RADIATION LABORATORY, UNIVERSITY OF MICHIGAN

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Summary: The Radiation Laboratory is one of the oldest university research laboratories in electromagnetics, and is now 32, 30 or 25 years old depending on the date selected for its birth. Its development is traced and some of the present research activities are described.

The Radiation Laboratory is part of the Department of Electrical and Computer Engineering of the University of Michigan, and like many organizations, its true date of birth is difficult to establish. When the University acquired Willow Run airport in Ypsilanti, Michigan, from the Federal government in 1946, the Michigan Aeronautical Research Center was established, and some of the hangars, peripheral buildings and even part of the Terminal Building itself were soon the site of a growing research activity. The initial thrust of this research was defense against V-2 type missiles and, later, intercontinental ballistic missiles. In 1948 an Upper Atmospheric Physics Section was set up as part of the Aerodynamics Group on the second floor of the Terminal Building, and one of its first members was Keeve M. Siegel (Kip), who had received his bachelor's degree in physics from Rennselaer Polytechnic Institute that same year. To many people, Kip's name is so indelibly associated with the Radiation Laboratory that it is tempting to use the November 1948 date at which he joined MARC as the start of the Laboratory.

Within three years the research activity at Willow Run had expanded to include the defense of the continental United States against all forms of air attack including piloted aircraft, and this required a knowledge of the radar cross sections of the targets involved. Because of the mathematics and physics backgrounds of most members of the Section, it was not surprising that the task of developing analytical and computational techniques for predicting the cross sections of complicated targets became their responsibility. To reflect this emphasis, the Section became the Theory and Analysis Group (later, Department) in 1952, with Siegel as Head.

The Department rapidly acquired a world-wide reputation in electromagnetic scattering. To predict the cross section of a complicated target, a technique was developed of splitting the target into components which were then modeled by simpler structures amenable to mathematical analysis, and this in turn led to detailed investigations of such bodies as the cone, parabolic cylinder, sphere and spheroid. Its reputation was further enhanced with the publication of a special series of reports entitled "Studies in Radar Cross Sections," which concluded with the 50th report in 1966, and in June 1955 the Department acted as host for the second URSI-sponsored Symposium on Electromagnetic Wave Theory held at the University. By this time, the Department had outgrown the space available in the Terminal Building, and in 1956 it moved into a vacant hangar, one quarter mile down the road. On 1 January 1957 the Department became a laboratory of the Department of Electrical Engineering with the name Radiation Laboratory. Though no records exist as to why the name was chosen, it is reasonable to assume that it was in recognition of the Radiation Laboratory at MIT which had had such an impact on electromagnetics during World War II.

In addition to the office space, hangar II had ample room for an experimental facility. The Laboratory had long since acquired a reputation for interpreting experimental data, and had found such data valuable in checking approximate scattering theories, as well as in guiding their development, but without a facility of its own, it had had to rely on data supplied by other organizations. This was remedied in 1958 when Ralph E. Hiatt was appointed Associate Head of the Laboratory, with prime responsibility to establish a microwave facility. A large anechoic chamber was constructed at the west end of the hangar, and within two years there was a complete microwave laboratory, a physical-organic chemistry laboratory (for the study of polar liquids that might serve as radar absorbers) and, in addition, a plasma facility.

This period saw many other changes as well. To bring the Laboratory into closer proximity to the EE Department (then, as now, in the East Engineering Building on the Main Campus), the non-experimental parts of the Laboratory moved to downtown Ann Arbor in 1957, first to a former funeral home, and then to a vacant laundry. The new quarters provided better, quieter and cleaner accommodation, but those who make frequent trips can appreciate the advantages of working at the airport. In late 1960, Siegel founded the Conductron Corporation and, for a time, directed both organizations. The Corporation was initially staffed by past and present members of the Laboratory, and its creation reduced the Laboratory to about 80 members. A year later, Siegel resigned from the Laboratory to devote full time to the rapidly growing Corporation, and Hiatt succeeded him as Head.

For a few years at least, the Laboratory enjoyed a period of relative tranquility in which previous research was continued and new areas developed. A topic of increasing attention was cross section reduction, including the design of low RCS targets and the use of reactive (impedance) loading and absorbers to minimize the scattering. Techniques for surface field measurement were developed to determine a surface field distribution with and without an absorber present, and in 1964 a second anechoic chamber was constructed in hangar II for surface field measurements alone. Antenna problems also became a major part of the Laboratory effort. The studies ranged from the basic to the applied, and included broadband antennas, conformal arrays, and mutual coupling problems, and prompted the creation of an outdoor range for pattern measurements. But the late 60s were also a time of change, not least in the type of research support that was available, and the publication in 1969 of the book "Electromagnetic and Acoustic Scattering by Simple Shapes" was almost a swansong for the mathematically-oriented basic research that had made the Laboratory famous.

In 1975 the Laboratory moved to the East Engineering Building, where it now is, and the author succeeded Professor Hiatt as Director. Two years later, a new tapered anechoic chamber designed and equipped for surface field measurements was constructed in the basement. Using a digital data acquisition and processing system, currents and charges can be measured at stepped frequencies from 120 MHz through C band or, alternatively, at a fixed frequency as the probe is varied in position. Additional experimental facilities consisting of a multi-purpose anechoic chamber, an RFI room, and an outdoor antenna/scattering range are located at Willow Run airport, on the opposite side of the field from our former home in hangar II.

The Radiation Laboratory is one of ten laboratories in the ECE Department, and has nine faculty and staff and about 20 students, graduate and undergraduate. It exists to provide students at all levels opportunities for training in electromagnetics, to enable faculty and staff to participate in challenging research in this area, and as a resource for the Federal government and industry. It is entirely supported by contracts and grants, and at any time there are approximately a dozen projects under active investigation. Most of these are concerned with electromagnetic waves--their radiation, propagation or scattering--and since many involve measurements, all students acquire some familiarity with experimental techniques.

Four areas of continuing research are as follows:

Electromagnetic Interference

Electromagnetic systems can interfere with one another and this is true, in particular, of automotive systems. The Laboratory has studied ignition-generated radio frequency interference, and has measured and characterized the RFI signals in both the time and frequency domains at various locations inside the hood and passenger compartment of U.S. cars; and has investigated the susceptibility of selected automotive electronic components to such interference.

For the last seven years a major effort has been directed at the interference produced by wind turbines (WTs) or windmills. When large WTs were first proposed for generating electrical power, we suggested that the reflection of a primary signal off the moving blades would produce a form of time-varying multipath which could affect the performance of electromagnetic systems operating in their vicinity. It was felt that television would be affected worst of all, and the video distortion that is created was demonstrated in 1976. Theoretical and computational techniques were developed for predicting the threshold level at which the interference becomes objectionable, leading to the specification of an interference zone around the machine. The results were confirmed by laboratory simulations and tests, and by full scale tests using the existing machines. The effects of other systems such as AM and FM radio, microwave communication links and navigational systems have since been investigated, and on-site measurements made at Sandusky (OH), Block Island (RI) and Boone (NC). It is now recognized that such interference is one of the major environmental effects of the large (up to 7 MW) machines now under development, and the Laboratory has been involved in the evaluation of most sites where these are being installed.

Surface Field Measurements

The ability to measure surface and near fields has proved to be a valuable tool in a variety of investigations, and for the past few years the measurement facility has been used almost continuously. The measurements are made either as a function of frequency at a fixed location in, on, or near a body, or at a fixed frequency as the probe (sensor) is moved in position. A field (current) component or the charge density is measured in amplitude and phase and calibrated using, for example, the corresponding quantity measured on a sphere or a ground plane.

With the minute probes that are available, it is possible to measure the field penetration into lossy dielectric materials, such as phantoms simulating biological tissue, and we have recently examined the field as a function of depth in absorber materials in connection with the design of pyramidal absorbers. Surface field measurements can be used to assess the characteristics of a material, and measurements on metallic and other plates have also shown how edge interaction occurs, and can be controlled. This, in turn, has led to improved ground plane designs. A project just concluded was concerned with the positional errors of the LORAN-C system close to large bridges, and by measuring the total field close to a model bridge mounted on a perfectly conducting plate when illuminated by a plane wave, it was possible to determine the features of the bridge that are responsible for the errors.

The facility is also employed to measure the currents and charges at selected positions on small scale model aircraft in a variety of configurations either in free space or close to the ground. The measurements are generally made over a 40:1 frequency range spanning the resonance region, and the resulting transfer function information is used for verifying and extrapolating the data from full scale tests in EMP simulators.

Antennas

Antenna problems range from the basic, involving the exploration of new types or the improvement of existing ones, to the development and, perhaps, construction of an antenna for a specific application. In recent years projects have involved electrically small and/or loaded antennas, broadband antennas (the rudimentary horn with a 20:1 bandwidth was developed by the Laboratory), slots and slot arrays, conformal and phased arrays, and reflector-feed combinations. A theoretical analysis of a conformal antenna called the dielectric-filled edge-slot array has just been completed, and we are presently investigating patch antennas and the application of the dielectric rod antenna to mm wave frequencies.

Scattering

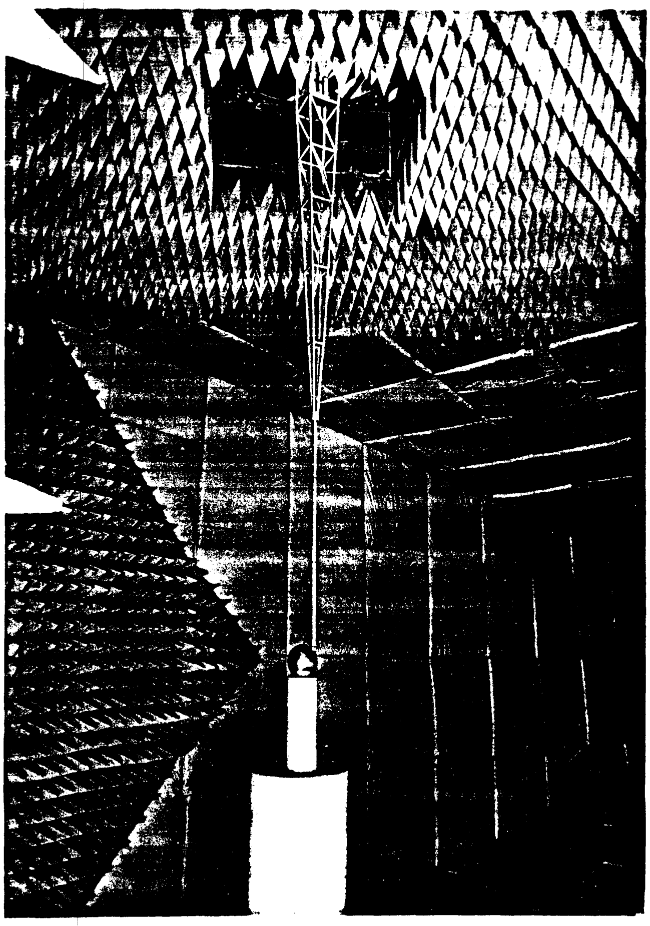
The Laboratory was first noted for the rigorous solution of basic electromagnetic problems, and the development of approximate and/or asymptotic scattering theories applicable to more complicated (and more realistic) geometries, and this type of research has continued to this day. Of late, the work has focussed on the effects that the material properties of a body have on its scattering.

The application of resistive sheet and impedance boundary conditions is being explored. Rigorous mathematical solutions are being developed for plane wave incidence on various sheet configurations, e.g., two half planes forming a wedge, an infinite stack of half planes, and a half plane in close proximity to a body. High frequency asymptotic solutions have also been derived for a resistive strip, and numerical techniques are being applied to problems such as a resistive or impedance plate with possibly nonuniform properties. These studies are of interest for their own sake and should also contribute to a better understanding of how lossy materials can be used to modify the scattering from a body.

A second area of research is low frequency scattering by dielectric and other bodies of various shapes. Improved methods have been developed for obtaining the successive terms in the low frequency expansion, and the effects of particle shape on material resonance phenomena are also being explored.

Legend for Figure

Fig. 1. Measuring the surface fields on a metal sphere. The probe traversing mechanism (from an old gun turret!) can be seen through the hole in the ceiling, which is normally blocked off during a measurement.



After a brief stint as a high school mathematics teacher, he received the B.Sc. and M.Sc. degrees in applied mathematics from Manchester University in 1949 and 1950 respectively, and the Ph.D. degree from Cambridge University (also in appl. math.) in 1954. While at Cambridge, he was a member of the Cavendish Laboratory under Mr. J. A. Ratcliffe. He was at RRDE (now the Royal Radar Establishment) in Malvern, U.K. from 1952 to 1957, when he joined the Radiation Laboratory. He is presently Professor of Electrical and Computer Engineering and Director of the Laboratory.

He has been active in URSI for the past 25 years, and a member of the U.S. National Committee since 1971. He has served as Editor of "Radio Science" (1973-78), Chairman of Commission B (1976-78), Secretary of USNC/URSI (1979-81) and is presently Chairman of the Committee. He is a Fellow of the IEEE, and a member of Sigma Xi and Tau Beta Pi.