A TRANSPORTABLE COMPACT ANTENNA RANGE

Joseph H. Pape and David R. Smith
MI Technologies, Inc. (now MI Technologies)

Charles L. Devor, Jr.
Paul E. Lehman, Inc. (Lehman Chambers)

Joseph M. Smiddie
Naval Surface Warfare Center Crane Div

ABSTRACT

The Compact Antenna Range is becoming the method of choice for indoor testing of many types and sizes of antennas. Implementation of a compact range requires a suitable parent building structure in which to house the chamber. The chamber is located within the parent building and the compact range is then installed within the chamber. In some cases an existing building may not be available for the range and it may be difficult to acquire a new building due to local or proprietary requirements. Once a building has been located, many problems still exist with coordinating installation of the chamber and compact range within this building. Overcoming these problems can be both time consuming and inefficient in terms of cost.

This paper describes a Compact Antenna Range conceived and designed to be totally self-contained and truck transportable. The compact range consists of a complete anechoic chamber facility with self-contained electrical, lighting, HVAC and fire protection systems. The compact range provides a 3 foot test zone over the 5.8 to 94 GHz frequency range. Once completed and tested at the factory, the facility is transported and set in place at the users' site.

Details are presented which describe the structural requirements of the chamber, the RF performance of the completed facility, and the transport and installation process. The integrated test positioner and an automatic feed changing mechanism are also described.

Keywords: Compact Range, Anechoic Chamber, Indoor Testing

INTRODUCTION

This paper describes a Compact Antenna Range that was developed for the Naval Surface Warfare Center, Crane Division (NSWC). The range has been delivered and installed at the NSWC facility located in Crane, Indiana. NSWC, Crane is the support center for various Naval systems. Many of these systems incorporate small antennas which require periodic alignment, re-calibration and testing. Indoor testing is desirable for these small antennas due to their susceptibility to weather and other environmental conditions. Furthermore, testing during the winter months is subject to weather related delays and short daylight hours.

The compact range offers an ideal environment for testing microwave antennas and antenna systems. Most types of antenna measurements can be performed on the compact range including beam patterns, gain, directivity, boresight and polarization. These measurements can be performed in a secure and controlled indoor environment in a relatively small volume as compared to a conventional outdoor range or far-field indoor chamber.

The typical commissioning of a compact range test facility involves several steps. A suitable location must be obtained, hopefully close to the production or engineering function, and if a location does not exist within an existing building, the proper local and internal approvals must be obtained and a parent building designed and constructed. Once a building is located or constructed, an anechoic chamber is fabricated within the building. Electrical service, HVAC and fire protection systems must be designed and provided for the parent building as well as the chamber. Only after these preliminary requirements have been met is the compact range installed within the chamber. Then comes the evaluation of the chamber to verify that the various separately designed parts work together to provide an accurate test zone.

The system developed for NSWC is a completely self-contained modular compact range assembled and tested at the factory. The completed range was transported and set in place at the NSWC test site. The range includes a MI Technologies Model 5703 Compact Range installed into a transportable anechoic chamber facility. The facility inside dimensions are 12 feet wide, by 30 feet long, by 11 feet high. The Model 5703 provides a cylindrically shaped test zone that is 3 feet in diameter by 3 feet long. Designed for the outdoor environment, the facility is complete with its own electrical distribution/lighting system, heating ventilation and air conditioning system, and fire detection/protection system. The entire package is designed to be moved by flatbed trailer to the range site and off-loaded by crane onto a supporting foundation. Screw jacks simplify the final leveling of the facility. Figure 1 depicts the layout of the facility showing the relative locations of the various range components.

The sections that follow describe in detail the compact range.

REQUIREMENT

Mission Objective

The Naval Surface Warfare Center, Crane Division Antenna Range was tasked to support depot maintenance requirements on the AN/SLQ-32 and AN/ALQ-99 Electronic Warfare Systems. Antennas operating above 6.0 GHz were tested on the outdoor antenna range. Inclement weather has been a problem on the outdoor test range which causes production delays. In 1989 NSWC decided a compact range would be required to support depot operations at Crane.

Selection Rational

During the planning meetings to develop the compact range proposal a major problem continued to surface - where would the indoor range be housed? There was no space at the present antenna range. Other locations would reduce test efficiency and add additional cost for equipment and personnel. Considering the time required for approval of new construction to add to the present antenna range, it was decided to propose that the contractor build the compact range in an enclosure that is self-contained. The enclosure is considered equipment for contracting and no approval for construction is required. The enclosure could be located adjacent to the antenna range and use existing controlling thereby eliminating additional personnel staffing requirements at a remote location.

During Desert Shield/Storm there was a definite need for test systems in the theater of operation. On-site test systems reduced logistic requirements and increased readiness for combat systems in the area. If a similar need arises in the future, the portable compact range could be relocated to a forward based area for readiness assessment on site.

FACILITY DESCRIPTION

Mobile Chamber Shell

The mobile chamber carrier consists of a welded framework of beams and structural channels. The main floor frame is made up of beams that run lengthwise and structural channels that extend between and outward from these beams to form the foundational base for the test enclosure. A reinforced floor structure is provided at the reflector, feed, and test positioner mounting point locations. A manually operated outrigger system consisting of eight (8) jacking points level the chamber to the existing site conditions. Four (4) lifting points are integrated into the main framework to provide for lifting of the facility by crane.

The mobile chamber shell consists of sheet steel welded together and in turn welded to a structural steel tubing skeleton to provide the interior surfaces of the chamber enclosure. The inside clear dimensions of this chamber prior to the installation of the radar absorbing material is 12 feet wide by 30 feet long by 11 feet high. A layer of 4 inch thick insulation between the vertical steel tubing skeletons help maintain the appropriate temperature and humidity levels. A final finished layer of 16 gauge galvanized sheet steel is applied to the outside of the steel skeleton. To provide for a completely weather-proof structure, a rubberized roofing system is installed onto the roof of the chamber shell.

A 6 foot by 8 foot double leaf door provides access to the chamber and its test equipment. The door provides ample space for moving the test articles in and out of the chamber. Figure 2 is an exterior view of the completed facility.

Heating, Ventilation and Air Conditioning

An independent, self-contained HVAC system was provided for the facility to maintain a constant temperature of 74° ±4 and a constant relative humidity of 50 % ± 10 %. The HVAC unit is installed on the front of the chamber, behind the reflector. This position eliminates any potential reflections and at the same time, with the appropriate ductwork, provides proper air flow circulation.

A control panel mounted on the front interior wall of the enclosure provides manual adjustment of the HVAC unit to maintain the desired temperature and humidity levels.

An emergency exhaust blower unit is installed in the chamber to remove smoke from the chamber in case of a fire. A switch located in the main breaker panel, just outside the chamber door, will activate the exhaust blower unit and will extract the smoke to the outside environment. Opening the chamber doors will complete the circuit to operate the exhaust blower unit.

Electrical Service

Incoming electrical service is 120/208 volt, 60 Hz, 100 amp, three (3) phase, four (4) wire, and is taken to a disconnect located on the exterior of the chamber. A main breaker panel is located directly above the disconnect. An interior breaker panel provides the power source for the chamber's lighting and for power requirements for the test equipment, HVAC equipment, and the numerous receptacles located in the chamber.

Five (5) 120 volt, 15 amp outlets are provided at various locations inside the chamber as well as one (1) 208 volt, 10 amp outlet near the reflector.

Lighting in the chamber consists of six (6) flush-mounted incandescent light fixtures that provide a lighting level of 60 foot candles directly above the quiet zone. Two flood light units were provided on the chamber sidewalls to illuminate the reflector. Switch circuits located in the main breaker control the lighting for the chamber. An exterior light is located directly above the chamber door to provide access lighting for the chamber. An emergency lighting unit located inside the chamber provides for illumination in the case of a power failure. A lighted emergency exit sign indicates the means of egress.

Fire Protection System

It was determined that the best system for protecting the chamber and its contents from fire is by use of a fire alarm and pre-action fire suppression system. The design of the fire alarm system is such that the detection of any possible combustion inside the chamber will generate an alarm at the fire control panel that will sound in the chamber and activate the next stage.

Ionization and photoelectric type smoke detectors located inside the chamber detect the presence of smoke or other combustion byproducts and activate the alarm system. The fire control panel, mounted just inside the chamber entrance, will signal through a combination of audible and visual alarms that a fire may exist. This is the first stage of the pre-action system.

The second stage of the system is activated approximately 30 seconds from the time the alarm is signaled. At that time, unless interrupted, the chamber will be deluged with a CO_2 fire suppression agent.

An abort switch is provided to stop the pre-action staging cycles should there be a false alarm situation. The abort switch only prevents the staging from taking place if it is depressed.

The CO_2 supply tanks are installed on the exterior of the chamber enclosure in a storage compartment and are connected to a manifold system which routes CO_2 through pressure lines to nozzles located in the ceiling.

Absorber Installation

The interior walls of the chamber are covered with fire retardant radar absorbing material. Eight inch pyramidal type absorber material is glued to the interior of the chamber walls and ceiling and is laid in place on three-fourths of the floor surface between the reflector and test positioner area. Twelve inch pyramidal type absorber material is glued to the rear wall of the chamber only. Careful attention was given to the installation of the individual pieces to ensure there were no gaps between them and that they formed perfect rows and columns. Additional pieces of absorber are used on the test positioner and feed positioner.

Openings are cut in the absorber to allow for the proper functioning of the fire suppression heads and smoke detectors. Since the absorber material was installed after the light fixtures, switches, and receptacles were in place, some pieces of the absorber are custom fitted and cut around these articles. Figure 3 is an interior view of the chamber.

EQUIPMENT

Model 5703 Reflector

The Model 5703 Compact Range, like all MI Technologies compact ranges, operates by illuminating the test antenna with an electromagnetic wave having a planar wave front. This plane wave is created by employing a parabolic reflector to collimate a spherical wave radiated by a feed antenna located at its focal point. The main component of the compact range is the large accurately machined parabolic reflector with a 12 foot focal length. The reflector is constructed of a very rigid monocoque backup structure. The front surface consists of a series of metal panels that are laminated with a reinforced epoxy material. This epoxy substrate is machined to a precision parabolic shape and covered with a thin conductive silver coating. A final white coating protects the conductive surface. Edge serrations approximately 2 feet long surround the perimeter of the reflector. The reflector surface dimensions are 108 inches by 108 inches. To minimize room height requirements and to reduce vertex interactions the reflector uses an offset FED, virtual vertex design with the reflector's focus located to the side and just slightly below the reflector. This provides a test zone centered only 5.5 feet above the chamber floor.

To insure the best accuracy, the reflector is machined as a single unit including the edge serrations. The reflector is designed to allow the serrations to be removed to reduce the reflector's overall size for shipment and to minimize the chance for damage or safety concerns during handling of the reflector. At installation, the serrations are re-attached using a MI Technologies developed technique which insures proper re-alignment to their original position.

The Model 5703 compact range is designed to operate over the 5.8 to 94 GHz frequency range. The test zone is a cylindrically shaped area 3 feet in diameter and 3 feet long centered longitudinally on the range axis. The reflector is shown in Figure 3.

Multiple-Feed Positioner System

The multiple-feed positioner system remotely locates any one of the four feed antennas to the focus of the Model 5703 parabolic reflector. Since the reflector is an offset geometry, and to maintain a minimum inside chamber width, the multiple-feed positioner system is designed for a minimum envelope size and to fit tight against the chamber side wall. Five inch pyramidal absorber material is used to transition between the larger eight inch absorber material mounted on the wall and the positioner unit. The unit includes full covers with three inch absorber material installed to minimize RF reflections. The only exposed areas are the feed apertures. The feed positioner system is designed to insure that the three off-station feeds are masked from direct line of site of the reflector. Refer to Figure 4.

The multiple-feed positioner system consists of four main components: a horizontal rotating mechanism, an RF rotary switch, a feed selection unit, and four orthomode feeds and associated control and RF cables. The horizontal rotating mechanism has a vertically oriented turntable. The turntable is driven by a DC motor with position information supplied via synchro transmitters. The turntable supports and positions the four orthomode feed antennas to produce optimum illumination of the Model 5703 reflector. The rotating mechanism is designed for maximum structural stiffness to allow the unit to be aligned and tested at the factory and maintain its alignment during shipment and installation.

The RF switch unit automatically activates the appropriate feed and provides for switching the feed polarization. The RF path is routed to one of the four orthomode feeds by a six position, low-loss RF coaxial switch (two spare positions are available for future expansion). The RF switch is controlled by micro switches located on the positioner turntable associated with each particular feed. As the turntable rotates, the micro switches contact a cam on the positioner housing and actuate the appropriate position of the coaxial switch.

Polarization switching is accomplished by a single pole, two position coaxial switch for each feed. These switches are operated via the feed select unit and include terminations so that the inactive port is properly matched.

The Feed Select Unit permits local or remote selection of the transmit feed polarization. The unit also provides a visual indication of the feed currently on station. A digital interface allows remote control of the polarization of any feed to be selected and confirmed.

The orthomode feeds consist of standard MI Technologies Series 31 feeds. The Series 31 feeds are broadband orthomode transducers implemented in circular waveguides. These feeds provide simultaneous dual linear outputs so that both orthogonal linear polarizations (V & H) are available without physically rotating the feeds. The multiple-feed positioner system is equipped with C-band, XN-band, X-band, and Ku-band feeds.

AUT Positioner

The AUT Positioner is a special configuration of rotation and translation axes to provide coordinate freedoms required for testing objects in a compact range environment. The positioner is configured in the following axis order: Roll over Elevation over Tower over Offset over Azimuth over Slide and is comprised of the following subassemblies:

- Slide Assembly
- Azimuth Positioner
- Offset Support Arm
- Positioner Mounting Tower
- Roll-over-Elevation Positioner

The AUT positioner is shown in Figure 5. Performance specifications for the AUT Positioner are listed in Table 3.1. The AUT Positioner is installed 8.3 inches below the floor surface to reduce the RF reflections and improved the overall functionality of the chamber interior. All control and RF cabling is routed below floor level improving access around the positioner system.

Table 3.1 AUT Positioner Specifications

Characteristics	Specification
Maximum Swing Radius	54.3 inches
Maximum Vertical Load	200 lbs.
Max Bending Moment (about elevation axis)	400 ft-lbs
Roll Axis Turntable to Azimuth Axis Offset	0 to 36 inches
Offset Adjustment Increments	Continuous
Range Height	66.0 ±0.5"

The slide assembly carries the azimuth positioner along a linear axis perpendicular to the compact range reflector. The slide precisely varies the distance between the device under test and the reflector over a 36 inch range of travel, while maintaining both horizontal and vertical alignment with the reflector within ⊥±0.01°. The motorized slide allows this distance to be varied and displayed remotely. The lower azimuth axis includes RF switch wiring and wiring for auxiliary axes.

The AUT Positioner includes a manually adjustable offset arm assembly. The offset support arm allows continuous adjustment of 0-36.0 inches between the roll axis turntable and the lower azimuth axis.

The positioner mounting tower places the roll axis at the range centerline height and provides a rigid interface between the Roll-over-Elevation positioner and the offset support arm.

The roll-over-elevation positioner consists of a MI Technologies Model 50230A Azimuth/Elevation Positioner. This standard positioner includes an RF path (DC-4 GHz) with twist loop and RF switch wiring.

CHAMBER TRANSPORT

The Transportable Compact Antenna Range was transported to NSWC via tractor trailer. To prepare the unit for shipment, external range cables were disconnected and spooled, support braces were installed on the AUT positioner, the reflector serrations were removed and bpxed separately, and the outside light was removed and packaged. Once the unit had been lifted, the chamber leveling jacks were removed and crated separately.

To accommodate the outside chamber dimensions of 34 ft long X 13 ft wide X 13.4 ft tall and a gross weight of 45,000 lbs, a double drop/stretch bed trailer was utilized. A mobile crane was used to lift the chamber and place it on the trailer bed. The overall height of the trailer and chamber combination was 15.4 ft. The HVAC system was positioned toward the rear of the trailer to prevent possible damage to the unit from tree limbs and objects thrown from the road. The chamber access door was secured shut to prevent accidental opening and to secure the inside equipment. The chamber was lashed to the trailer bed at eight locations to provide stability during transit.

Special state permits were required due to the unit being over height and over width. Restricted hours of travel and escorts were also considerations for the shipping of the unit.

CHAMBER INSTALLATION

Installation at the Naval Surface Warfare Center at Crane Indiana was accomplished in a minimal period of time. Upon arrival at the Crane facility, a lightning storm delayed off-loading of the unit for several hours. Once the weather had cleared, the Government furnished a mobile crane, crane operator and rigging support and lifted the chamber from the trailer and moved it to the desired location. The eight leveling feet were installed and the unit leveled to within 1/8 inch along its length and 1/16 inch along its width to insure proper operation chamber access door. The mobile crane and riggers were released at this time. The total off loading and setup time was approximately 2 hours, excluding the storm delay.

The next step was to install the external AC power. A Government furnished electrician accomplished this task in approximately 45 minutes. The exterior light was then reinstalled and the support braces on the AUT Positioner removed. The HVAC system was turned on and the chamber closed for the night to allow the interior temperature to stabilize.

Once the chamber temperature had stabilized, the reflector serrations were installed. This task was accomplished by two trained personnel in approximately 5 hours. The external range cables were run to the control room and connected to a Government owned MI Technologies Model 2083 Antenna Analyzer System. After approximately 1 hour of overall checkout, the Transportable Compact Antenna Range was ready for operation.

To verify that the Transportable Compact Antenna Range met specification after shipment without additional alignment, phase and amplitude patterns were made in each frequency band. The data taken at Crane compared favorably with data collected at the factory prior to shipment. No degradation to the original data taken in Atlanta was apparent.

The total elapsed time to install the Transportable Compact Antenna Range and verify its performance in four frequency bands was 4 days.

RANGE PERFORMANCE

The Transportable Compact Range performance is summarized in Table 7.1.

Table 7.1 Range Performance	
Frequency Range	5.8 - 94 GHz
Amplitude Taper	0.5 dB
Phase Taper	10° (f< 18 GHz) 20° (f> 18 GHz)
Cross Polarization	-30 dB (typical)
Gain Accuracy	+/- .25 dB (typical)
Sidelobe Accuracy (Typical)	Level Accuracy -15 dB; +/- 0.3 dB -30 dB; +/- 0.5 dB -45 dB; +/- 1.75 dB

SUMMARY AND CONCLUSIONS

The Transportable Model 5703 Compact Range Antenna is ideal for applications where an existing building does not exist for the range. Procurement and fabrication of the facility is greatly simplified due to the integration of all components into one complete package. The range is completely assembled at the factory, tested and transported to the customer's site. Installation consists of off-loading to a prefabricated foundation or pad and connecting to primary power.

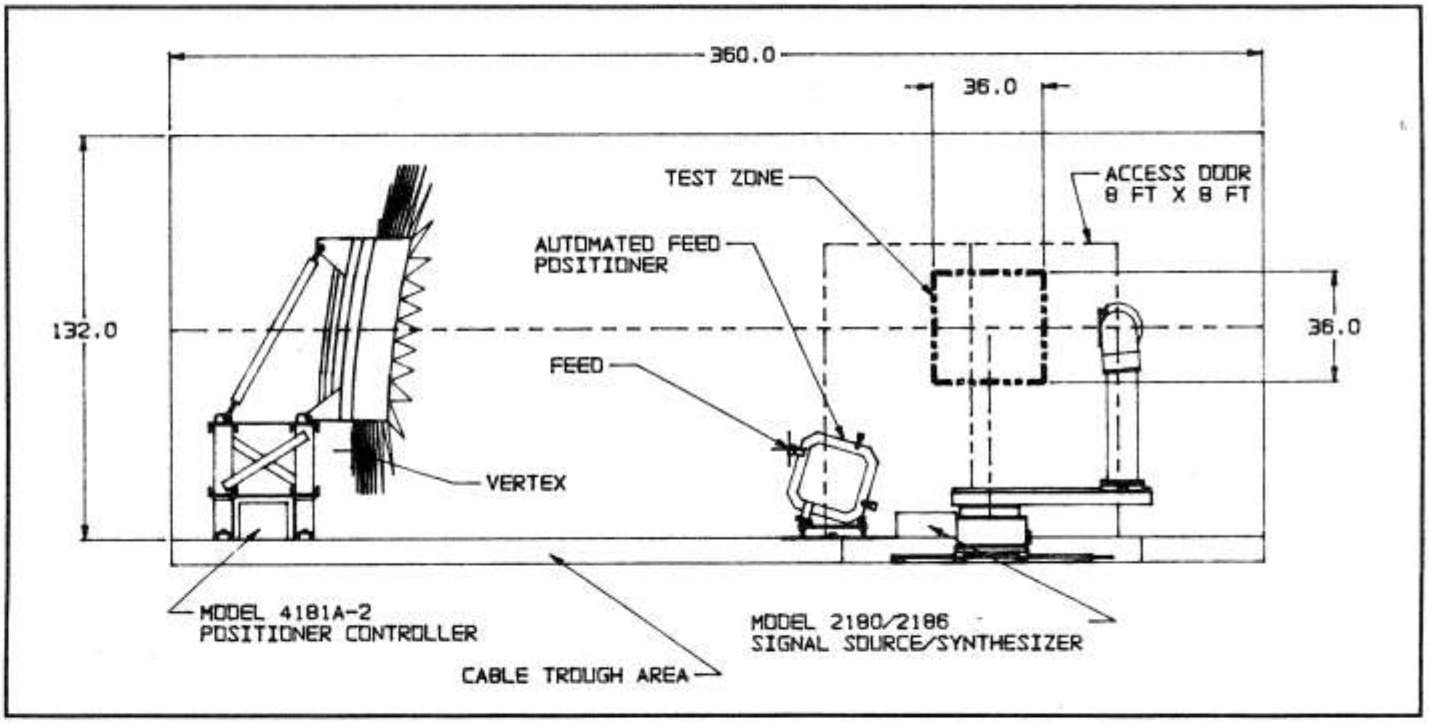

Figure 1 Range Layout

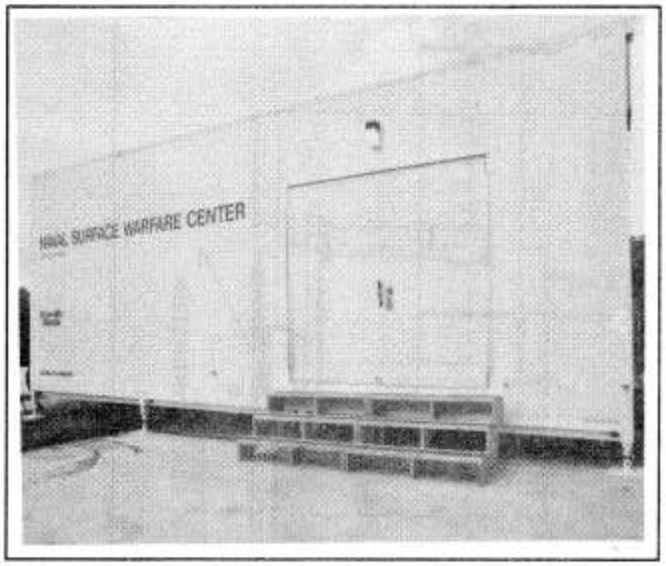

Figure 2 Exterior View

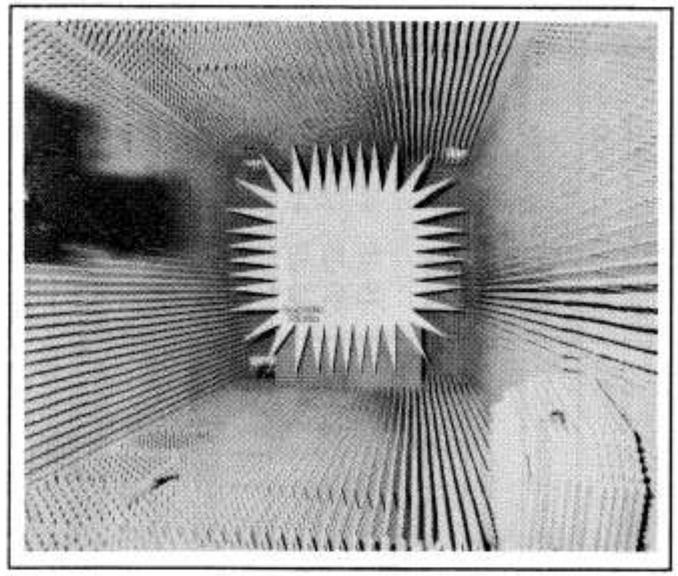

Figure 3 Interior View with Model 5703

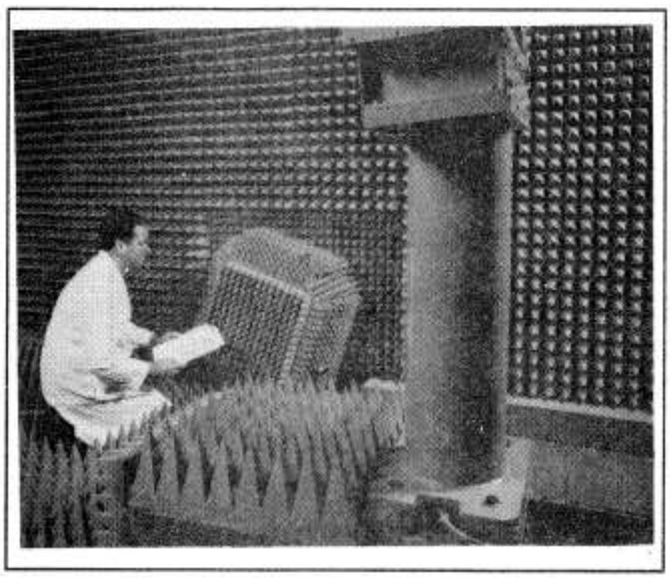

Figure 4 Feed Positioner

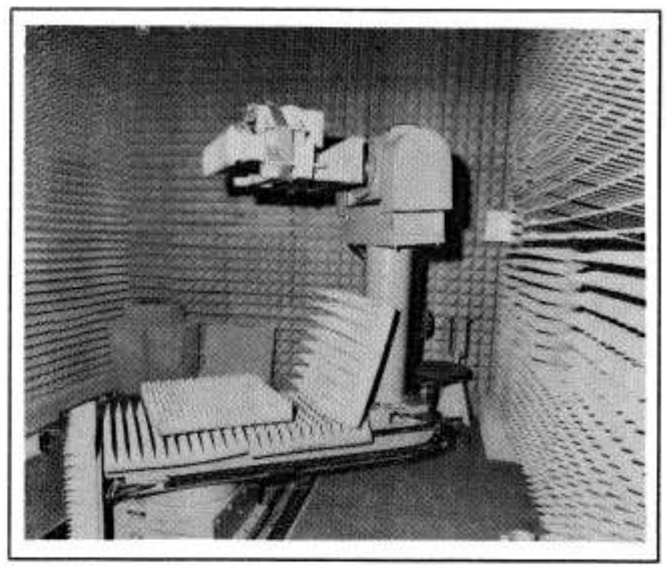

Figure 5 AUT Positioner