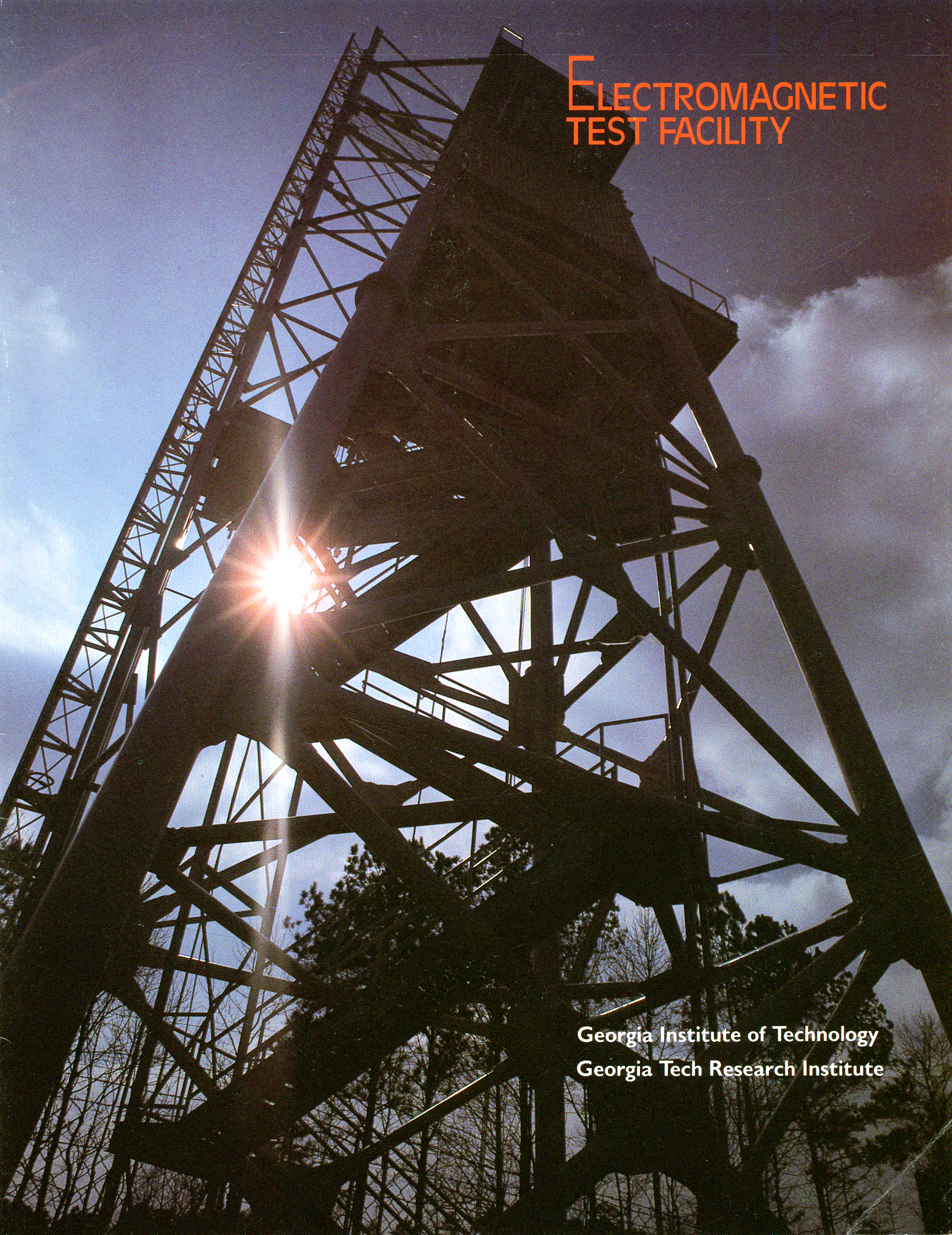
Electromagnetic Test Facility



Georgia Institute of Technology
Georgia Tech Research Institute

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ON THE COVER: Georgia Tech's Electromagnetic Test Facility includes this 90-foot source tower. It is part of the facility's far-field antenna range and turntable radar cross section range.

INTRODUCTION

Georgia Tech's Electromagnetic Test Facility is located at the university's Cobb County research complex near Dobbins AFB. Shown here is the far-field antenna range's 64-foot receive tower.

Over the last several decades, the Georgia Tech Research Institute (GTRI) has developed extensive measurement facilities to support high-quality research in all aspects of electromagnetics, from purely theoretical analysis through advanced applications in phased array radar systems. GTRI has been a national leader in the development of mechanically and electronically scanned antennas, near-field measurement techniques, millimeter wave technology, and threat radar systems.

These capabilities have been greatly enhanced by the construction of the Electromagnetic Test Facility at GTRI's off-campus research site fifteen miles northwest of Atlanta. This multi-million-dollar complex can accommodate a variety of antenna and radar cross section measurements. It is now one of the leading facilities of its kind in the nation and the largest affiliated with any university. The facility includes a far-field antenna range, a look-down radar cross section range with a heavy-duty target turntable, and a rooftop radar test and calibration range. It became fully operational early in 1987.

In addition to its physical attributes, the facility offers the advantage of being operated by a high-quality, independent R&D organization.

Georgia Tech engineers are able to efficiently respond to varied requests, ranging from quick-reaction, short-term studies requiring low levels of effort to major developments of complete operational electronic systems designed from the ground up.

This booklet describes the new Electromagnetic Test Facility in general terms. It also summarizes other electromagnetic facilities and research capabilities at GTRI. □

FAR-FIELD ANTENNA RANGE

The Far-Field Antenna Test Range includes the following design features:

☐ A heavy-duty (40,000 pound capacity), three-axis positioner capable of handling antennas up to 30 feet in diameter;

☐ Very low reflection levels for accurate low sidelobe and polarization measurements; and

☐ Very stable platforms at both ends of the range for precision polarization and/or millimeter wave pattern measurements beyond 96 GHz. In 40 mile-per-hour winds, lateral deflection is constrained to 0.05 inch and torsion rotation is limited to 0.1 milliradian.

The overall height of the source tower is approximately 90 feet, while the receive tower is 64 feet in height. They are positioned 1,300 feet apart. The range's length can be extended to as much as 30,000 feet through use of remote transmitting sites. The source tower is stable enough for use in boresite testing of precision tracking radar systems through the millimeter wave region.

By utilizing the natural terrain, the range allows low reflection level measurements. This feature and the source tower's rigidity make the range well-suited for low sidelobe measurements, accurate cross-polarization measurements, and narrow beamwidth millimeter wave antenna measurements.

The 90-foot source tower also has applications for systems tests of radars, direction-finding systems, and radar warning receivers. The control room near the top of the tower is an excellent location for testing direction-finding systems, especially in the millimeter wave region where vibrational stability is a necessity.

The antenna range is completely equipped with Scientific-Atlanta antenna measurement instrumentation and ancillary test equipment as delineated in the following section. ☐

The source tower of the far-field antenna range is stable enough for use in boresight testing of precision tracking radar systems through the millimeter wave region.

ANTENNA RANGE INSTRUMENTATION

The antenna range receiver is a Scientific-Atlanta 1783 Three-Channel Programmable Microwave Receiver which provides frequency coverage from 20 MHz to 107 GHz using an assortment of mixers and downconverters. This receiver is capable of making high-speed phase and amplitude measurements over a 90-dB dynamic range with a maximum sensitivity of -120 dBm. Programmable pre- and post-detection bandwidth selection allows for a compromise between measurement speed and sensitivity.

The standard signal source for the antenna range is the Hewlett Packard 8340A Synthesized Sweeper. It provides frequencies from 10 MHz to 26.5 GHz with an output level of at least +1.0 dBm at 26.5 GHz and up to 16 dBm for lower frequency ranges. Accuracy is exceptional with an aging rate of less than 1×10^{-9}/day and 2.5×10^{-7}/year. Other capabilities of the 8340A include pulse and amplitude modulation, swept frequency, fast CW switching, and IEEE-4888 programmability. Remote control of the 8340A from the receive site is possible via a fiber-optic IEEE-488 link. Other signal sources covering selected frequency ranges between 26.5 and 140 GHz are also available, and others can be added. Manual or automatic control of the three-axis antenna positioner is possible with a Scientific-Atlanta 4181-2 Positioner Control System used in conjunction with a Scientific-Atlanta 2012 Positioner Programmer. These instruments allow programmable raster scanning and selection of data sampling points during scans.

This three-channel programmable microwave receiver is effective from 20 MHz to 107 GHz and uses an assortment of mixers and downconverters.

The receive tower can accommodate antennas weighing up to 40,000 pounds.

A Scientific-Atlanta 1885 Position Indicator provides a direction indication of the angular position of each axis to a resolution and accuracy of 0.01°. The 1885 Position Indicator displays ranges of 0.00 to 359.99° or ±180° and adjustable offsets for ease in re-defining zero reference angles.

A Scientific-Atlanta 4116 Positioner Control System is used to control the Scientific-Atlanta 56160 Polarization Positioner and the Scientific-Atlanta 56821 Polarization Positioner Adjustable Mounting Fixture for source antenna alignment. The Scientific-Atlanta 1885 Position Indicator provides a digital display of source antenna position.

A Scientific-Atlanta 1581 Antenna Pattern Recorder is used to generate analog patterns of amplitude or phase versus direction. An assortment of chart paper and pen colors suits a wide variety of antenna pattern measurement requirements.

A field probe built by Gemco Engineering and Development according to GTRI specifications is available for range validation prior to testing. ☐

TURNTABLE RCS RANGE

The turntable RCS range consists of a heavy-weight turntable at ground level and an elevatable platform on the side of the nearby source tower. The tower is 90 feet high and 150 feet from the turntable.

The three by four foot elevatable radar platform will support 2,500 pounds and can be positioned at any level from the tower base to a 90-foot height. Researchers can thus perform RCS backscatter measurements on tank- and aircraft-sized targets at elevation angles from near zero to 32 degrees. The elevation angle accuracy is ± 0.05 degree.

The 22.5-foot diameter turntable was designed with an edge-mounted roller system to support a vertical load of over 200,000 pounds without degrading the accuracy of elevation measurements. An encoder provides a direct digital readout of angular position over a full 360 degrees to an accuracy of 0.01 degree. The area surrounding the turntable is cleared of any protrusions which might produce extraneous backscatter or reflections which would corrupt the accurate measurement of target characteristics.

A controller system allows the rotational speed of the turntable to be variable between 1.5 and 0.10 degrees per second (corresponding to 15 and 1.0 revolutions in 60 minutes, respectively) while maintaining a speed stability of 1 percent. The target support structure atop the turntable is level to within ± 0.1 degree, thereby allowing very accurate elevation angle pattern cuts to be taken.

A research area currently receiving much attention is that of measurement and analysis of "full polarization matrix" target characteristics. An essential element in making such measurements is a very stable platform which allows highly accurate phase measurements to be performed. The mass and stiffness of the source tower of GTRI's test facility inherently provide the necessary stability for such measurements. The source tower and elevatable platform combination allow phase measurements to be made with an accuracy of less than ± 18 degrees at 95 GHz, thereby easily satisfying the accuracy requirement for measurement of the target polarization matrix.

Extensive radar cross section and infrared measurement instrumentation is available to support target characterization as described below.

The turntable range is supported by a variety of instrumentation radars at frequencies from 5 to 140 GHz. Essential characteristics of the available radars are given in Table 1 on page 8. Characteristics of particular importance in radar measurement of target parameters include multiple polarizations for polarization matrix definition, wideband frequency agility to enable high-resolution range profile determination, extensive data collection and recording facilities, and on-line and near-real-time data processing for "quick-look" data evaluation.

Infrared measurement systems are available in both the 3-5 μm and 8-12 μm bands to support thermal characterization of target signatures. These systems can also be used simultaneously with the radar instrumentation to provide dual-mode millimeter wave/infrared target signatures. □

Above, this 22.5-foot diameter turntable can support vertical loads of more than 200,000 pounds without affecting the accuracy of elevation measurements. Far right, the elevatable radar platform can be positioned at any level of the source tower and support up to 2,500 pounds.

RADAR TEST & CALIBRATION RANGE

This elevated laboratory on a building at the GTRI off-campus research complex is an ideal location for test and calibration of prototype radar systems. It offers an unobstructed view of several test target locations up to 500 feet away from an elevation of 30 feet. The topographical features within the complex also accommodate measurements of target characteristics in or near selected types of ground clutter (such as low vegetation and tree lines). In addition, the laboratory has a direct line of sight to the antenna range source and receive towers approximately 1,000 feet away for propagation measurements. □

OTHER FACILITIES

GTRI maintains a number of additional facilities important in its electromagnetics research programs. They include the following:

Compact Antenna Range. This fully automated indoor range is located in a 24 by 30 by 20 foot anechoic chamber. It uses a 12 by 16 foot section of an offset-fed paraboloidal reflector to produce plane wave illumination for a variety of test antennas and scatterers. The facility is instrumented for antenna and RCS measurements in the 2-18 GHz region. A recent upgrade makes possible measurements of pulsed signals.

Near-Field Ranges. GTRI has two near-field ranges. The automated planar scanner is one of only a few of its kind in the United States. It employs a precise XYZ positioner to directly measure phase and amplitude distributions of apertures as large as eight feet. The other, a cylindrical range, is fully automated, occupies a room approximately 20 by 40 feet, and is entirely lined with absorber. The linear field probe traverses 12 feet, and probe motion is linear within ±0.005 inch.

Outdoor Antenna Test Range. A 1,000-foot outdoor antenna range has a receiving site located on top of an eight-story building on the Georgia Tech campus. A three-axis pedestal rated at 1,500 pounds dead load is suitable for measurement of antennas up to eight feet in diameter. The range is also suitable for measurement of sidelobe levels as low as -50 dB.

Shielded Anechoic Chamber. A well-shielded, absorber-lined chamber permits equivalent free space measurements to be made in an interference-free environment at frequencies from 450 MHz to 20 GHz. This facility supports a variety of electromagnetic compatibility measurements.

Animal Radiation Exposure Facility. Researchers use a specialized animal exposure facility to evaluate the effects of controlled exposure of animals to RF and microwave radiation, at variable power levels, over long time periods.

Portable Measurement Facilities. GTRI maintains a 40-foot semitrailer which is useful as one end of a propagation range. This semi-portable facility has a beam waveguide system for distributing local oscillator power to each of four mounted antennas. It is capable of measuring atmospheric effects on propagation of all wavelengths of interest. A second, smaller truck can be used as a transmitter facility. It has provision for mounting its single antenna pedestal to a concrete pad.

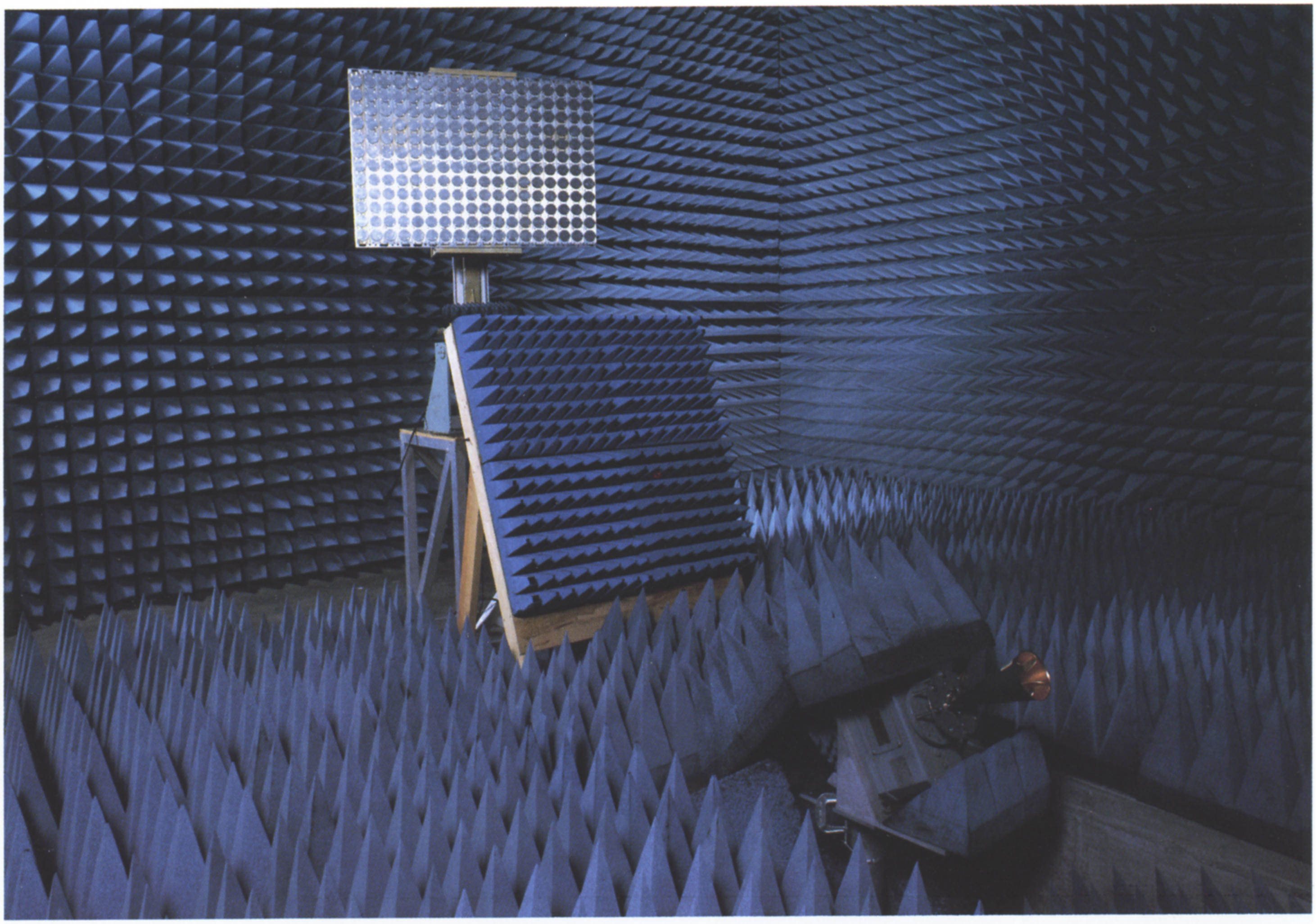
GTRI also has two radar instrumentation trailers (20 foot and 40 foot lengths) which can be used to provide mobile laboratories suitable for off-site measurements utilizing any of the instrumentation radars listed in Table I shown below.

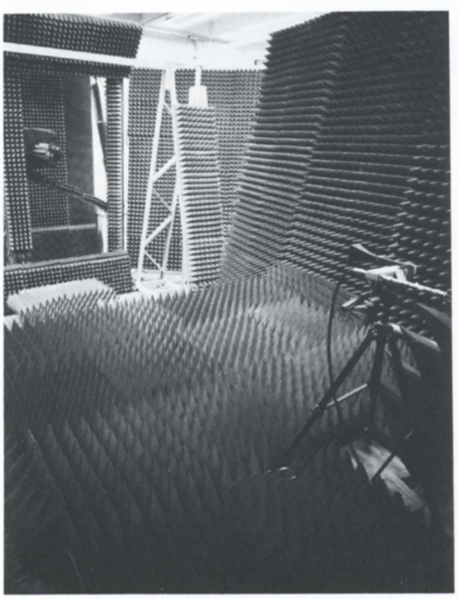
Airborne Laboratories. GTRI maintains two Convair airplanes which serve as airborne test platforms for electronic systems. They are equipped for measurements and data collection, system integration tests, technique evaluation and equipment analysis. The two Convairs (a C-131B and a T-29B) are twin-engined, cargo type, pressurized aircraft large enough for research payloads but small enough for relatively economical operation. Each has a large belly radome, and the T-29 has a large nose radome. The C-131 can carry equipment pods under the wings or fuselage, has a large cargo door and two optical glass windows suitable for photographic mapping. □

TABLE I. GTRI INSTRUMENTATION RADARS AVAILABLE FOR USE WITH THE TURNTABLE RANGE

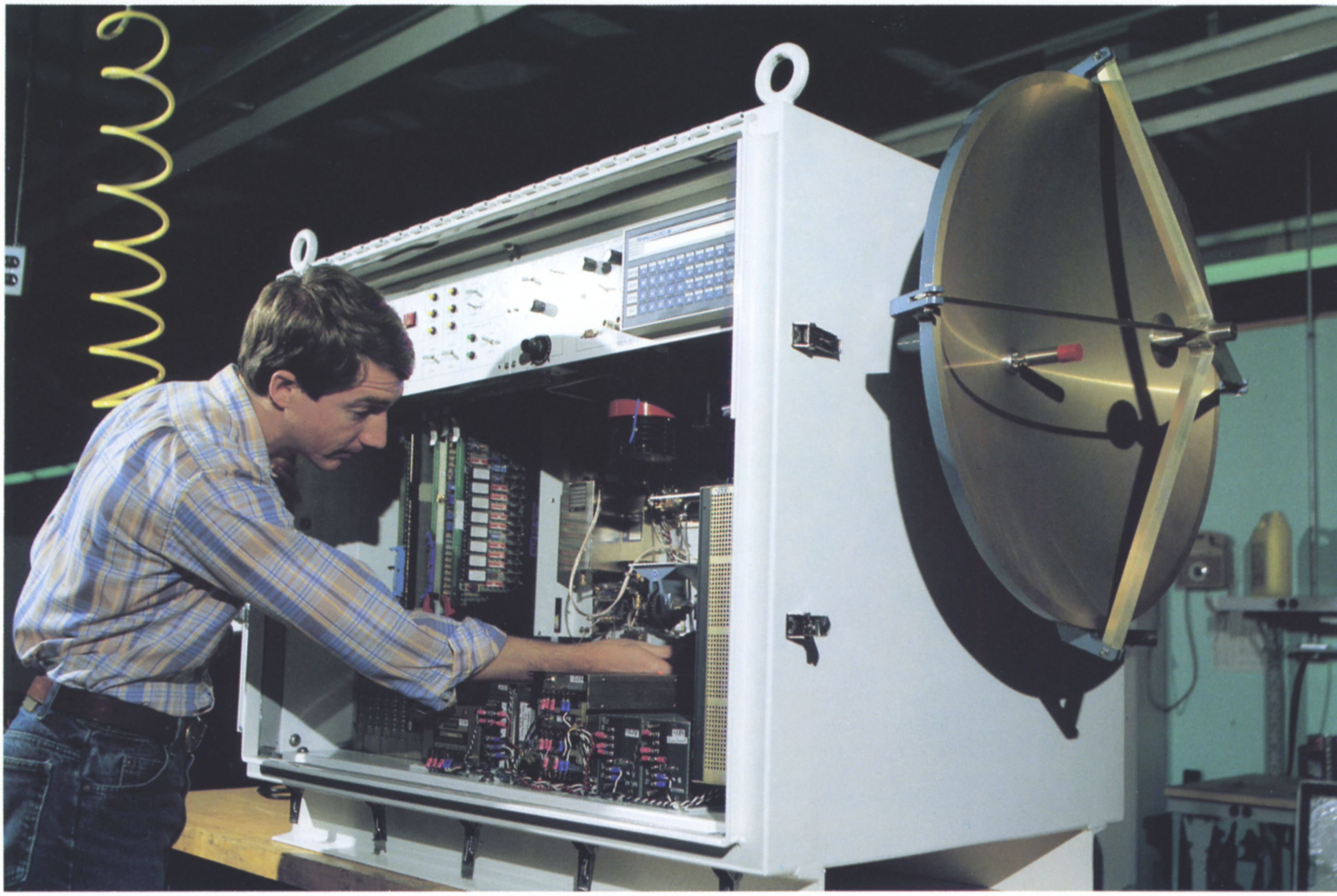
Frequency (GHz)	Peak Power	Pulse Length (ns)	Polarization	Antenna Beamwidth	Detection
5	1 W	50 - 250	Vertical or Horizontal	15° (std. gain horn)	Logarithmic
10	1 kW	10 -250	Dual Polarized	2.5°, 3° pencil beam	Logarithmic In-Phase and Quadrature
10	10 kW	50, 200	Agile Transmit Dual Polarized Receive	1.5° pencil beam	Logarithmic
16	40 kW	50, 200	Dual Polarized	1.5° pencil beam	Logarithmic
35 (agile)*	3 W (coherent)	2**, 100	Agile Transmit Dual Polarized Receive	1°, 2°, 5° pencil beam	Logarithmic, In-Phase and Quadrature
35	20 kW	50	Dual Polarized	1°, 2°, 5° pencil beam	Logarithmic
95 (agile)*	1 kW (200 W coherent)	100	Agile Transmit Dual Polarized Receive	0.7°, 2°, 3.5°	Logarithmic In-Phase and Quadrature Polarimetric
95	1 kW	100	Dual Polarized	0.7°	Logarithmic
95 (FMCW)	20 mW	1 foot ***	Dual Polarized	0.2°	Logarithmic In-Phase and Quadrature
140	100 W	50 - 250	Dual Polarized	0.5°, 15° pencil beam	Logarithmic

*These systems have digital interfaces to the Data Acquisition Facility.
**Equivalent pulse length after processing coherent, frequency stepped data.
***Resolution is approximately 1 foot after processing the FMCW waveform.





Clockwise from the top of the facing page: a fully automated compact range for antenna and RCS measurements in the 2-18 GHz region; one of two research aircraft available at Tech for airborne testing of electronic systems; and a near-field range with an automated planar scanner.



Georgia Tech researchers have developed HIPCOR-95, the first high-power, coherent radar system operating at 95 GHz.

The Georgia Tech Research Institute is one of the country's largest university centers for applied engineering research and development. It serves outside sponsors on a non-profit basis and operates as an integral part of the Georgia Institute of Technology.

The Research Institute has a staff of approximately 1,300 employees, of whom around 560 are full-time professionals in various engineering, scientific, and economic development disciplines. In the fiscal year 1986, GTRI's research spending totalled around $65 million. Approximately 70 percent of its contract income came from federal agencies, with 60 percent from the Department of Defense.

GTRI is well-known for its electronics research activities. Its work in the electromagnetics field has involved applications in radar, radiometry, biomedical engineering, communications, electronic countermeasures, and tracking. The following paragraphs summarize capabilities and accomplishments in the electromagnetics area:

Measurement techniques. GTRI engineers have performed state-of-the-art antenna measurements all over the world. However, they have been more than just practitioners. They have contributed significantly to the theory and technique of antenna measurement. Examples include the invention and development of the compact antenna range; construction of the first operational planar-surface near-field measurement system; development of the first automated planar near-field measurement system; and development of the theory of cylindrical-surface near-field measurements.

Analysis. GTRI has many years of experience in the analysis and design of special-purpose and one-of-a-kind radar antennas. In support of these projects, several unique computer simulation tools have been developed for design of both reflectors and phased arrays. Other analytical research has focused on problems such as phased array antenna development, shipboard antenna siting, effects of damage on antenna performance, antenna hardening, electronic warfare, radar scattering, radar cross section modeling, countermeasures, RAM modeling, 3-D modeling and electromagnetic compatibility.

Antenna systems. GTRI researchers have designed and built specialized microwave antennas for many years, including complex antennas and support structures. GTRI has fielded a number of still-operational systems at various military installations. In the millimeter wave region, engineers here have developed numerous antennas, including a narrow-beam, rapid-scan antenna for one of the first operational millimeter wave radars in the country. During 1986, GTRI began a $7.266 million project to build a microwave telemetry phased array antenna. The system will be among the largest ever mounted on an aircraft. Its antennas will allow the Air Force to collect telemetry data on up to five missiles and drones at once. The system may be the only operational phased array antenna of its size and capability which is flyable and operates at S-band frequencies.

Technology. A variety of components and technology are necessary for building state-of-the-art electromagnetic systems. GTRI engineers have significant capabilities in the areas of quasi-optics, mixers/receiver components, microelectronics, polarization techniques, and transmitter/receiver development.

Fundamental studies. For more than 30 years, GTRI investigators have defined the reflectivity characteristics of target and clutter. They have performed radar cross section measurements on virtually every type of target and terrain. GTRI researchers have also studied the effect of environment on electromagnetic propagation — most recently in a landmark study of millimeter wave transmission in turbulent atmospheric conditions. In addition, engineers have characterized the properties of many materials, using a broadband reflectometer covering the 2 to 160 GHz frequency band. □

Georgia Tech researchers have established their expertise for modeling a variety of targets and predicting target signatures.

For More Information

Georgia Tech's Electromagnetic Test Facility is available for use by outside sponsors. In all cases, GTRI personnel operate the range facilities. Access to the ranges is part of services offered by GTRI through normal contracting arrangements.

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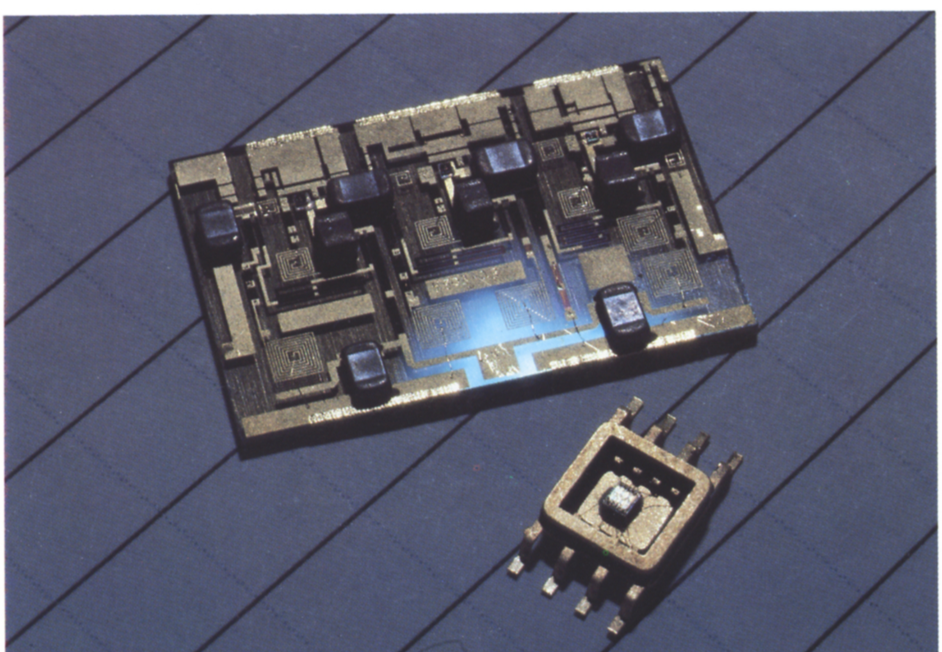

GTRI's recognized capabilities in microelectronics device development give it additional strength in advanced electromagnetics research.

GTRI

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