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AREA REPORT: ANTENNA AND PROPAGATION RELATED WORK IN EUROPE AND ISRAEL

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* Naval Research Laboratory, Arlington, VA

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This is a report of visits made by the author to universities, industrial and other technical establishments while serving as a liaison scientist at ONR London from October 1979 to October 1981. The report begins by highlighting the most important topics, then goes on to describe research in France, Israel, Italy, The Netherlands, Switzerland, Turkey, West Germany, and Yugoslavia. A previous report covered activities in Denmark, Norway and Sweden.

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AREA REPORT: ANTENNA AND PROPAGATION RELATED WORK IN EUROPE AND ISRAEL

SUMMARY AND HIGHLIGHTS

This is a report of visits made by the author to universities, industrial and other technical establishments while serving as a liaison scientist at ONR London from October 1979 to October 1981. The report begins by highlighting the most important topics, then goes on to describe research in France, Israel, Italy, The Netherlands, Switzerland, Turkey, West Germany, and Yugoslavia. A previous report covered activities in Denmark, Norway and Sweden.

Polarization: In Europe, considerable emphasis is placed on the use of circular polarization to suppress rain echoes in radar systems. At Thomson CSF, (Companie de Telegraphie Sans Fil) Michael H. Carpentier, the technical director, claims that such polarization should be the most important requirement for any ground radar. It has been suggested in Europe that the lack of concern about circular polarization in the US may be due to better weather, with fewer rainy periods, even though the total rainfall may be large. In the US, emphasis was placed on a good moving target indicator (MTI) to remove rain clutter.

Polarization switching is used by the AEG Telefunken Company for sea-clutter rejection, and polarization diversity is used to double the available bandwidth of satellite communications-broadcasting systems, as it is in the US. For the last application, considerable effort has gone into the design of various circular corrugated horns that give polarization-independent radiation patterns. Elliptical horns giving elliptical radiation patterns have been developed at the University of Eindhoven.

Phased Arrays: There are several major phased-array developments. Dr. Jan Snieder and his team at The Netherlands' TNO, The Hague, have developed a noteworthy C-band space-fed phased-array lens (CASE), assembled with greatest precision from 850 waveguide elements, each containing a ferrite phaseshifter. The lens apertures are superbly matched over a 10% band. The team's interest extends to mm waves.

The Thomson CSF Radar Division in Bagneux, Paris, has developed various phased-array radars. The division is under Mr. Jean-Paul Biansan; the antenna work is under Dr. S. Drabowitch. Some of the work has been published; it describes advanced techniques including a parallel-plate radial-mode feed system and rain-rejecting circular polarization.

A team under Mr. Reinhart Bradow at Siemens AG, Munich, is developing an S-band space-fed phased-array lens system with an elliptical aperture. The first experimental model will have 1,290 elements in the form of a square matrix of dipoles. (2,580 elements are planned for the final model.)

Selenia, in Rome, has started to give serious attention to a phased-array system and may well embark on a substantial development program.

Dr. W.D. Wirth (FGAN, Germany) has developed a thinned phased-array radar and has operated it for several years. (The acronym FGAN stands for a civilian, nonprofit research organization that frequently functions on behalf of

the FRG's Ministry of Defense.) He has included some self-calibrating modes using an external RF element. Transmitting and receiving apertures are separate; both are thinned and the transmitter is active.

Vertical Plane Phase Scanning: At AEG Telefunken in Ulm, West Germany, Dip Ing. W.V. Gerlitzki is directing the development of a C-band mobile phased-array search radar, TRMS, using a flat-plate antenna from Hughes Aircraft. The antenna is rotated mechanically in azimuth and scanned by phase in the vertical plane. Polarization diversity is available and includes circular polarization for rain rejection.

Dr. B. Palumbo at Selenia in Rome has also developed a mobile surveillance radar with a mechanically rotated array. The vertical beam-former uses dual waveguides giving separately optimized sum-and-difference monopulse channels. There are three such parallel vertical beam-forming networks, each with its own phaseshifters, allowing for the formation of three independently scanned beams.

Line Arrays: Many different types of slotted line arrays, some very long and with polarization diversity, are being produced at Christian Huygens Laboratorium, a small company in The Netherlands. One application, ARTEMIS, gives a high- precision bearing-and-range indication as required, for example, by the offshore oil industry for navigation.

A slotted-line array with performance similar to ARTEMIS has been developed by AEG Telefunken for a harbor-control radar. The antenna provides a beamwidth of about 0.35° at X-band and has arbitrary polarization. Sea-clutter rejection is obtained by means of both frequency and polarization diversity. The antenna has also been used in the remotely controlled unmanned mine-sweeping system TROIKA.

Remote Sensing: Prof. Schanda (Univ. of Bern, Switzerland) has been able to estimate the characteristics and the potential water content of snow by remote sensing. He does this by correlating emissivity and reflectivity measurements. His group also studies the atmosphere and its composition by radiometric means.

Microwave probes consisting substantially of open-ended cavities with non-radiating fringing fields are being developed at the Technical University of Lausanne, Switzerland, by Prof. Fred Gardiole and Jean-Claude Besson. The probes are being used for dielectric measurements of materials ranging from human tissue for medical diagnostics to the sandstone structure of cathedrals to determine their water content.

Nonlinear Media: Prof. G. Franceschetti (Univ. of Naples, Italy) is trying to formulate the characteristics of EM fields in a nonlinear medium. Applications range from perhaps dangerously high-level radiation of harmonics to nonlinear behavior of the human body when irradiated.

Countermeasures: Elettronica, a unique, privately owned company in Rome, specializes in electronic countermeasures that it markets worldwide; in support of this, the company produces a whole range of traveling wave tubes with two octaves of bandwidth.

Wide-Band Antennas: Simple radiators like monopoles and dipoles, loaded with dielectric materials, have been developed at the universities of Belgrade and Ljubljana in Yugoslavia. Bandwidths of 1 to 2 octaves have been obtained.

Near-Resonant Targets: It is difficult to determine the reflection coefficient of radar or sonar targets that are 1 to several wavelengths in size. The problem is being studied theoretically at the universities of Belgrade and Ankara.

Medical Applications: Microwave imaging, particularly within the human body, is being investigated at DERMO in Toulouse, France.

At the University of Ljubljana, Yugoslavia, electric control of muscles is applied to enable paralyzed people to walk and to supply the required stimulus for other body functions.

Industrial Applications: DERMO, in Toulouse, France, has used microwaves to provide heat for the polymerization of plastics. An unaccountably small amount of energy was found to complete the task in a fraction of the time normally used. The phenomenon is not understood and is still regarded with some uncertainly.

FRANCE

Thomson CSF (Bagneux, France)

Thomson CSF belongs to the nationalized Thomson-Brand group. In 1980 Thomson CSF employed some 80,000 people and had a turnover of $4 billion, almost double that of 1978. The company is active in most of the electronics fields. The radar facility in Bagneux, which employs some 20,000 people, contains the special techniques group where remarkably good phased-array developments are carried out. The group is headed by Mr. Jean-Paul Biansan. Much of the work is classified but some has been published by Drabowitch, the manager of the antenna group, jointly with Gautier in the Revue Technique, Thomson CSF, 12, 1, March 1980. The group would like to start cooperative efforts with an organization in the US.

An interesting development is the disc antenna (antenne disque). It consists of a circular parallel plate region to which radiating elements are coupled with dual self-matching probes. Each element has its own phaseshifter; it uses a helix wound on a tulip-shaped form giving circular polarization with rain-rejecting features. The parallel plate cavity is fed at the center with a sum-and-difference feed. Scanned monopulse performance is obtained.

Other developments include MATADOR (TRS2215) and SATRAPE TRS2230, which are S-band, mobile or fixed air-defense radars. The antennas are rotated mechanically and phase-scanned in the vertical plane. The radiating element is the same as that used in the disc antenna and gives circular (rain-rejection) polarization. The elements are fed from a stack of horizontal waveguides.

DERMO (Microwave Research Department "Grande Ecole," Toulouse): In France, the best of the technical schools are called "grandes écoles;" they are more competitive and more difficult to enter than universities. There is a grande école in Toulouse that specializes in aeronautics and space; it contains a research center in which DERMO is a department devoted to research in microwaves. Students with the equivalent of a MS attend DERMO for 2 years to earn a doctorate in engineering. Among other research activities, DERMO has used microwaves to provide heat for the polymerization of plastics specially formulated for this purpose. An unaccountably small amount of energy (2$\frac{1}{2}$8)

was found to be sufficient to complete the task in one-quarter of the time normally required. The phenomenon is not understood and is still regarded with some uncertainty. Prof. Leo Thourel, professor at the grande école and director of DERMO, is primarily supported by the Department of Defense. He is conducting research in the areas of antennas and radomes, microwave components, and medical and industrial applications.

Studies by DERMO's antenna group include applications of GTD (Geometric Theory of Diffraction) to reflecting systems, taking into account diffraction by the feed and its supports. DERMO has primary responsibility to the French Navy for the design and test of radomes for aircraft as well as for missiles with speeds up to MACH 7.

Dielectric constant and loss-tangent (tan δ) measurements become difficult at mm wavelengths. For that reason an open-air quasioptical cavity has been developed at DERMO, with two mirrors forming a focal region in the space between them. The sample is placed in that region. The measurements have been found to have an accuracy of about 1.5% in (ε-1) and 10% in tan δ. In another microwave program, an attempt was made to develop a phase shifter using three to five PIN-diodes cemented together, one above the other, and placed adjacent to the sidewall of a flattened waveguide. Phase shift varied as a function of bias. The work its still in the early stages.

Medical work has included the development of an applicator for the 400- to 1000-MHz band that matched to water, which, it is claimed, has an impedance similar to that of human tissue. Image formation was attempted by transmitting through a tank of water, with the object moving across the field to simulate the normal application for transmitter and receiver scanning.

ISRAEL

University of Tel Aviv: Dr. Mark Beran is professor of Engineering Sciences at the University of Tel Aviv, Israel's largest university, with more than 15,000 students. Beran investigates scattering due to turbulence or internal waves; such scattering applies to electromagnetic and optical transmission systems as well as to acoustics. His secondary interest is in caustics that are encountered with acoustic propagation in the ocean and are the result of partial focusing of acoustic energy due to the variation of velocity of propagation with depth. In the Department of Mathematical Science, Dr. Steve Blank is working on antenna-array radiation-pattern optimization. He has developed an iterative procedure he claims provides rapid convergence and flexible criteria.

Technion: The Technion, Israel's prestigious Institute of Technology in Haifa, has renowned faculties in engineering, science, and medicine. It has about 8,000 students and provides most of the country's engineers.

Dr. S. Raz is an associate professor whose chief interest is inverse scattering, where a measured field, defined by the phase and amplitude of signals over an aperture, is inverted. The objective is to reconstruct an image of the scatterers. Raz's involvement is in acoustic seismic work directed at oil exploration; the process is also of importance in many other applications, ranging from nondestructive testing to medical diagnostics and inverse synthetic aperture radar processing. Raz has developed a focusing technique in which he has abandoned an exact inversion in favor of an approximate procedure which, he

claims, includes some of the procedures that were found empirically to be advantageous.

Elta Electronics Industries, Ltd.: The company, a subsidiary of Israel's Aircraft Industries Ltd., is in Ashdod, south of Tel Aviv. Its major division produces radars. Although the company is government owned, it must be competitive in bidding for government contracts. Most of the developments at Elta were started from scratch and cover almost every aspect of radar from airborne applications to air-traffic control and shipborne installations. Dr. Nino Levy is the deputy managing director. Antenna work is under the direction of Mr. Herbert Auslander.

The EL/M2021 radar, which fits into the nose of an aircraft for air-to-air and air-to-surface operations, is coherent and includes track-while scan. The antenna is a twist-reflector Cassegrainian type in which a fixed feed illuminates a parabolic mirror built with a grid of closely spaced wires parallel to the polarization. Beyond the parabolic reflector is a planar, hinged reflector that includes a device for rotating the polarization through 90°. The reflected radiation passes unhindered through the wire grating of the parabolic reflector. Scanning is achieved by tilting the reflector; the feed remains fixed and no rotating joints are required.

The 2106 is a relatively short range (about 15 Km), point- defense radar at L-band, designed for easy deployment. The construction is solid state throughout, even the display uses LEDs. The antenna is a simple horizontal slotted array feeding an offset parabolic dish.

Elbit Nes-Ziona: The company, a subsidiary of Elbit Computers Ltd., is active in the development of many types of electronic equipment. It has developed a wide range of antennas, mostly for military vehicles, where low profile and blast resistance are important. The EA-5 whip antenna, in particular, is only 167 cm high and is blast resistant. The electrical response, it is claimed, exceeds that of NATO's AS-1729, which is 3 m high and requires tie-down during travel. In another model, EA-518, wideband matching has been achieved (voltage standing wave ratio 3:1) over 50 MHz (30 to 80 MHz) with an 185-cm high whip. Many different types have been designed, and combinations with single and multiple radiators, covering various frequency requirements, have been developed.

Elbit has also developed instantaneous-direction-finding antennas and receivers, with horns arranged in a cylindrical assembly, covering 2 to 18 GHz. Some of the receivers use GaAs FET preamplifiers complemented with instantaneous frequency measurement intercept receivers.

ITALY

Technical University of Turin (Politecnico di Torino): The university has about 5,000 students, 1,500 of whom are in the electronics-oriented Engineering Department (IE&T), which has 28 full and associate professors. Interwoven with the research activities of the university in the field of antennas and propagation are the research activities of CESPA (Center for Propagation and Antenna Studies), which is a research center of Italy's National Research Council. Prof. Radolfo Zich is director of CESPA; he and most of the 10 members of his research staff are also on the university staff.

The research work at CESPA includes an investigation of corrugated horns that give polarization-independent radiation patterns; bandwidths of 1.5:1 have been achieved and elliptical cross-sections have been investigated for elliptical radiation patterns. The work is directed towards satellite communication systems. Aircraft radar cross-sections have been investigated using GTD (Geometric Theory of Diffraction) by superposition of the contributions from elementary parts of the geometry.

Dr. Mario Orefice, an associate professor, has studied large reflectors, with special reference to the suppression of side lobes and back lobes by shaping the rim. Similar work, but including dielectric rim-loading, is in progress at the University of Naples.

University of Rome: Dr. Giovanni d'Auria, a professor in the Electronics Institute of the Engineering Department, heads the antenna and propagation group. His main interest is in the application of statistical techniques. The research studies include propagation measurements in the 3- and 1-cm bands over a 40-km transmission path, using an interferometer receiver with a 2.5- or 5-m baseline; the group is also examining the statistics for remote sensing of atmospheric conditions.

Dr. Vegni, a member of d'Auria's group, has been investigating printed-circuit antennas formed by large patches printed on a circuit board. He feeds the radiators from the surface with a strip-line circuit, a method that is inherently narrow band, nevertheless, he has achieved a bandwidth of 6.5% with a 2:1 impedance mismatch. He has designed a 7-element array with such radiators and has included mutual coupling effects. Prof. Domenico Salimini and Dr. Patrizia Basili are using ground-based infrared radiometric measurements to study thermal gradients and turbulences. They have successfully used inversion of the data by Kalman filtering.

University of Naples: The University of Naples is large, accommodating some 50,000 students, with about 9,000 in engineering. The Electrical Engineering Department has about 1,000 students and includes a group, headed by Prof. G. Franceschetti, which specializes in antennas and radiation. Franceschetti, who is well known in the field, holds an adjunct professorship at UCLA. Under the heading of biological investigations, Dr. Gugliemo d' Ambrosia, an associate professor, uses microwave cavities where the field is "stirred" with rotating metal vanes, giving a uniform field (time-average) for observing in vivo samples and measuring incident and absorbed energy.

In the relatively new field of nonlinear environments, Franceschetti is attempting to solve Maxwell's equations for any medium. The application includes nonlinear loading of antennas and could be applied to the Solar Power Satellite project where enormous amounts of solar power are captured in space and beamed to earth with microwaves. Even very low level generation of harmonics could then result in dangerously high spurious radiation.

Prof. Ovidio M. Bucci has investigated large reflector antennas giving special attention to the design and construction of the rim for the reduction of far-out side lobes. His work is more general than that of Zich at the Technical University of Turin and includes dielectric loading and shaping of the rim of the reflector and the subreflector, when such is present. His approach includes the "tunnel antenna" where the rim extends in cylindrical form, usually for the suppression of far-out sidelobes.

Mariteleradar, Livorno: Mariteleradar, a communications and radar laboratory established in 1916, is at the Naval Academy in Livorno. Its more formal name is Istituto Radar e Telecomunicazioni Giancarlo Vallauri. A total of over 100 people work at the laboratory under the director, CAPT Roberto Palandri. The antenna section is headed by LCDR Fernando Crescembini. The work includes equipment evaluation as well as shipborne communication antenna design with the help of models. Radar cross-sections of ships are routinely measured. The ship being measured circles and sends rotational position information by radio. Passive IR measurements are carried out in the same way. Attempts are being made to reduce the reflectivity-emmissivity.

Comelit (GTE), Milan: Comelit is a subdivision of GTE Telecomunicazioni SpA, a subsidiary of GTE in the US. The company, in Cassina de Pecchi, just outside Milan, specializes in communications equipment. The engineering manager is Cesare Bassi. Comelit is active in the antenna field; one group, under Dr. Ing. Carlo Campora, designs and produces a large number of different reflector-type antennas. The reflectors are usually made of molded fiberglass and include parabolic reflectors and Cassegrain systems, with or without radomes, in a wide range of sizes, up to 90 ft in diameter for tropospheric scatter communications. The feeds for the reflectors are designed to respond to single or dual polarization and cover the range from 400 MHz to 13GHz. Very low side lobes, especially at wide angles, are achieved in one configuration with an absorptive shroud around the rim of the reflector.

Selenia: Selenia is one of the major companies belonging to the Italian Government's giant subsidiary STET (for historical reasons STET is the acroynym for Societa Finanziaria Telefonica p.A.), whose holdings include, among others, the Italian Telephone Company. Selenia employs a total of 6,400 people and has a yearly turnover of $250 million. The main facility is just outside Rome. The company started in association with Raytheon and has been active in radar for about 30 years. In more recent years, it has become involved in missiles and space technology, communications, and laser developments. Its products, which are sold worldwide, include missile systems furnished to Iraq, from where Italy obtains much of its oil.

The technical director of Selenia is Ing. Raffaele Esposito; Dr. Benito Palumbo is head of the antenna section. At the time of the author's visit (1981) Selenia was debating whether or not to embark on a phased-array development program; by now they have probably decided to go ahead with the development of a naval system, perhaps C-band with circular polarization.

A previous surveillance radar development that has already reached the production stage is a 3-D rotating planar array using phase shifters to steer the beam in the vertical plane. The aperture is formed by waveguides fed with dual systems that give separately optimized monopulse sum-and-difference distributions. The transmitter uses only part of the aperture and provides floodlight illumination. The receiver has three beams, separated by frequency, that can be steered independently in the vertical plane by three separate sets of phase shifters.

Elettronica SpA: Elettronica is unusual, not only because it is owned by its president, Ing. Filippo Fratalocchi, but also because it manufactures, almost exclusively, electronic warfare equipment, mainly for export. Its products have justly achieved a worldwide reputation. The company, with about 2,000 employees, had a turnover of $60 million in 1980. The general manager is Dr. Baminir

Polic, the engineering manager is Dr. Ing. Gianfranco Scafa, and the antenna section is headed by Dr. Ciro Nocolai.

In support of its ECM equipment, Elettronica produces high-power traveling wave tubes with almost 2 octaves of bandwidth, covering the frequencies from 1 to 18 GHz. The company is also active in the infrared field.

Elettronica has developed a 16-element high-power phased array covering 8 to 20 GHz. The elements are H-plane horns, adjacent in the E-plane for easy matching. The aperture, covered by a radome with metal strips arranged to rotate the polarization to 45°, operates over the whole (2.5:1) band.

The company has also developed multibeam systems with "Constant K" and Luneburg-type spherical lenses. They were designed to focus inside the surface, but the feeds were placed at the surface. The phase error that results from this arrangement is greatest at the high frequencies that normally would give the narrowest beams. The phase error, therefore, gives the most degradation in the form of beam-broadening at the high frequencies. This compensates to some extent for the change in beamwidth with wavelength, and beam crossover variations with a multifeed system can be kept within acceptable limits over a wide range of frequencies.

CSELT (Centro Studi E Laboratori Telecommunicazioni SpA): CSELT is the research laboratory of STET, mentioned earlier. The laboratory is in Turin. Its antenna department is headed by Dr. Paolo Bielli under the technical director, Ing. Salvatore de Padova. There is much collaboration between the antenna group and Prof. R. Zich at Turin's Technical University. There is also much interest in ground-based and on-board antennas for satellite communication systems. The antenna design aims at high efficiency. Polarization diversity is used to double the available channel capacity. To this end polarization-insensitive corrugated horns have been designed as primary feeds for the reflector antennas, dimensioned for low sidelobes.

A polarization tracking system has been developed to maximize channel polarization isolation. It operates at C-band and tracks a linearly polarized beacon signal. Other work includes the development of antennas giving elliptically shaped beams that are obtained by introducing controlled spherical phase errors in one plane of a circular reflector by proper variation of the cross-section.

THE NETHERLANDS

University of Delft: The Electrical Engineering Department has approximately 1,500 students and a staff of about 400. The microwave laboratory forms a substantially autonomous unit within the department. It is headed by Prof. Ir. L. Krul and has a staff of 13. Research is supported both by the university and by government institutes. A remote sensing system with a sensor mounted on an airborne platform is used in an attempt to recognize changes in the environment, detect diseases of crops or forests, and determine soil moisture contents. The sensor is a modified X-band radar (side-looking, real aperture); there are plans to complement this with an 8-mm Frequency-Modulated Continuous-wave (FM-CW) radar. Another group is using cavities for the measurement of dielectric constants over a range of temperatures. The procedure has potential applications in industrial heating by microwaves, for example, to cure wood

and also in medicine. The group is studying the last aspect in collaboration with the Medical School of the Erasmus University of Rotterdam in connection with the irradiation of the throat as a treatment for cancer.

The Microwave Laboratory is also investigating the troposphere with a sensitive 3.3-GHz FM-CW system equipped with separate transmitting and receiving antennas. The minimum range of the system is 60 m and it is claimed to be capable of detecting a speck of dust at 1 km. Clear air turbulences are observed and studied.

University of Eindhoven: The university, founded in 1956, has about 1,000 students in the Electrical Engineering Department. Drs. M.E.J. Jeuken and Ir. V. Vokurka are on the department's research staff and are active in antenna development. They have found a way of calculating and building an elliptical corrugated horn that has a polarization-independent radiation pattern. Such horns are important to stationary satellite television distribution systems that require an elliptical radiation pattern to match the required footprint and dual polarization with low cross-talk to permit the use of two channels for double information bandwidth. The horns are difficult to build; they were constructed with a complex electroforming technique.

Another method of achieving similar elliptical beams that has been studied uses a circular corrugated horn feeding a two-cylinder reflector system, collimating successively in the two orthogonal principal planes.

Jeuken and Vokurka have also investigated indoor antenna measurements. Near-field methods, by means of which the field closely in front of the antenna under test is probed, are currently popular. Their method differs from the near-field technique in that it creates a planar wavefront with constant amplitude in which the antenna under test is measured. They obtain such a uniform field with two orthogonal cylindrical reflectors and claim to have achieved a larger test zone than was previously obtainable with equal reflector size, greater polarization purity, and higher accuracy.

TNO: The director of the Physics Laboratory, TNO, in the Hague, is Ir. M.W. van Batenburg. The microwave division is under Dr. J. Snieder; he and his team have long concentrated on phased-array developments. An extremely well designed and most carefully constructed space-fed phased-array lens system has been built with 849 waveguide elements. The elements are remarkably well matched by irises and an external dielectric sheet for scan angles up to 60°. The antenna, which operates over a 10% band at C-band, has been fully tested with a monopulse feed. It uses 4-bit ferrite phase shifters. At the time of the visit (1980) a larger system was being planned. Supporting phase shifter development work is being carried out and both diodes and ferrite phase shifters are being evaluated for applications from S-band to 96 GHz (3 mm).

A solid-state module has been designed and evaluated with a linear array. It uses PIN-diode phase shifters and phase-locked IMPATT diode amplifiers giving 60 mW CW at C-band.

Christiaan Huygenslaboratorium B.V.: This small company is in Nordwijk. Ir. R. Blommendaal is the associate managing director. The company specializes in antennas, specifically in linear array antennas and high-precision position-fixing systems. It has developed slotted array configurations with arbitrary polarization. This was achieved with three arrays; two, which are combined,

have shunt-displaced longitudinal slots and one has transverse slots in the sidewall. The arrays form, respectively, the top and bottom or the end piece of a wide corrugated horn that provides gain in the vertical plane. The polarization is determined by the phase relationship between the two types of array. Other more conventional types of slotted arrays have been built up to the millimeter band with beamwidths as narrow as one-quarter degree. Such beams have been used for airport and harbor control systems.

A mobile, single-point-reference, range-bearing system, ARTEMIS, using a long linear X-band array,has been developed and is in production. The system provides accurate azimuth and ranging information and tracks a target for off-shore, harbor, or estuary operations.

SWITZERLAND

Technical University of Lausanne (EPFL): EPFL (Ecole Polytechnique Federale de Lausanne) is 1 of the 2 technical universities in Switzerland that are controlled by the federal government; other universities are under local (Canton) control. EPFL, in the French-speaking part of Switzerland, has some 2,000 students. Electromagnetics and acoustics are studied in LEMA (Laboratoire d'Elecromagnetisme et d'Acoustique), a department led by Prof. Fred Gardiol with a staff of some 16 people.

One of the research efforts at LEMA (Jean-Claude Besson) was directed to the measurement of dielectric constant and loss tangents of materials. The medium was probed with the fringing field of an open-circuited coaxial transmission line. The technique was applicable to biomedical materials and also to diagnostic measurements of sandstone, which is used extensively in the construction of cathedrals and other public buildings. Modern heating systems cause the sandstone to breathe; this is accompanied by the transport of water and particles from the inside to the surface and leads to rapid erosion. Measurements also were made with probes at the point where the coaxial structure was extended by the outer conductor forming a cylinder, well below cut-off. The cylinder could be filled with a test material, in particular, a liquid. All the dielectric measurements needed calibration points that were not always available. Other work included a study that involved loading cavities with metallic or dielectric structures in order to reduce their physical size and a radiometric project carried out with the Department of Agriculture at EPFL.

University of Berne: Prof. Edwin Schanda is director of the Institute of Applied Physics (IAP-Institut für Angewandte Physik) and also heads the Department of Microwave Physics where he has a staff of 14 people, primarily involved in remote sensing projects. Of special interest to the group are wide-band (2 to 90 GHz) reflectivity (radar) and emissivity (radiometric) measurements of snow and their variations with time of day and season. Different types of snow can be recognized and the total potential available water content can be estimated. An experimental data-collection station has been established on one of Switzerland's glaciers. Similar measurements are made of vegetation-covered ground (1 to 12 GHz). The work is initially carried out from a crane rather than from the air. It is a systematic study in an attempt to measure the moisture of the soil and to characterize vegetation.

Higher frequencies, 118 to 270 GHz, will be used in experiments scheduled to be conducted in 1984 from the Space Laboratory, aimed at quantifying various components of the atmosphere.

Post, Telegraph, & Telephone R and D Division: The Post Office (PTT) in Switzerland is responsible for communications including telegraph and telephone as well as mail. The Research and Development Division, with a staff of about 250, has laboratories in Berne. The six-member microwave group, under Mr. Bernard Eicher, is responsible for acceptance testing. The team has also developed a number of components, for example, coaxial-to-waveguide transitions, attenuators, and directional couplers. These are primarily designed for high-precision measurements and have a flat frequency response and excellent impedance match. The group is in the fortunate position of always having ample funding.

TURKEY

Middle East Technical University: The university is just a few miles outside Ankara. Surprisingly, all of its functions are conducted in English. There are some 12,000 students, almost 10% of whom are in the Electrical Engineering Department. The staff frequently spends prolonged refresher periods in the US and UK and many of the staff members have studied abroad. Prof. A.F. Fer, the department's assistant chairman, and Dr. Altunkan Hizal, an associate professor, obtained their PhD degrees at the University of Birmingham. They are both members of the microwave and antenna group. The work is mainly theoretical and thus avoids the need for a well-equipped laboratory. In the past, Hizal has devoted much attention to resonance scattering, that is, scattering by objects of the order of a wavelength in size. He has a general theoretical description of the problem, applicable to metallic and composite scatterers but requiring rotational symmetry. Applications include many diverse subjects, e.g., scattering by raindrops, acoustic scattering by underground rivers, and scattering absorption studies of the human body.

Other work includes studies of wire antennas and of "thick" antennas, for example, of a half-wave height cone above a ground plane, with octave bandwidth.

Prof. Canan Toker, who works on microwave devices, is especially interested in wide bandwidths; he uses nonlinear (exponential) transmission lines for impedance matching.

There is a close association between the university and the Aselson Company described below.

Aselson Company: This electronics company has been set up by Vakif, which is a well-endowed Turkish foundation supported by private contributions and tasked to support the Turkish Army. Vakif is administered by a retired army general. Aselson, with a staff of 400, plans to double in size every year for at least a few years. Ample buildings and electronic equipment are available and more laboratories are being constructed. At present, production is primarily aimed at "walkie-talkie" communication equipment; it is not produced anywhere else in Turkey. Recent legislation gave Aselson preference for supplying the Army.

WEST GERMANY

University of Aachen: Prof. H. Lueg heads the Electronics Institute at the Technical University of Aachen. A senior member of his staff is Dr. C. von Winterfeld, who also heads a group at FGAN described below. Research at the institute includes a study of mutual coupling of conformal arrays. Of particular interest is an "earth radar" that was being developed for studying and radar imaging below-the-surface structures. The intended application is for surveys on the island of Santorin, north of Crete, where an ancient culture is buried under volcanic ash and debris. The radar pulse is envisaged as a 1 μs wide Δ function (a dc pulse).

Technical University of Munich: The High Frequency Institute of the Technical University of Munich has been active in researching and developing electronically small antennas. Some of the work had been pioneered by the director, Prof. H.H. Meinke, who found ways of improving the match of very small antennas by incorporating transistors. After Meinke retired, the group continued under the leadership of Prof. F. Landstorfer and now includes investigations of reflector shapes for antenna sizes up to 2 or 3 wavelengths in diameter. A small antenna array, particularly useful for TV reception, was developed, with wires shaped in the form of a tulip, hence its name, "tulip antenna." It has a gain of about 11 db and is easily fabricated.

FGAN: One of FGAN's research institutes, FFN, which deals with electronics and mathematics, is in Wachtberg-Werthoven near Bonn. Dr. W.D. Wirth started an S-band phased array radar program (ELRA) at FFN in 1971. The radar has separate transmitting and receiving apertures, both of which are "thinned," i.e., the aperture is sparsely filled with pseudo-randomly distributed radiating elements. This provides a cheap array, but the antenna gain is reduced and sidelobes are correspondingly high. The 200 elements in the receiving aperture were to be increased to 800 in 1980. Five simultaneous, independent beams were also to be instrumented. Beam forming was at IF. The transmitter uses a triode power amplifier at each element, preceded by a three-bit PIN-diode phaseshifter. Calibration is carried out frequently during operation by reference to the signal from a transmitting radiator in close proximity. The near-field phase curvature from that probe is calculated and taken into account.

An experimental 3-D volume phase array was investigated. It contained 39 radiators placed pseudo randomly within a sphere. Beam forming could be carried in all directions without "scanning loss." To avoid interference, the radiators were in the form of horizontal loops and were fed from vertical transmission lines.

Also at Wachtberg-Werthoven, von Winterfeld is in charge of antennas and scattering at the Institute for High Frequency Physics (FHP). He is doing research on mutual coupling effects of conformal arrays. Mr. K.W. Hofman is responsible for operating a large (34 m) trainable Cassegrainian reflector. The antenna is built with considerable precision and can be used to 36 GHz, where it gives a beamwidth of 1 minute of arc. Ing. Gniss and Ing. Magura use mm wave (36-GHz) radars in a target recognition study. Another group at the institute studies mm wave propagation through rain.

Siemens A.G.: Siemens A.G., which employs over 300,000 people, is one of the world's largest electrical engineering companies; it had sales of $15 billion in 1977-78. The Munich plant employs some 20,000 people; it has an antenna

design and development group under Mr. Anton Brunner. Phased-array work, under Mr. Reinhart Brawdow, started with a 256-element S-band lens using 3-bit diode phaseshifters. A 2,580-element system was later designed, and a half-size (1,290 elements) prototype was expected to be available by the end of 1981. Other work at Siemens includes large reflector antennas for satellite-related applications. Overall efficiencies of 75 to 80% were claimed with a two-mirror subreflector system. Special attention was given to polarization purity. A whole family of radar antennas was designed and produced for all frequencies of interest.

AEG Telefunken: Second in Germany only to Siemens A.G., AEG Telefunken has sales of about $7 billion annually and employs over 150,000 people. Radar and antenna development is carried out by 10,000 employees in a plant at Ulm, near Munich, where the systems engineering department is under Dip. Ing. Werner Gerlitzki. It has developed a 3-D C-band mobile phased-array radar, TRMS (Telefunken Radar Mobile Search), with electronic scanning in the vertical plane and rotation in the horizontal plane. The antenna, from Hughes Aircraft, permits a choice of polarization, including circular polarization for rain rejection. Future developments may go to S-band with solid-state modules. Telefunken has developed a sea-clutter-resistant coastal- and harbor-control radar for shipping. High resolution is obtained with a slotted line array giving a horizontal beamwidth of 0.35° with pulses that can be as short as 100 nsec (50 ft). Sea-clutter rejection is obtained with frequency and polarization diversity.

A radar-controlled mine-sweeping system, TROIKA, with three shock resistant unmanned minesweepers commanded from a lead boat, has been fully developed. The coastal-radar high-resolution antenna is used to provide accurate navigational inputs.

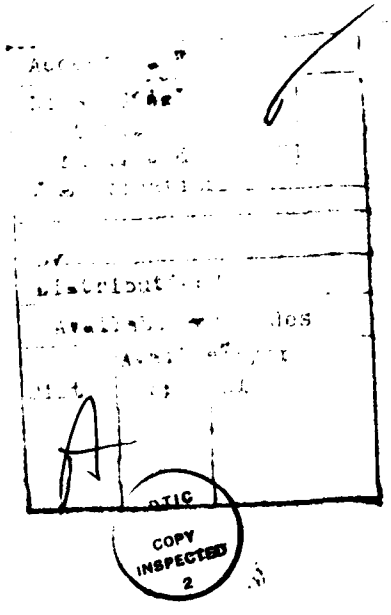
YUGOSLAVIA

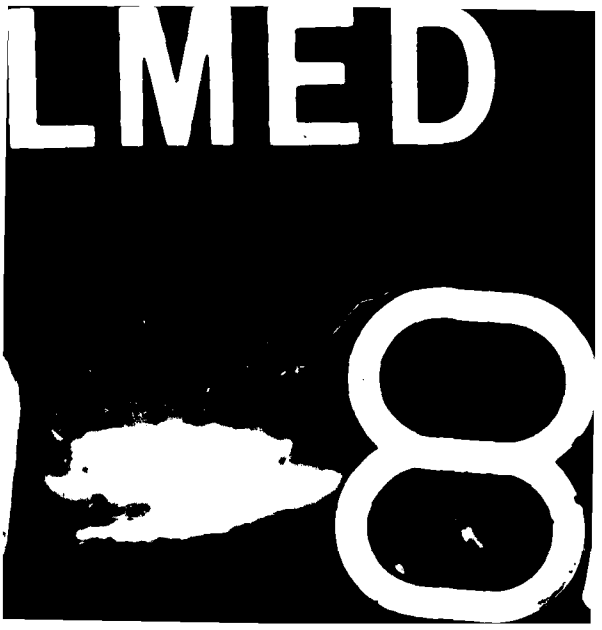
University of Belgrade: The university is in the capital of Yugoslavia where Serbo-Croatian is spoken and Cyrillic script is used. It has about 60,000 students, of whom approximately 2,000 are in the Electrical Engineering Department. The department has a strong and active antenna group led by Prof. Branco Popovic, who has taught at the Virginia Polytechnic Institute. The work of his group is mainly theoretical; few laboratory facilities are available. Detailed analyses have been made of electrically small cylindrical radiators, and very wide bandwidths (3:1 in frequency) have been obtained with dielectrically loaded dipoles. In another application, cylindrical resistive material was used to produce a 2-octave bandwidth device over which the impedance match was better than 1.3:1, with an efficiency of 80%. The radiator was ½ wavelength long at the lowest frequency. Another 2-octave radiator, developed for aircraft, was comblike, trapezoidal in shape, and had a directivity of about 6 dB. For experimental verification of the work, the team frequently uses the laboratory of the University of Ljubljana.

University of Ljubljana: Ljubljana is in the northern part of Yugoslavia, where Slovenian is spoken. The university has some 11,000 students; about 10% are in the Electrical Engineering Department. The dean of the department, Dr. Josko Budin, is primarily interested in antennas. He came to the university from the state-owned Iskra Company, which is the largest general electric manufacturing company in the country, and has maintained many ties, for example,

the university and Iskra share a laboratory. Here, as the University of Belgrade, there is much interest in wideband antennas; the group has achieved a 3:1 bandwidth with corrugated horns. The devices give equal E and H patterns and are used to give very pure circular polarization. A number of such horns stacked in a circle could be used as receivers for detecting and locating radars.

The department has a renowed group, under Prof. Alosz Kralj, working on biomedical engineering and industrial robotniks. The group has a cooperative relationship with the University of Southern California and has been involved in the electric stimulation of muscles since the early 1960s. It has achieved remarkable success. Electronic stimulation can be used therapeutically to help patients who are paralyzed through brain or spinal cord damage and cannot move about. It can also help patients to regain control over certain bodily functions. Other stimulation can bring control to a paralyzed hand, enabling it, for example, to grip a glass firmly.

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