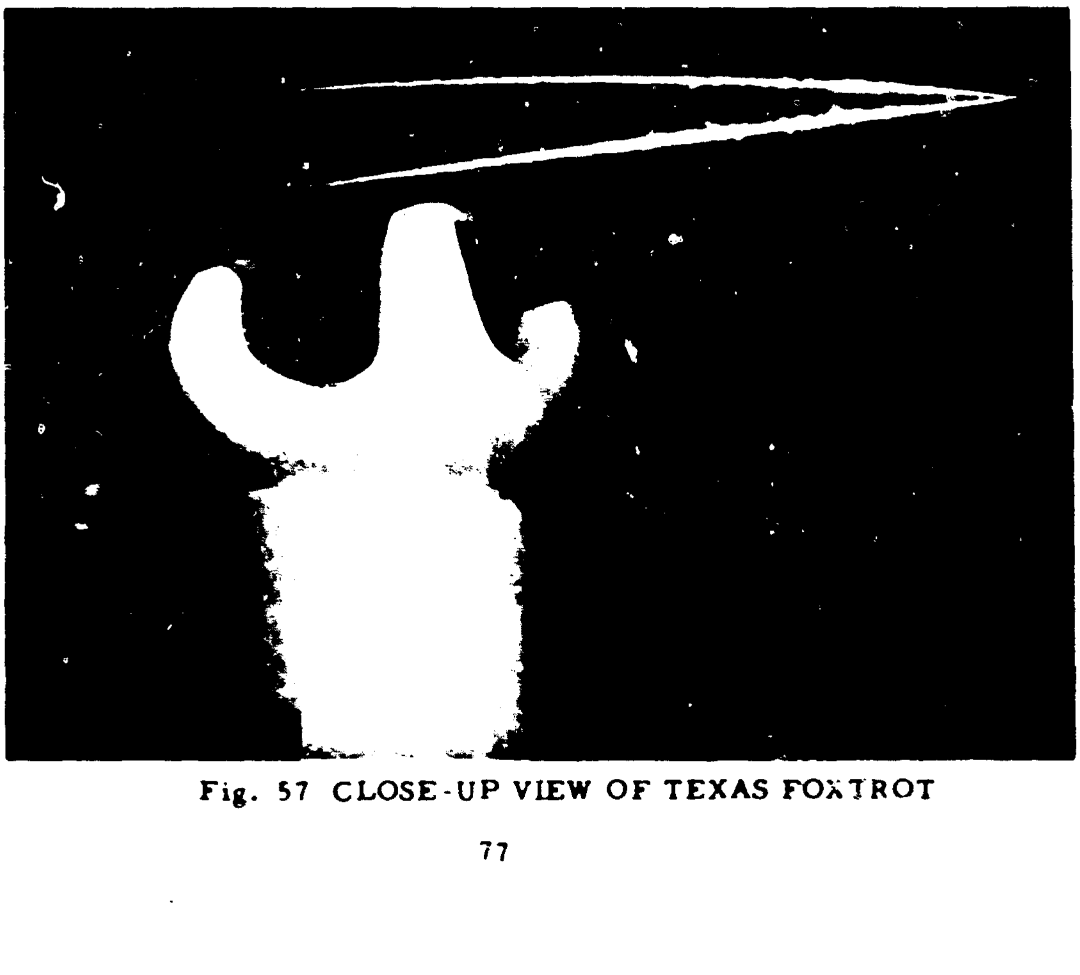


Fig. 57 CLOSE-UP VIEW OF TEXAS FOXTROT

Figure 58 is another type of column used at RAT SCAT. The model is a special cone-sphere India model mounted on a tapered column. The use of proper mounting techniques sometimes permits the omission of nylon tie-down cords. In such cases, the saddle consists of a hollow taper cone section which fits onto the tapered cone section of the column.

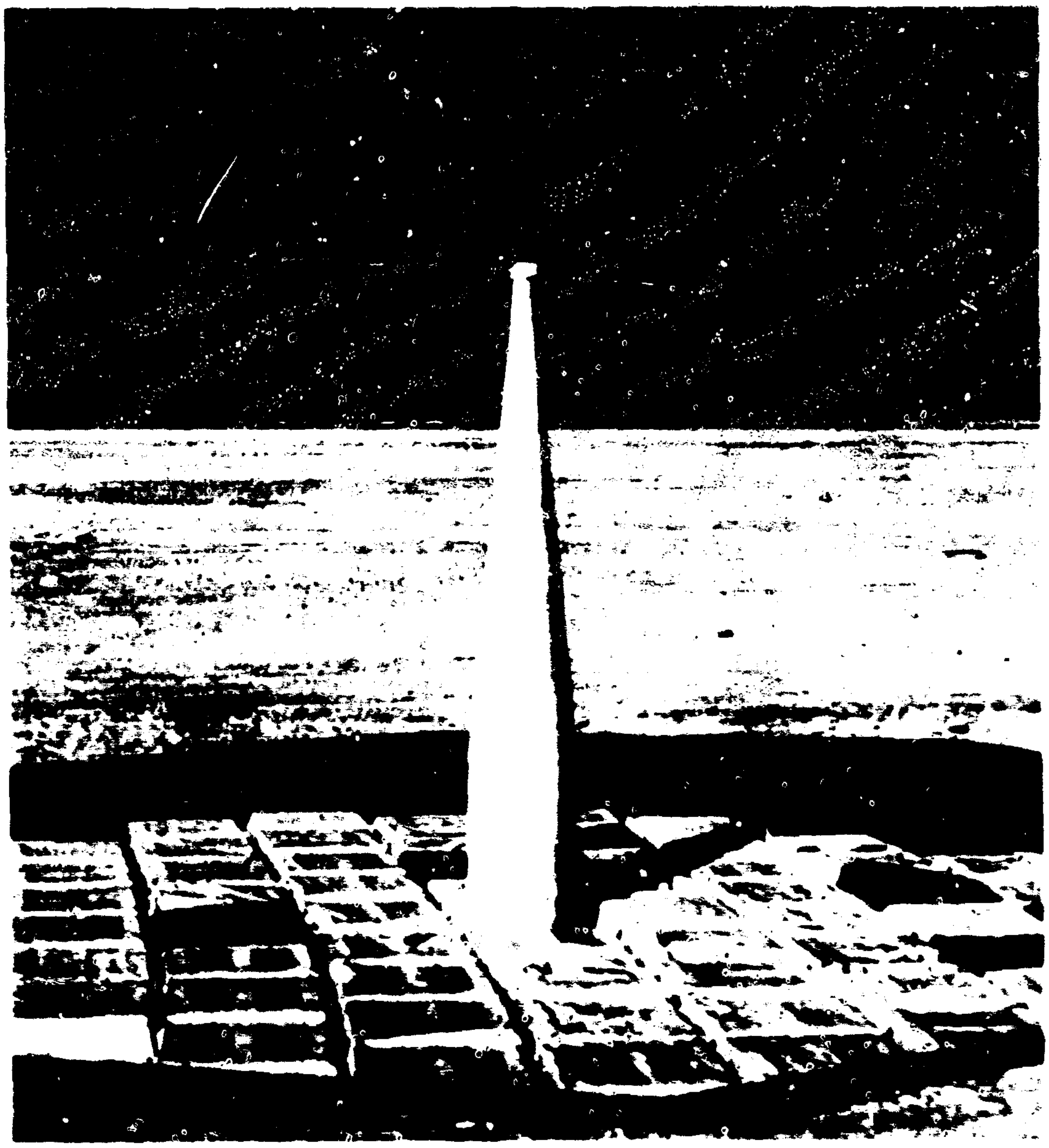


Fig. 58 TAPERED COLUMN MOUNTING FOR INDIA SPHERE CONE

Figure 59 is a photograph of the column and transition used to support the Telstar communications satellite. Measurements were made of the satellite using both fixed frequencies and frequency stepping at X-band.

Figure 60 is a photograph of a "picture frame" transition used for small targets requiring random orientation.

Field Probes

Vertical probes are taken at the target area to determine that the electromagnetic field is uniform over the area occupied by the target. Optimal operating conditions are realized when the field is constant throughout the area occupied by the object to be measured. Horizontal probes at the target area have been shown to be characterized by consistent repeatability and are therefore unnecessary for the majority of targets. For this reason, these probes are taken only upon specific request. Figure 61 illustrates the set-up used to measure the vertical field for part of the Polaris measurements. This type of set-up is used when relatively large vertical target dimensions or target heights are involved. With this type of set-up one-way probes are made for each antenna. For target heights up to approximately 12 feet, the vertical probe is obtained by measuring the return from a sphere as a function of target height. The target height is varied by moving the rotator table up and down.

Range Calibration

System calibration is accomplished prior to a test series by mounting a precision primary standard, i.e., one of the standard spheres (Figure 62) on the target support. Precision spheres made of a uniform highly conductive material are used since the radar cross section of a sphere can be readily calculated and the return is invariant in azimuth. The return from the sphere is recorded. The return from a secondary standard, at a location remote from the primary standard, is singled out by range-gating, and the return is recorded on the same plot as the sphere primary standard return. The secondary standard is thus calibrated by reference to the primary sphere standard.

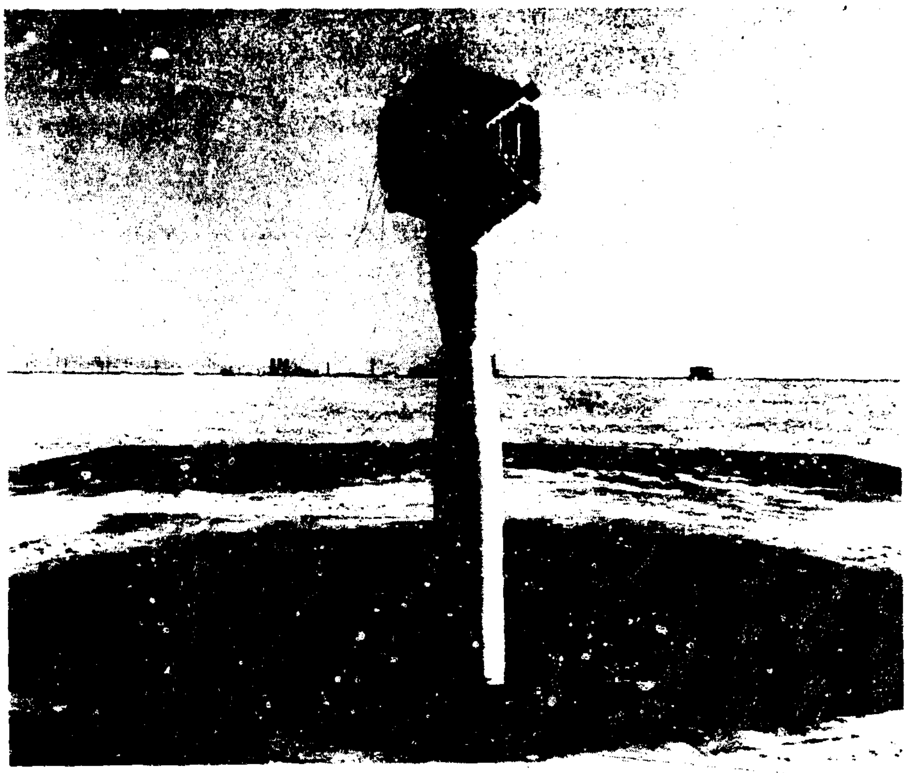


Fig. 59 TELSTAR COMMUNICATIONS SATELLITE

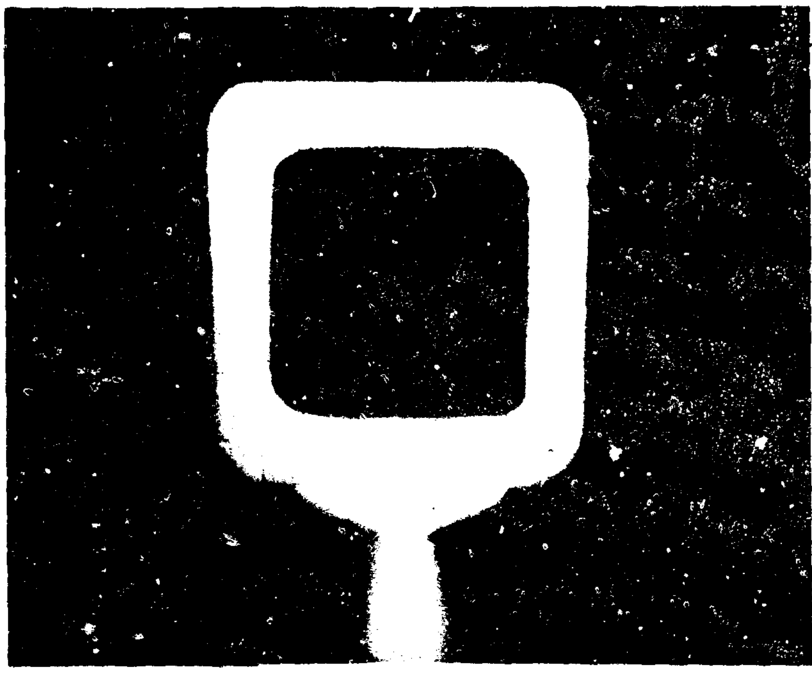


Fig. 60 PICTURE FRAME TRANSITION

Fig. 61 PIT SET-UP FOR ONE WAY VERTICAL PROBE

Fig. 62 PRIMARY STANDARD SPHERE

During target measurements, the primary standard sphere is replaced by the target. Range-gating is used for alternate selection of the target area and the secondary standard area. Each data record then contains a plot of the return from the target and the secondary standard; these plots insure quality calibration for each target plot. Although equipment long time stability has been verified, this calibration technique obviates the necessity for erecting a primary standard before and after each measurement since each run is calibrated by reference to the secondary standard (a known invariant level).

The device used for a secondary standard is not exceptionally critical since its orientation with respect to the radar is fixed and its cross section is measured rather than calculated. The secondary standard normally utilized at RAT SCAT consists of a retractable corner reflector (Figure 63) mounted a sufficient distance from the target area to permit discrimination between the two targets by use of the range-gate. Other similar retractable secondary standards contain Luneberg lenses in place of corner reflectors.

The secondary standard is recalibrated by means of the primary standard at the conclusion of each test series to insure the quality and accuracy of the data.

Error Evaluation

The report provided each user includes target plots, a log of pertinent data runs and background data. Background data is included to permit the evaluation of the effect of the background on the target measurements. Examples of the effect of the background level on the accuracy of the measurements are shown in Figure 64. Incoherent background is typified by random noise such as that found in radar receivers, where the phase is also of a random nature. Coherent background is typified by the return from real scatterers where amplitude and phase are correlated and are not random. This type of background return is amenable to cancellation or subtraction techniques to minimize its interference.

Vehicle Reference

A three-axis system, referenced to the three planes of a vehicle, is illustrated in Figure 65. In this system three mutually perpendicular planes (yaw, pitch, and roll) pass through the vehicle so that the pitch and yaw planes mutually intersect on the longitudinal axis of the vehicle. These planes remain fixed with respect to the vehicle, regardless of the

Fig. 63 SECONDARY STANDARD (MID RANGE)

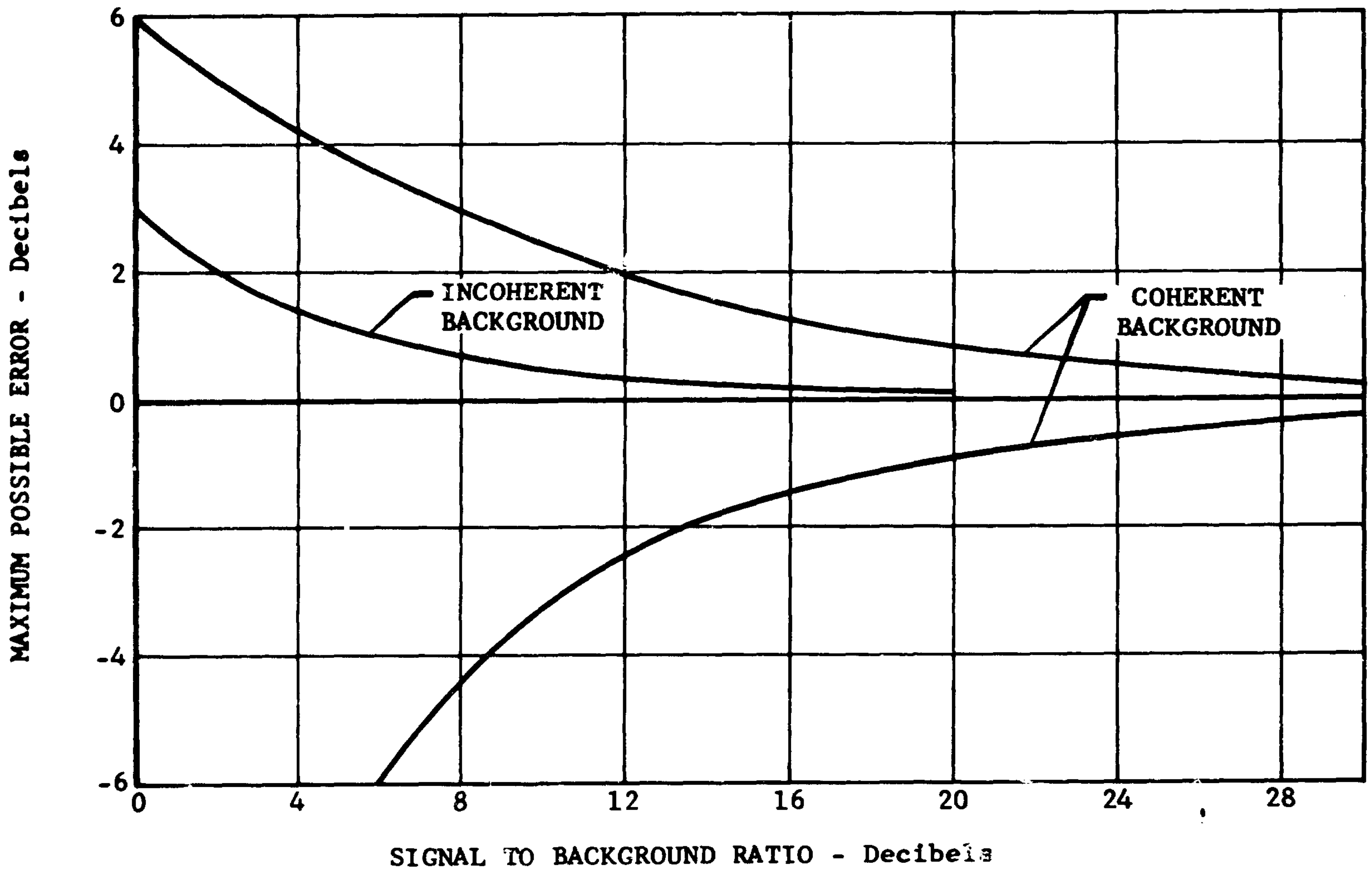


Fig. 64 PLOT OF ERROR INDUCED BY BACKGROUND

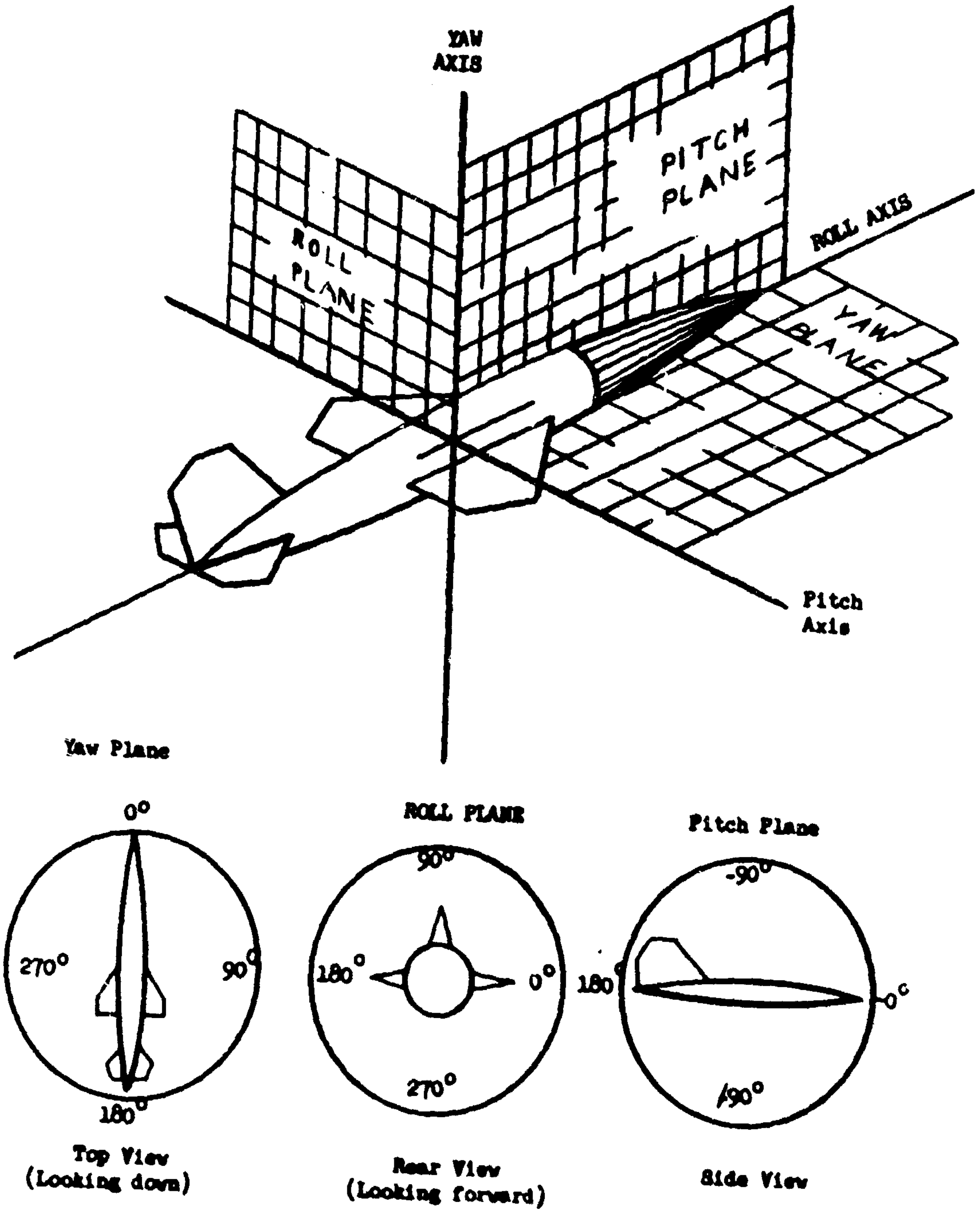


Fig. 65 VEHICLE COORDINATE SYSTEM

vehicle rotation with respect to the radar or ground plane. The yaw plane, which includes the pitch axis and the roll axis, is numbered from zero degrees to 360 degrees in a clockwise direction when the vehicle is viewed from above. The nose-on aspect corresponds to zero degrees, the starboard side of the vehicle corresponds to 90 degrees, and the port side to 270 degrees. The pitch plane, which contains the roll axis and the yaw axis, is numbered from zero degrees to ± 180 degrees; the +90 degree point is below the center line. The roll plane contains the yaw axis and the pitch axis. It is numbered from zero to 360 degrees, and the numbers increase in a counterclockwise direction when the vehicle is viewed from the rear. The coordinate system described herein has been adopted as a standard for orientation of targets for RAT SCAT operations. The system is referenced both to the vehicle being measured and to the measurement site.

Site Reference

As previously stated, the coordinate system is fixed with respect to the vehicle. It is referenced to the site by means of three index marks. The exact value of any of the three angles is determined by noting the value of the vehicle coordinate opposite the index marks. Even though the index marks are imaginary, in the sense that they cannot be seen, they can be established by means of such devices as bubble levels, inclinometers, and transits.

As illustrated in Figure 66, the index for roll angles is normal to the axis of rotation. As illustrated in Figure 67, the index for pitch angles is normal to the axis of rotation and in line with the apparent source of radiation. For measurements at the RAT SCAT site, targets can be mounted to provide desired pitch and roll angles.

Coordinate System Tilt

For small targets another angle, "tilt," can be utilized in recording useful data. This angle, equipment-limited to 15 degrees, is formed by the axis of rotation and the normal to the line-of-sight to the apparent source of radiation. Since, in a ground plane range, radiation can be considered to emanate from a point with zero height directly beneath the antennas, a zero-degree tilted axis of rotation is slightly off the geometrical vertical. This small deviation from the geometrical vertical is neglected in the following discussions. This tilt angle adjustment is necessary as the resultant wavefront from the direct

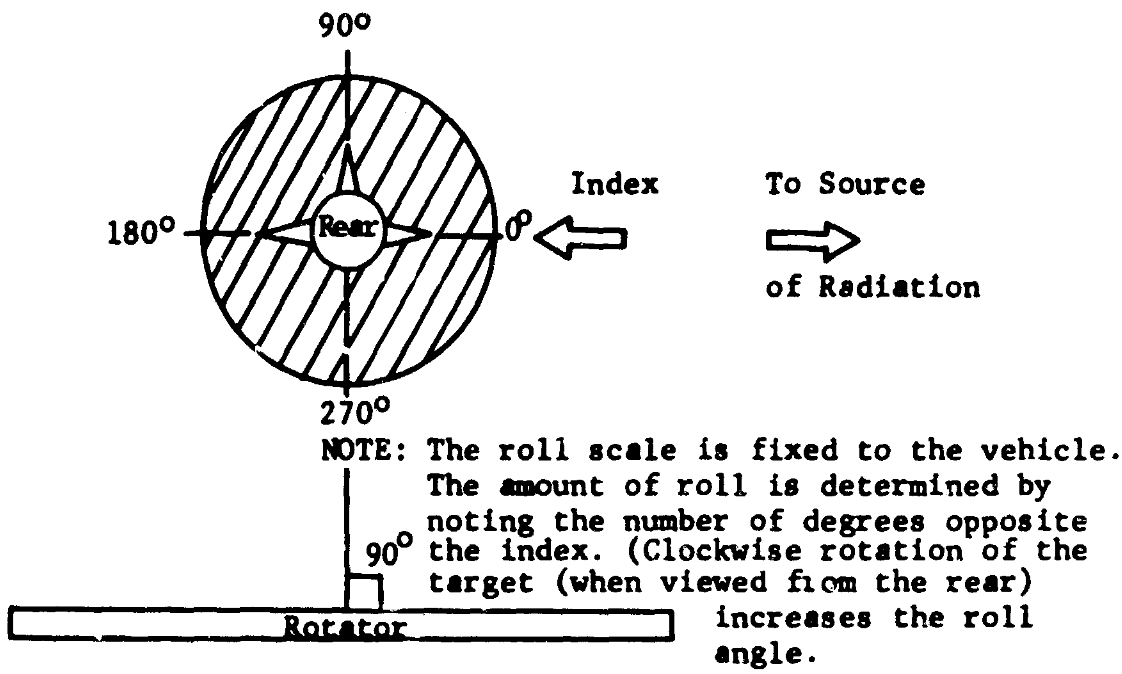


Fig. 66 ROLL ORIENTATION

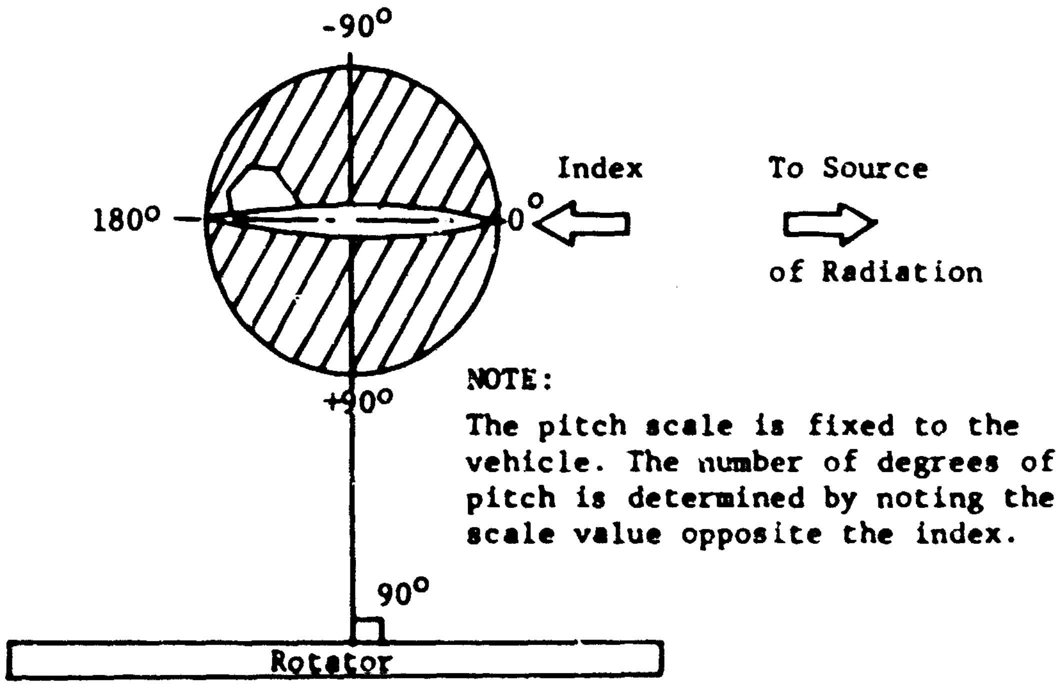


Fig. 67 PITCH ORIENTATION

and reflected wave has an upward vector from the horizontal. A target mounted with a pitch angle other than zero displaces the yaw axis from the vertical, but not the axis of rotation. The axis of rotation is displaced from the vertical only when non-zero tilt is employed. Tilting toward the radar is considered positive tilt. Without exception, tilt will be positive and will be measured in the vertical plane containing the line of sight between the radar and the target. The difference between pitch and tilt is shown in Figure 68.

Data Format

Data recorders obtain azimuth angle information by means of synchro signals from the target rotators. The line of sight from the antennas to the center of the rotator, as illustrated in Figure 69, indexes azimuth angles. As used here, the term azimuth refers to the position of the target rotator. With zero degrees of pitch and roll, azimuth and yaw are identical. Unless noted otherwise in the Data Plot Index, it is standard practice to turn the rotator in a clockwise (CW) direction as viewed from above. Consequently, the azimuth angle varies, for example, from 180 degrees (tail-on) to 90 degrees (starboard side) to zero degrees (nose-on) to 270 degrees (port side), back to 180 degrees (tail-on).

Polar and Rectilinear Plots

Most information pertinent to each plot is contained in the information block located in the upper right hand corner of the rectilinear plots and in the second quadrant of the polar plots. The report's Data Plot Index contains additional significant data and the run numbers of significant plots. On each rectilinear plot, 270 degrees (port side) is positioned on the left side of the plot, zero degrees at the center, and 90 degrees (starboard side) on the right hand side of the plot, as shown in Figure 70. Since the paper moves from left to right under the recorder pen, it should be noted that measurements are initiated at 180 degrees in order to obtain continuous measurements on the recorder paper. The table on the polar recorder is rotated in the same direction as the target; consequently, the 90 degree point appears on the right side of the polar plot, the 270 degree point on the left, and the zero degree point at the top of the plot.

Data

At the user's request, radar cross section data are available in digital form on chadless punched tapes. The 11/16-inch tape is punched

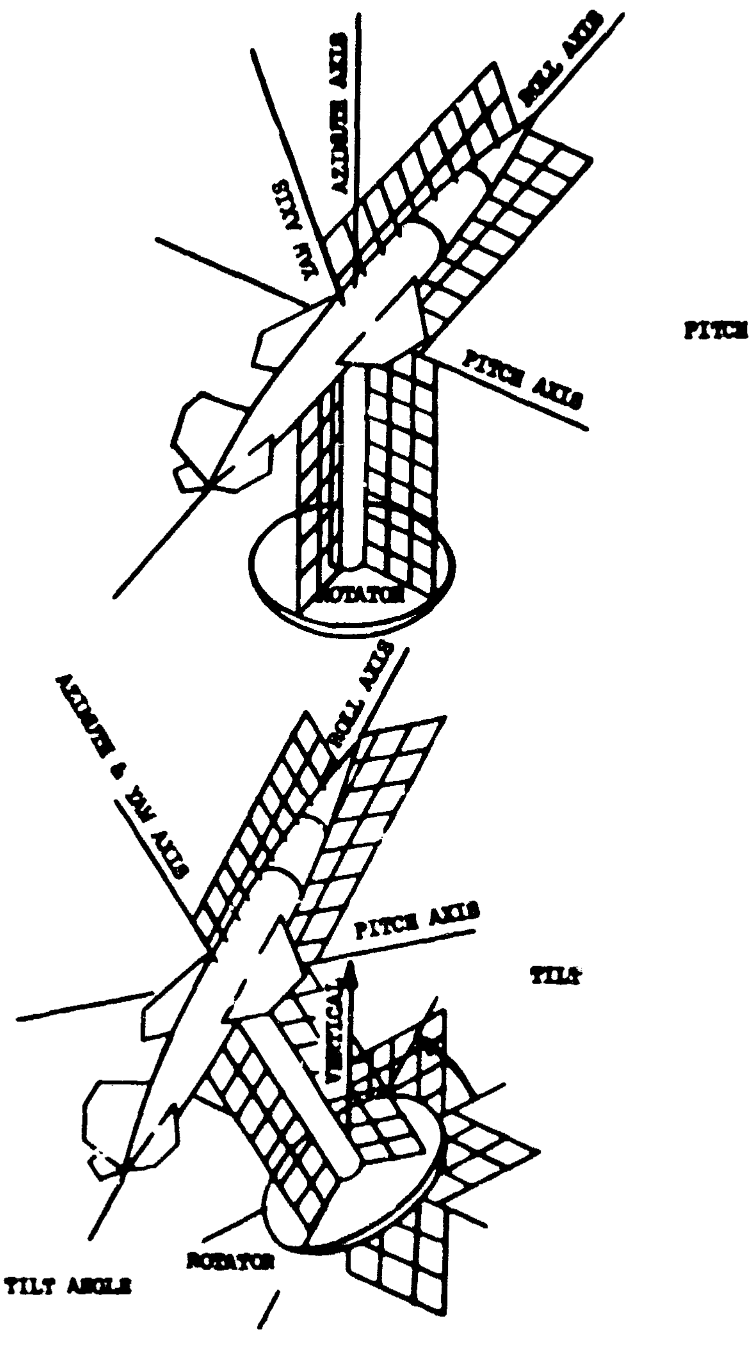
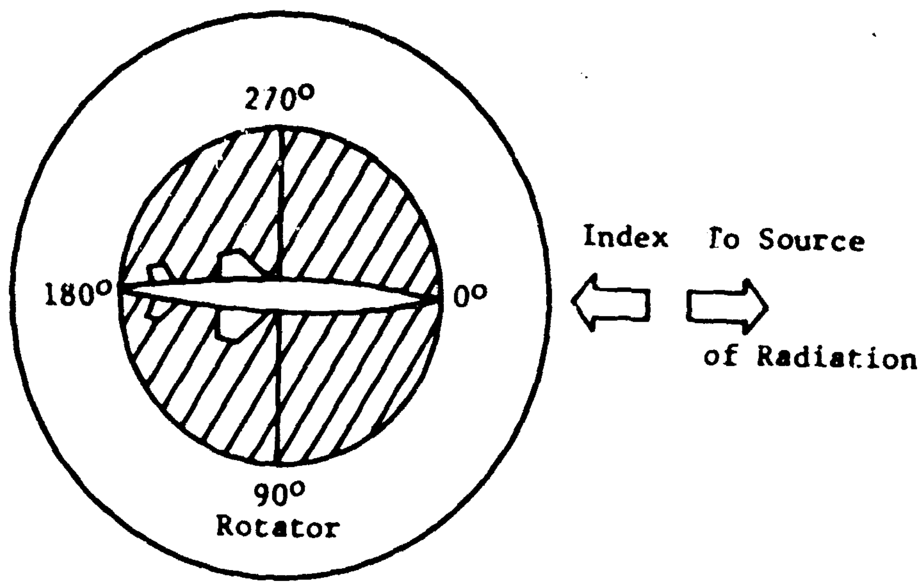


Fig. 68 COMPARISON OF PITCH AND TILT



NOTE: The azimuth scale is fixed to the target rotator. The azimuth value is determined by noting the value of the scale opposite the index mark as the rotator and scale revolve. The index is the line-of-sight from the radar antennas to the center of the rotator. (Azimuth angle data are transmitted to the data recorders by means of synchro signals.) The standard direction of rotation will be clockwise.

Fig. 69 TARGET ORIENTATION

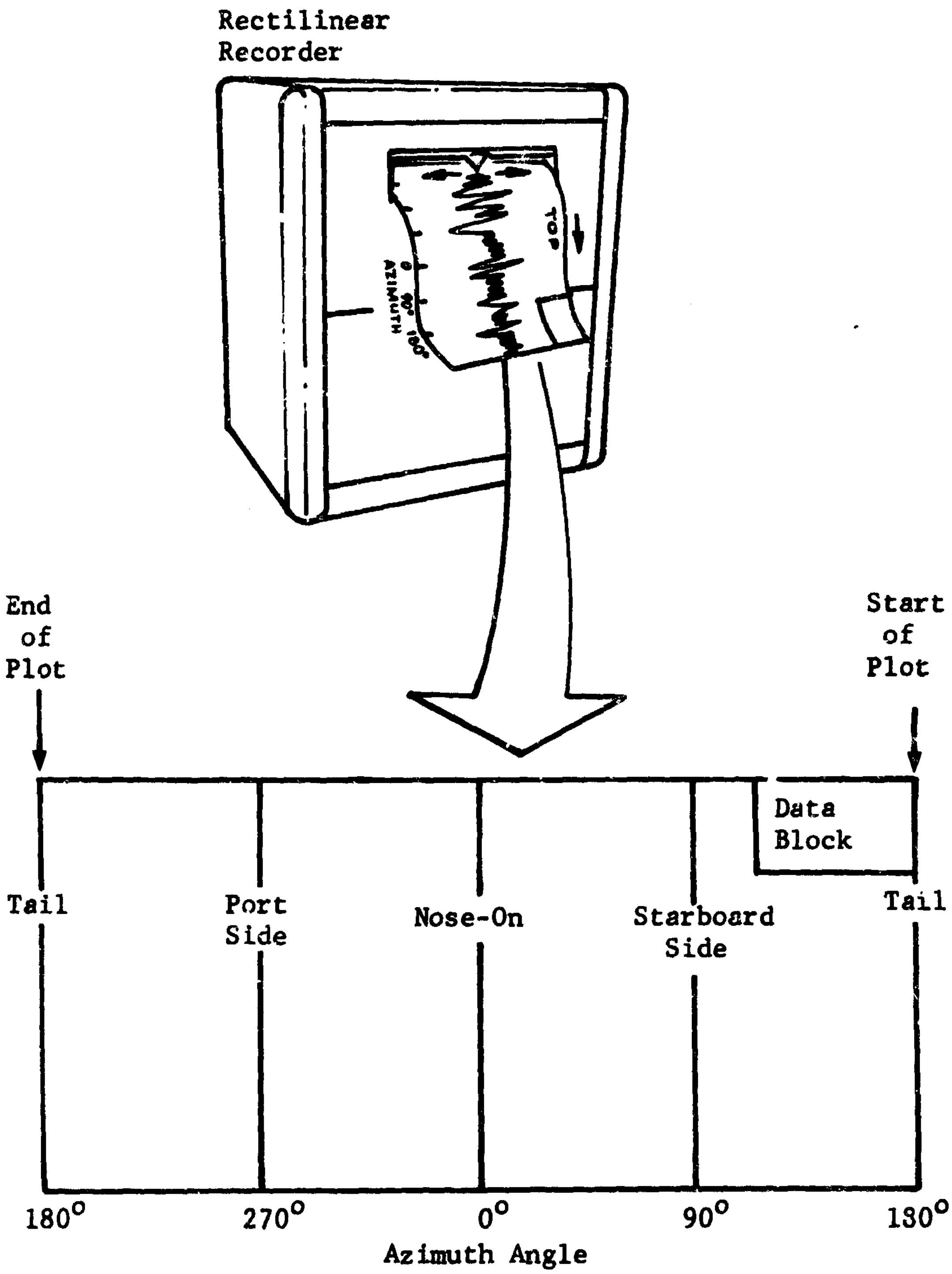


Fig. 70 FORMAT FOR RECTILINEAR PLOTS

with the standard TELETYPE COMMUNICATIONS (Type 3) code in which 5-bit characters are used. Sigma servo positions, quantized to tenths of a db, are recorded at specified azimuthal increments (0.1, 0.2, 0.4, 1.0, 2.0, or 4.0 degrees). Each of these recordings are preceded by the corresponding value of the rotator azimuth position. Since all three recorders are synchronized to azimuth positions of the rotator, the digital data, as in the case of the rectilinear plots, begin at the tail end of the vehicle and progress as if the vehicle were turned clockwise.

On each digital data run, a section of paper tape, called the header, precedes the run; this tape contains information identifying the run. A format, along with a standard set of symbols, has been chosen to facilitate identification of different portions of the header. It is also used to process the paper tape in a form that can be used as an input to a digital computer. Format symbols are the following:

Carriage Return	≤
Line Feed	≡
Figures	↑
Letters	↓
Start Identification Information	(
Stop Identification Information	)
Start Data (exclamation point)	!
Plus Sign (quotation mark)	"
Minus Sign (dash)	-
Secondary Standard (ampersand)	&
Primary Standard (dollar sign)	$
Target (question mark)	?

The following format, consisting basically of three sections, provides a uniform procedure for recording and identifying data:

1. Identification Information - The identification information section includes pertinent information applying to a particular run. This section, enclosed in parentheses, includes control number, run number, date, time, polarization, frequency, and brief description.

2. Secondary Standard Data - Data representing secondary signal levels follow the identification information. These data are preceded on the recording tape by an identifying symbol, ampersand (&), followed by a plus or minus sign, three digits, and an exclamation point, such as &"40.0!. In this example "40.0 is the conversion constant referred to in the subsequent paragraph on digital tape calibration.

3. Target Data - The target data format is identical to this secondary standard data format, with the exception that the ampersand (&) is replaced by a dollar sign ($) or a question mark (?), depending on the object being measured. The former ($) is used for primary standards; the latter (?) for vehicles, background, etc.

Unlike the graphical forms of data output, the digital tapes and digital printouts are not calibrated, and as such do not represent the actual radar cross sections. Information from the printouts can be calibrated, however, by subtracting the conversion constant, following the symbol identifying the type of data from one-tenth the value of each digital printout. It is important to note that, as the recording tape progresses, each conversion constant supersedes all prior conversion constants. This calibration method is illustrated by the following example: Suppose one-tenth the value of the target signal level printout corresponding to 180 degrees is 58.0, and the conversion constant is "50.0" (decoded this equals 50.0 dbsm). Then the actual radar cross section of the target at 180 degrees would be +8 dbsm.

ANNEX 1

CHARACTERISTICS OF ELECTRONIC EQUIPMENT

ANNEX 1 CHARACTERISTICS OF ELECTRONIC EQUIPMENT

Power Output	1 KW minimum
Pulse Width	0.1 to 1.0 microsecond
Pulse Repetition Frequency	500 to 5000 pps
No. of Receiving Systems	Two per band (one monostatic and one bistatic)
Receiver Minimum Detectable Signal	-94 to -106 dbm (proportionate to frequency)
Receiver Bandwidth	2 or 10 mc (selectable)
Range Gate Width	0.1 to 1.0 microsecond (50 to 500 feet)
Dynamic Range	50 db
Accuracy	+0.5 db
Equipment Stability	0.1 db/hour (Average)
Analog Data Format	Polar and rectangular plots of cross section and phase vs. aspect angle
Digital Data Format	Punched paper tape recorded at 0.1 - to 4.0-degree azimuth increments
Antennas	2-, 3-, 6-, 10-, 16 and 30 foot parabolic dishes
Antenna Feeds	Log periodic and horns all with VSWR less than 2.0 to 1.0
Polarization	Horizontal, vertical, right and left circular, elliptical in any cross combination of transmitting and receiving configuration
Background Level	As low as -80 dbsm (frequency dependent)
Background Reduction	Tuned columns and vector subtraction by using phase and amplitude measurements to reduce background by 20 db or more
Phase Measurement	Unique RAT SCAT capability for vector subtraction or scattering matrix applications
Azimuth Resolution	0.1 degree
Target Weights	Greater than 10,000 pounds
Target Size	Greater than 60-foot length
Bistatic Capability	500-, 1200-, and 2500-foot range for 0- to 120-degree bistatic angle
Frequency Coverage	100 to 12000 mc (7 bands) (Lower capability part of R & D effort) Band 1 - 100 to 250 mc Band 2 - 250 to 500 mc Band 3 - 500 to 1000 mc Band 4 - 1000 to 2000 mc

ANNEX 1 (Continued)

Frequency Coverage (Cont'd)	Band 5 - 2000 to 4000 mc Band 6 - 4000 to 8000 mc Band 7 - 8000 to 12000 mc
Range Length (for field)	300 feet minimum to unlimited. (Mobile) Building/Pit 1 - 458 feet Building/Pit 2 - 1158 feet Building/Pit 3 - 2458 feet Monostatic Van/Pits 1, 2, or 3 - Unlimited range length Monostatic Van/auxiliary rotator - Unlimited range length

ANNEX 2

REQUEST FOR STATIC RADAR MEASUREMENTS

(REFSRAM)

RADAR TARGET SCATTER FACILITY

RAT SCAT

AIR FORCE MISSILE DEVELOPMENT CENTER

MDLRR, HOLLOMAN AIR FORCE BASE, NEW MEXICO

REFSRAM

No. ______

<u>RE</u>QUEST <u>F</u>OR <u>S</u>TATIC <u>RA</u>DAR <u>M</u>EASUREMENTS

NOTE: This REFSRAM may be reproduced and must be submitted in triplicate with all copies signed by the Military or Governmental user. A user conference at RAT SCAT site is desirable to clarify parameters and scope of effort.

REFSRAM CLASSIFICATION: ______________________________

USER CONTROL NUMBER (If Applicable): ______________________________

1. USER: ______________________________

Agency	Symbol	Contractor

Complete the following in detail: (include Area and Zip Codes)

a. Military — Contractor/Manufacturer

Project Officer (Prime)	Project Officer
Name:	Name:
Rank & Title:	Title:
Office Symbol:	Symbol:
Business Phone:	Business Phone:
Home Phone:	Home Phone:
Address:	Address:

b.

Project Officer (Alternate)	Project Officer
Name:	Name;
Rank & Title:	Title:
Office Symbol:	Symbol:
Business Phone:	Business Phone:
Home Phone:	Home Phone:
Address:	Address:

c. User's Project Engineer (To be contacted in case of questions)

Name:	Name:
Rank & Title:	Title:
Office Symbol:	Symbol:
Business Phone:	Business Phone:
Home Phone:	Home Phone:
Address:	Address:

d. Documentation Information:

Work to be Performed for: (Specific Agency)
Contract No.:
Program Element:
Program Structure:
Program/Project No.:
Command, Service Unit and Lower Unit Priority:
Objective: What is objective for requesting RAT SCAT radar cross section measurements.

2. Vehicle:

a. Unclassified Title or Reference:____________________
Model: ________________Serial Number:____________________

b. Physical Dimensions:

Length:____________	Location of CG: ____________________
Height: ____________	Location of Roll
Weight: ____________	Orientation:____________________

c. Remarks: (Describe unusual requirements and/or characteristics, of vehicle; i.e. paint, coating, or other)

d. Attach applicable drawings, mark hard points and understructure CG and C/L:

e. Special Handling Instructions: (Temperature limits, soft points, etc.)

f. Will special ground handling equipment be supplied?

g. Are cradles, dollies, and slings available other than shipping box?

3. Classification of Vehicle (including downgrading group number):

a. Describe:

b. External View (>20'):
External View (<20'):

c. Shipment:

d. Photographs: Are there unclassified views/positions, if so list?

e. Physical Dimensions:

f. Data Classification:

Analog Polar ______________ Digital Punch Tape ___________
Analog Rectangular _________ Digital Printout ______________

h. Publicity Release: (Attach if applicable) Is the fact that cross section measurements are being made at RAT SCAT classified? If so, what classification?

i. Proprietary Information:

j. Several user representatives may be on the facility simultaneously. What are your desires:

Visual Observation____________Physical Contact_________Data____________

4. Shipment:

Means of Shipment:_______________________________
Estimated Arrival Date:____________________________
Estimated Required Return Date:_______________________

Ship to: AFMDC (MDLRR)
Attn: Major H. C. Marlow/John Henderson
Holloman AFB, New Mexico 88330
Phone: GR3-6511, X 679-7222/8

NOTE: User will be responsible for all transportation of vehicle to and from site. Include Fund Code chargeable to user for return under Armed Guard if applicable. Fund Code for GBL if applicable. RAT SCAT will package and crate vehicle according to instructions furnished by user. State fund citation for return.

Person to be contacted for return shipment instructions:

Name:_______________________________
Address:_____________________________
Phone Number:_________________________

5. <u>Data Requirement</u>: (Mark "X" in boxes below)

Analog		Digital **		Special - Describe
Rectangular *	Polar	Tape	Tape Readout	
*Quick Look supplied in one copy normally. Specify recipient.				

**Specify increments.

6. <u>Measurements Desired:</u>

a. Describe here measurements desired but not available at RAT SCAT. This information is used for future planning and programming.

b. Person(s) authorized to change measurement requirements:

c. Names of representatives to be on site during measurements:

d. Name of person or persons to be notified of scheduled start of measurements if notification is desired:

e. <u>Measurements Desired</u>: A preliminary on site conference is requested to review measurement requirements. List one measurement per line.

Item No.	Frequency	Pol.	Roll	Pitch	Bi-Static	1 to 2 Gc only Phase	VFS	Tape * Increments	Configuration and Remarks
1									
2									
3									
4									
5									
6									
7									
8									
9									
10									
11									
12									
13									
14									
15									
16									
17									
18									
19									
20									
21									
22									
23									
24									
25									

*Increments normal = 2°, available from 0.1° to 4.0°.
Use Continuation Sheets as applicable.

f. Distribution of Data Reports.

(1) Final Report: Copies will be sent thru the AFMDC Stinfo Office to Defense Documents Center, Defense Supply Agency for authorized DOD distribution.

*Copy #1 - MDLRR, Chief, Radar Target Scatter Facility, Holloman AFB, New Mexico
2 - AFMDC (MDLR), Holloman AFB, New Mexico
3 - Battelle Memorial Institute, 505 King Avenue, Columbus, Ohio 43201
4 - MIT (Lincoln Laboratories) P. O. Box 73, Lexington, Mass. (Attn: V. A. Nedzel) (2 copies)
5 - User desires ______ copies. List name, office symbol and address of all recipients below:

Quick Look Data (Mail to): ______________________________
____

Copies of Tape (Mail to): ______________________________
____

Signature: ______________________
Military Agent:
Title:
Office Symbol:

Signature: ______________________
HAROLD C. MARLOW
Major, USAF, MDLRR
Chief, Radar Target Scatter Facility

*Authorized to amend list.

AFSC (AFMDC-HAFB) 1965