# RATSCAT INTEGRATED RADAR MEASUREMENT SYSTEM

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## ABSTRACT

This paper presents an overview of the Integrated Radar Measurement System (IRMS) installed at the Air Force Radar Target Measurement Facility (RATSCAT) for AFSC/6585 TG/RX Holloman AFB, New Mexico.

Keywords: RATSCAT, Ground Plane Range, Radar Instrumentation

## 1. GENERAL DESCRIPTION

The Instrumentation system integrated into the RATSCAT north range as illustrated in Figure 1 was designed to operate continuously from 1-18 GHz and spot at 35-36 GHz at distances of 2000-7500 feet.

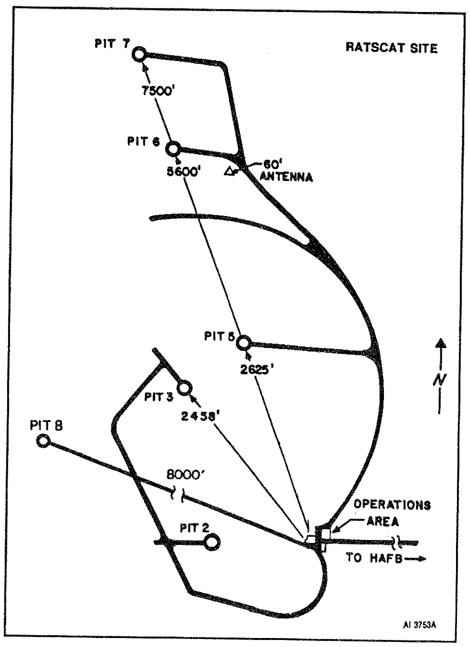


Figure 1: RATSCAT Site

The antenna subsystem and associated instrumentation are installed at the two separate locations on the range. The 7500 foot range location covering from 1 GHz to 18 GHz and 34 GHz to 36 GHz is installed at the existing RATSCAT Main operational Facility. The 140 MHz to 1 GHz system is installed at the 60 foot antenna location approximately 2200 feet from the target position.

The bands are divided as follows:

| | |
|---|---|
| Band 1 | 140 MHz to 500 MHz |
| Band 2 | 500 MHz to 1 GHz |
| Band 3 | 1 GHz to 2 GHz |
| Band 4 | 2 GHz to 4 GHz |
| Band 5 | 4 GHz to 8 GHz |
| Band 6 | 8 GHz to 12.4 GHz |
| Band 7 | 12.4 GHz to 18 GHz |
| Band 8 | 34 GHz to 36 GHz |

The design is modular and while the basic system operates over the specified frequency range additional capability can be added with minimum effort and down time. The IRMS includes two complete Instrumentation Radar Subsystems for operation from the main or spur range.

For bands 5 through 8 two antennas per band are used. This allows wideband imaging without physically moving the antenna to compensate for ground plane effects. The dual antenna system also provides for glint measurements in these bands. The dual antenna system requirement will be elaborated on later in this discussion.

The main antenna farm is located as close to the main operations building as possible to reduce losses. Each antenna feed interfaces with an RF unit which contains polarization switching transmit/receive duplexing, forward and reverse power monitoring and low-noise amplifiers.

The high-power amplifiers and RF units are mounted on the antenna structures in weatherproof enclosures. These units move with the antenna during positioning adjustment. Air conditioning and waveguide pressurization are supplied for each band.

For the 34 to 36 GHz band, frequency translators, HPA and RF units are packaged in the same enclosure.

For low-frequency operation, 140 to 500 MHz, the 60 foot antenna, located at a the spur range position is used while a 12 ft. antenna covers the range from 500 MHz to 1 GHz. A separate transmitter/receiver unit is used for the low frequency subsystem and timing control and data transmission from this range to the central data collection system is provided by a fiber optics link.

The normal operation is automatic and all functions are under computer control to perform measurement parameters as instructed by the operator in the test setup.

The system can collect data on six bands essentially simultaneously; collecting horizontal and vertical polarizations on both the target and a reference. The reference can either be an external target on the range or an internal reference furnished with the system. Data can be collected at approximately 60 KHz Rate for target, reference, and both polarizations. A dual channel receiver and dual-range gates are incorporated to permit the improved data acquisition rates and pulse-to-pulse calibration.

The radar utilizes a rapid-tuning, directly-synthesized source to permit near simultaneous measurements on up to six frequency bands and provides high speed frequency stepping for down and cross range high resolution imaging. The radar also incorporates a mode for doppler measurements up to a doppler frequency of ± 50 KHz.

The system computers, peripherals, and software provide the capability for data recording, processing, plotting, and transferring information to a VAX computer. Separate computers are provided for system control/storage, data acquisition, and engineering work stations.

## 2. CONTROL ROOM LAYOUTS

The primary room is located in the main operations building, and the remote site control room is located in the base of the GFE 60 foot antenna. The two sites and target positions are connected via a fiber optics link. System operation will normally be performed from the main control room, however the remote site can be operated from the 60 foot antenna control room location.

## 3. BASELINE RADAR SYSTEM

A block diagram of the RCS measurement system is given in Figure 2. The heart of this system is an automated turnkey instrumentation range gated short pulse radar with menu selectable software for automatic or manual control of calibration, target positioning, data acquisition, display and recording. This system is capable of rapid, multiple frequency RCS measurements of both amplitude and phase, including the complete polarization matrix required to determine RCS versus frequency, RCS versus aspect, RCS versus time, RCS versus range, and cross range with both low and high resolution, with high accuracy.

Custom designed outdoor RF Units are used to accommodate the RF power requirements specific system configurations. These RF Units contain high power amplifiers (with necessary switching, isolation, and monitor components) and low noise amplifiers (LNAs) to ensure an acceptably low receiver noise figure for the various frequency bands. Polarization switching and system calibration and test capabilities are also included in this subassembly. For the 34 to 36 GHz frequency band, a frequency translator is included which converts the 9 to 11 GHz band to millimeter wave frequencies.

The instrumentation radar systems contain transmit and receive electronics. The transmit portion consists of a Stalo Synthesizer, Stalo Distribution Unit, COHO Generation Unit, Upconverter, and Calibration Attenuator Unit. The receiver portion consists of Downconverters, IF Unit, Coherent Detector Units, and Analog Processor. Each of these are controlled by a local System Control Unit (SCU) and Radar Control Computer. The Antenna and Target Positioners are also controlled by the control computer. A common buss ties the Radar Control Computers, the System Control Computer, the three workstations, and the VAX together.

## 4. COMPUTER SYSTEM OVERVIEW

A generalized block diagram for the IRMS Computer System is shown in Figure 3. The 1-18/35 GHz radar in the main building and the 140 MHz to 1 GHz radar at the 60' antenna each have a computer for radar control and data collection. The central system controller provides a central point of control for the range and large mass storage capabilities. The 3 graphics workstations provide on line monitoring capability during data collection as well as off line data reduction and processing capability. the VAX computer is connected into the system for archiving transferring data and programs to and from the IRMS computers.

## 5. RADAR CONTROLLERS

The radar controller at each radar system performs the following functions:

1. Control radar instrumentation, antennas and target positioning.
2. Performs calibration of the radar and creates calibration data for transmission to the system controller and/or workstations.
3. Collects data, monitors radar operations and reports error conditions.
4. Buffers on line data for transmission to the system controller for storage and the workstations for display. Target data is not placed on local mass storage.
5. Executes radar test modes and calibration sequences under local operator control.
6. Accepts test setup parameters from the system controller.
7. Terminates data collection on demand from the system controller or the local operator.
8. Transmits and receives data over the local area network.

## 6. SYSTEM CONTROLLER

The system controller provides the following functions:

1. Allows the system operator to create test parameters for either radar and sends them to the radar controllers for implementation.
2. Queries the radar controllers and workstations to determine and display their current operation and status.
3. Accepts on line data from either radar controller and archives it to disk or tape. A quick look plot of raw data is available.
4. Sends data files to any workstation or the VAX from its storage on demand.
5. Provides a hard copy system log of IRMS operations.
6. Performs off line tape format conversions.
7. Transmits and receives data over the local area network.

## 7. WORKSTATIONS

Each of the three engineering workstations is capable of the following functions:

1. Capture and display on line data from the radar controllers.
2. Provide full data reduction capabilities on just captured data, locally stored data and data requested from the system controller or GFE VAX. The workstation is the only location in the system that provides data reduction with full user interactive graphics.
3. Request data files from the system controller or GFE VAX.
4. Receives data over the local area network.

## 8. SOFTWARE

The data acquisition and processing capability has been designed to be user friendly, versatile, easily modified for special requirements and provide calibration and system health checks. Some of the capabilities are delineated below.

General:
- Multi-user, up to 8 simultaneous Operators.
- True multi-tasking
- Fully Integrated Acquisition, Analysis, and display.

Hardware:
- HP825S and HP8255RX

Log on and Access:
- Operator Name/Password
- User access limited by Data classification and test program need to know.
- Three levels of access restricts user specified menus.
- Default configuration and parameters saved for each operator.

User Interface:
- Menu Driven/Function Key or Mouse menus selection.
- Parameters changed on exception basis.
- Operator prompt for parameter entry.
- Toggles for limited selection entry.
- Limit checking.
- Automatic Calculation of Interrelated Parameters.
- Expert Model bypasses Menu Tree.

Positioner Control:
- Select from 6 axes
- Scan, step, or slew operation
- Speed or Rotation Control
- Algorithm suggests maximum speed for pending measurement
- Algorithm suggests Nyquist Interval for Imaging Start, Stop, Center, Span Angle entry and display provided.

Frequency Control:
- Single or Multi-Frequency
- Up to 1024 Frequencies
- Uniformly or non-uniformly spaced calibration
- Up to 14 bands of operation

Data Destination:
- Tape, Disc or Local Area Network

Polarization:
- 1, 2, or 4 - Single Acquisition

Calibration Standards Calculated:
- Sphere
- Cylinder
- Rectangular Plate
- Circular Plate
- Dihedral
- Trihedral

Drift Correction:
- Uses second range gate and secondary standard to compensate for system drift.

Background Subtraction:
- Single angle or multi-angle, multi-frequency coherent subtraction.

Data Analysis Modes:
- RCS vs Range
- RCS vs Frequency
- RCS vs Aspect
- RCS Isometric (RCS vs. Range vs. Aspect)
- ISAR Imaging, simple and focused
- RCS vs Frequency vs Aspect
- RCS vs Cross Range
- Doppler
- Glint

Data for all processing modes may be extracted from a single RCS vs Frequency vs Aspect acquisition.

Calibration modes may be enabled or disabled:
- Frequency
- Drift
- Background Subtraction

RCS vs Aspect Statistics:
- Arithmetic Mean
- Geometric Mean
- Maximum Value
- Median
- Percentiles
- Probability Densities

Zero-Fill Interpolation for FFT processes up to 1024 points

Zero Doppler Clutter Rejection Optional

Windows:
- Rectangular
- Triangular
- Hann
- Hamming
- Blackman
- User Defined

File Comparison:
- Processed File addition or subtraction
- Linear or Logarithmic

Graphics:
- Multiple Device Graphics
- Supports up to: 6 CRT Displays, 4 Plotters, 1 Printer

Maximum CRT or Pen Plotter Colors:
- Graphics Display Dependent

Plot Format
- Linear
- Polar
- Contour
- Color Fill
- Isometric (Pitch Plane)

Plot Overlays:
- Up to 4
- Multiple Plots: 1, 2, 3, or 4/Page
- Overlay or Tiled or Combination

Manual Scaling:
- Axis Scaling
- Axis Divisions
- Grid Type
- Line Type
- Axis Titles
- 3 Title Lines
- Security Labels

Workstation Graphics:
- Interactive User Scaling of Plots
- Interactive Tracking Function for Displaying Discrete Data Values
- Tracking Coordinated with 3D Target Wireframe

Diagnostics/Utilities

Transfer Function:
- Steps Calibration Attenuator through entire dynamic range and plots received level vs. attenuator value.
- Target or Reference Channel.
- IQ Circularity Check
- Range Walk

## 9. RADAR SYSTEM ERRORS

Any design that requires instrumentation accuracy must address sources of potential error. Some major sources of error in RCS radar design and measurements include non-linearity, RF image rejection, I/Q non-circularity, drift between I & Q channels and antenna position to maintain a flat field over the target on a ground plane range. The capability of the IRMS system to solve these problems will be addressed.

The linearity for the IRMS receivers is shown in Figure 4. The system linear dynamic range of nearly 100 dB, with integration, before the noise contaminates the signal is obtained by using overlapping 16 bit A to D convertors.

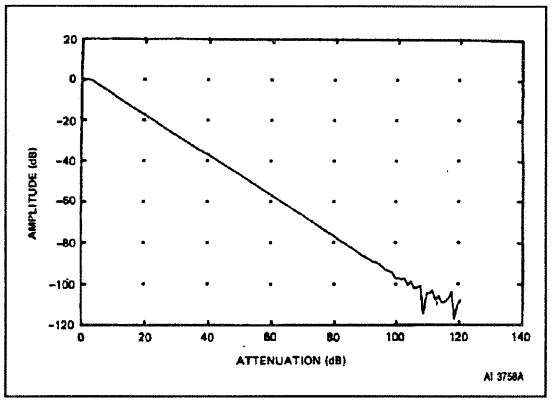


Figure 4: Receiver Linearity Measurement

Poor system RF image rejection can degrade system accuracy in the narrow band mode and can generate spurs in wide-band pulse compression and imaging modes. Figure 5 depicts the problems associated with wide-band spurs due to image response. The top plot shows a pulse compressed waveform for a sphere with the peak corresponding to the primary return and the secondary peak corresponding to the creeping wave of the sphere. The smallest pikes are sidelobes caused by the particular weighting function applied prior to the inverse FFT. The lower plot illustrates the same return with only 30 dB image rejection. Notice that a spur is generated for both the target and calibration measurements. Also note that the spurs are 30 dB down from the main response, the same as the original rejection.

The IRMS system has greater than 100 dB image rejection which will cause spurs to be some 100 dB below the maximum signal.

This is achieved by dual conversion on both transmit and receive.

In-phase and quadrature circularity in the detector is crucial for accurate measurements. If the I/Q characteristic is elliptic instead of circular then it will generate ripple in the narrow band (single frequency vs aspect) mode and will generate spurs in wideband or imaging modes.

A 6 bit phase shifter in the Coho reference line is provided. The phase shifter is controlled by the Radar Controller and is used during system calibration procedures. Since this signal is used by the Coherent Detector Unit as the reference for its coherent detection process, rotation of this reference signal phase by a full 360 degrees allows the Radar Controller to measure the circularity of the I/Q detectors and determine a correction matrix which is applied to the I and Q data to correct for any I/Q non-circularity.

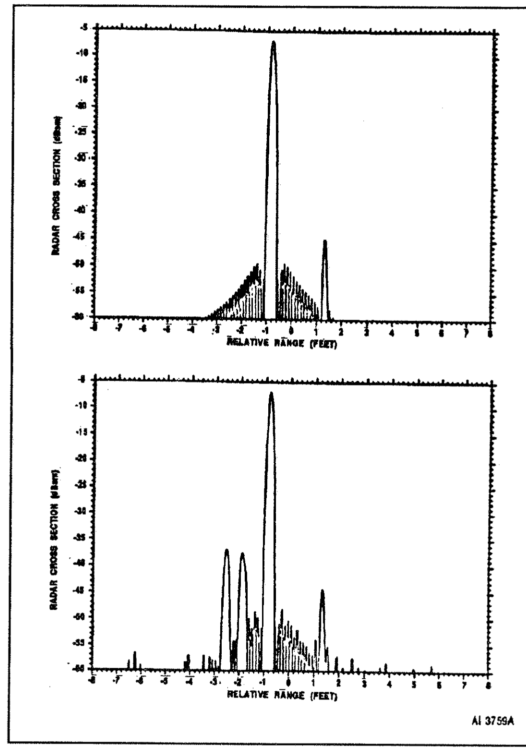


Figure 5: Image Rejection

Figure 6 depicts the general antenna configuration at building 7000. Two antennas are used for bands 5 through 8. These antennas are set at different heights to compensate for the beam shift that occurs over a frequency band. By using this approach aspect angle or imaging data can be obtained over a full frequency band without adjusting the antenna height by maintaining a good field distribution over the target. As an example the frequency range of 4 to 8 GHz has two antennas set at heights of ≈ 3.1 feet and 4.3 feet. Figure 7 then indicates the ground plane gain vs field distribution ± 20 feet over the target position. As shown a single antenna height could have as much as 12 dB gain variation over half the frequency band.

The use of the two antennas can assure a good field over the full frequency band without repositioning the antennas and thereby improving measurement accuracy.

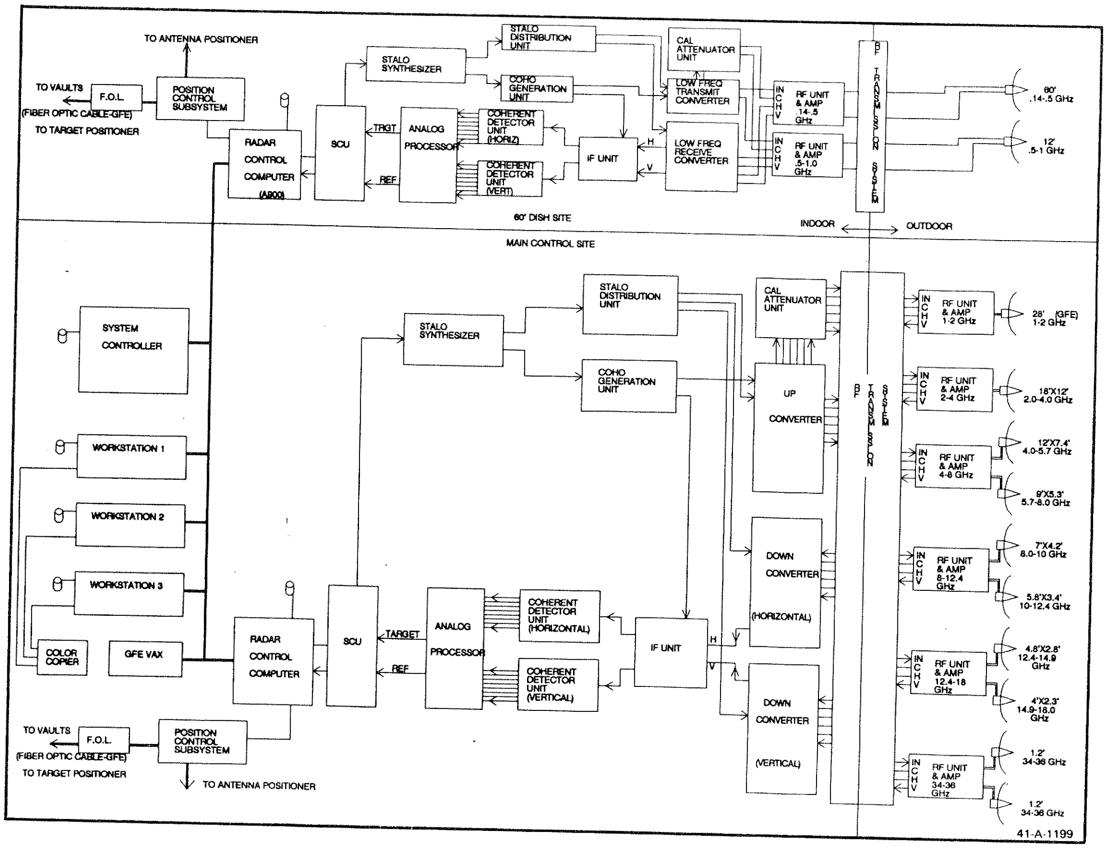


Figure 2: System Block Diagram

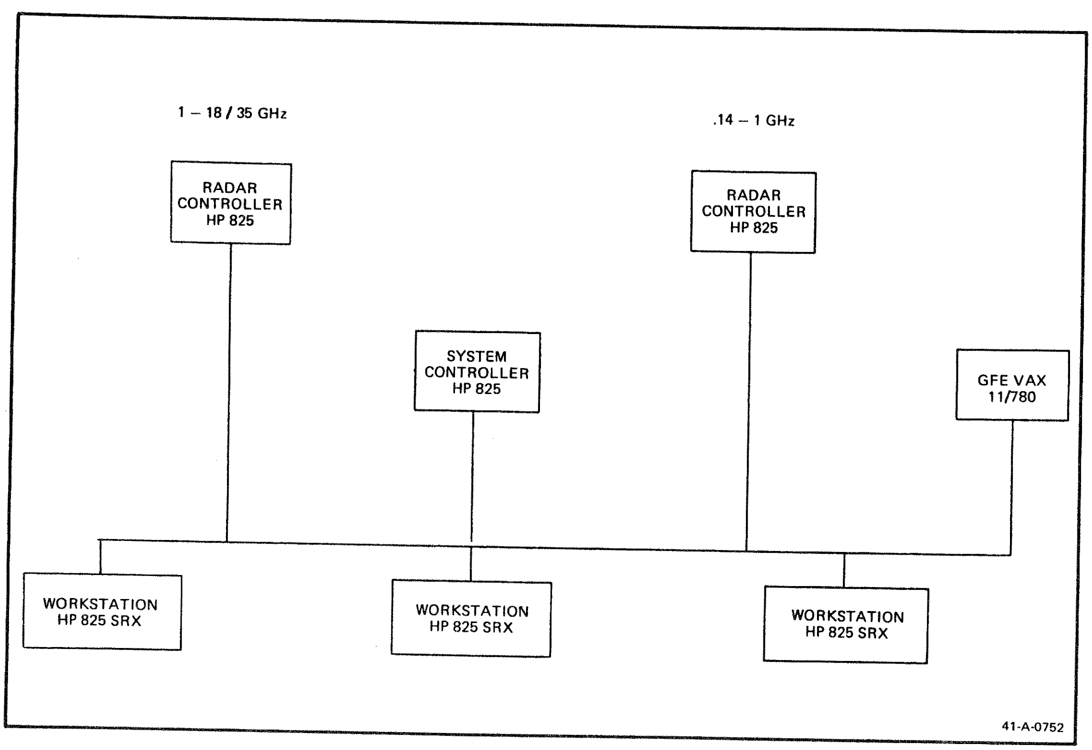


Figure 3: IRMS Computer System

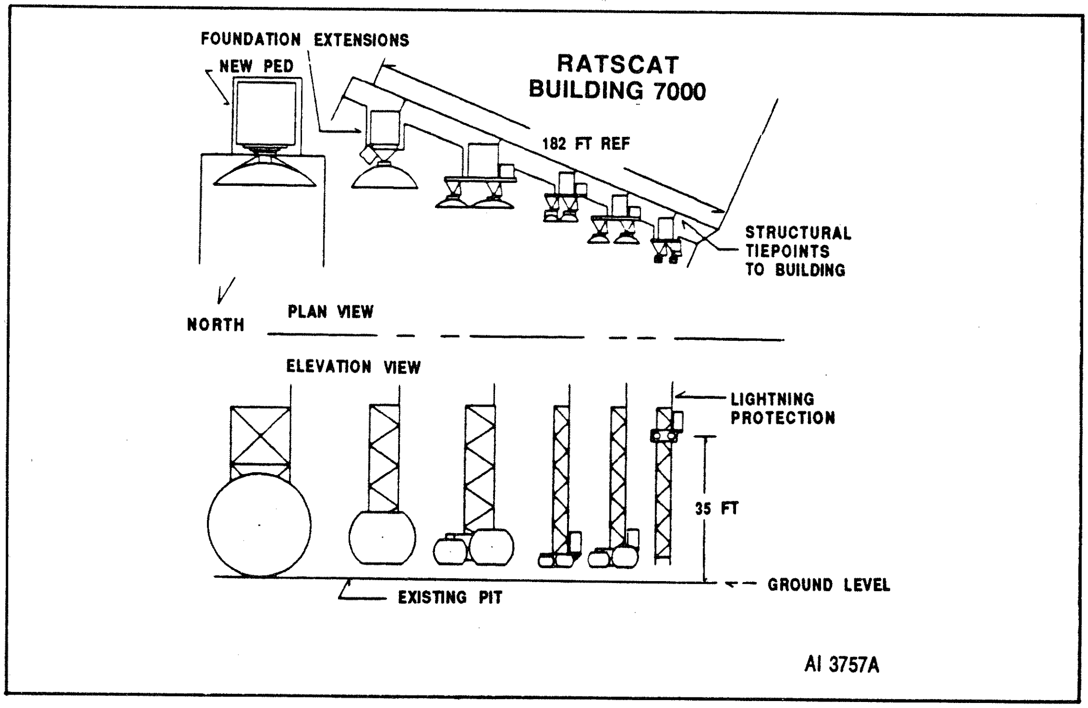


Figure 6: Main IRMS Antenna Geometry

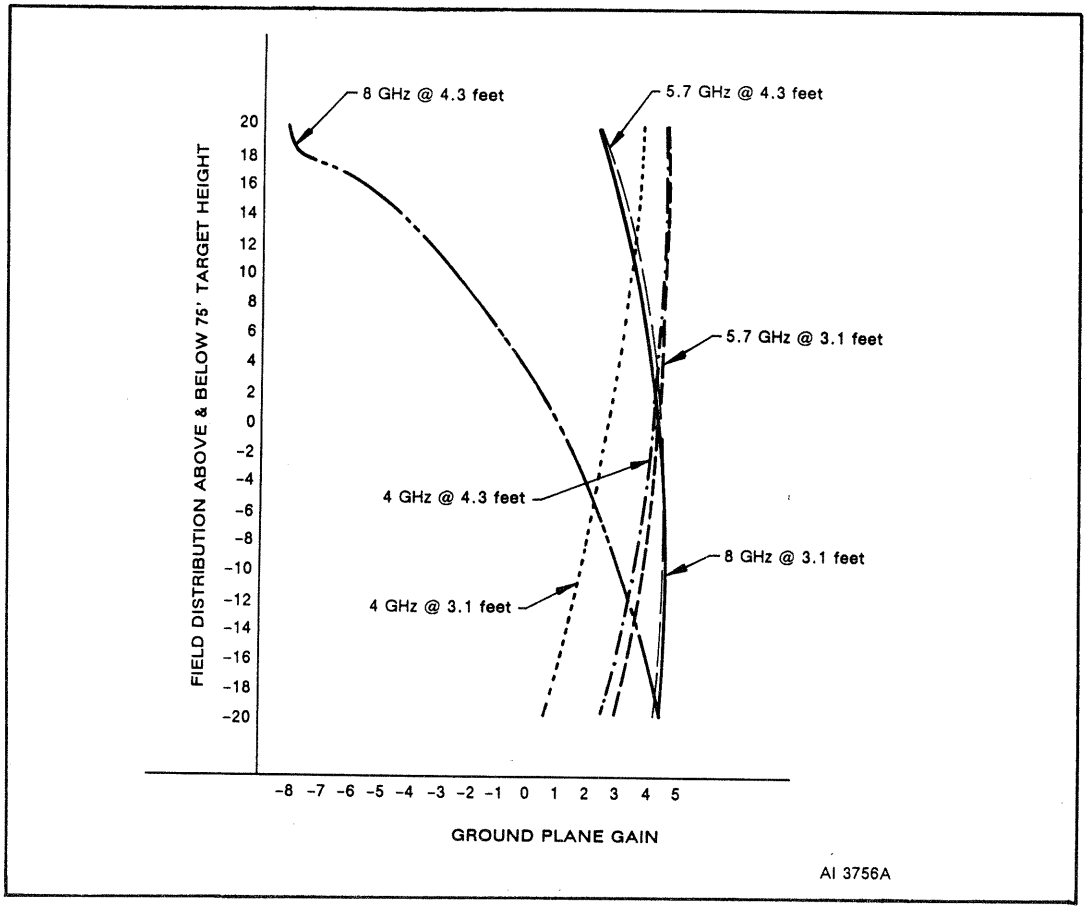


Figure 7: Ground Plane Gain