Microwave Education in Belgium

André Vander Vorst, *Fellow, IEEE*

Abstract—**Belgium is a small country, with 10 million inhabitants in a 30 000 km^2 area. Engineering education is provided by 7 universities and a military school on a 5-year program, as well as by a limited number of schools on a 4-year program. This paper describes microwave education within the universities. It emphasizes the link between research and education, showing similarities and differences among the various centers of education. Specific microwave design expertise, capabilities, and facilities are described.**

I. Introduction

BELGIUM is a small country, with about 10 million inhabitants residing in an area of about 30 000 km^2. It has been occupied during a number of occasions, throughout the centuries, due to its specific location in Europe—it is almost exactly across the border between the German world and the Latin world, which has induced (and still does) a rather permanent turbulence within the country. It has two main languages, almost equally split: a Latin one (French) and a Germanic one (Dutch); actual German, spoken in a small part of the country, is also an official language.

Belgium, with a population of merchants, has an extremely old tradition of transnationality. Large cities in Belgium built up their prosperity by buying and selling goods all over Europe in the Middle Ages. Later, the range of trade extended to the Middle East, the Far East, Africa, and South America. Many Belgians settle abroad. Many travel a lot. Moving a short distance from Brussels—less than 200 km—brings the traveler into the four neighboring countries: France, the United Kingdom, The Netherlands, and Germany, each with its own language (French, English, Dutch, and German). So, many educated people in Belgium speak, or at least understand, 3 or 4 languages (the author of this paper came out of high school with French, Latin, Greek, Dutch, English, and German).

More recently, the transnational character of Belgium received even more emphasis because of the continuous trend in the country toward union and unification with other countries. Very shortly after World War II, an economic and monetary union was established between Belgium and Luxembourg. A little later, there was a union between the three neighboring countries of Belgium, The Netherlands, and Luxembourg—the Benelux—with a present total population of about 24 million people, and with three different languages. At that time, already, a number of Belgians of high international stature were working very actively toward the unification of Europe, at the political level, of course, but also at the economic and social levels. The unification of Europe is following a road which has been paved by a series of partial agreements: on coal and steel, on nuclear engineering and power, on space research and technology, etc. Then came the Common Market, which shares its seat in Brussels with the present European Commission, as well as with other entities. So, Belgium is used to being "not just a small country."

What is less well known, while more directly related to the subject of this paper, is the place that Belgium has taken in the development of radio communications. Early in this century, the King of Belgium, Leopold II, who had acquired in Africa what is now Zaïre, was made aware of the experiments by Marconi, whom he invited to his palace for a demonstration (the place where it was held is still visible). Then, experiments were also held by Marconi in the Congo. They were quite convincing, and the decision was made to install a 2500-km-long telegraphic communication link along the river Congo, with stations separated by 250–500 km. One is totally amazed to learn that the order, which was placed in 1910, was followed by the design and development of the system, the transportation of the equipment by ship from Belgium to Africa, the transportation on shoulders along the river, and the local installation in a not-too-civilized environment, and that the system was operational two years later, in 1912, involving 5-kW transmitters.

The interest of the Royal Family in the field of radio communications is also demonstrated by the fact that the first concert to be radioed in the world came from the Royal Palace in Belgium, at the initiative of Queen Elizabeth—the founder of the famous contest—in 1913. This induced in Belgium the formation of a "wireless" international union, which became the URSI, with its seat and its secretary-general still in the country.

Specific engineering degrees have been granted by Belgian universities since about 1860. University education operates within a legal framework which goes back to 1929.

Schools of engineering are within complete universities. One advantage is that the engineering students can educate themselves in a humanistic environment. One disadvantage is that the schools of engineering have to live with constraints on programs and budgets which may not be centered on engineering points of view.

In Belgium, it is also possible to obtain an engineering degree through a 4-year curriculum, in a limited number of schools, different from the universities. The degree is called *industrial engineer* . The program is a rather broad one, and is appreciated by national and international industry. It is geared toward the education of practicing engineers, while the university engineering programs practice, to some extent, "education through research."

Manuscript received May 26, 1992; revised October 5, 1992.
The author is with Microwaves UCL, Bâtiment Maxwell, B-1348 Louvain-la-Neuve, Belgium.
IEEE Log Number 9208350.

II. General Description

There are seven schools of engineering in Belgium—they are called *Faculties of Applied Sciences*—while the Royal Military Academy also offers an engineering program (which is not covered in this paper). They are not very large—only about 1500–2000 students per school. The Electrical Engineering Departments are not very large either—there are about 60–100 students per year in the curriculum.

The Belgian universities have a compulsory 5-year program, leading to the degree of *engineer*. Hence, the comparison to the U.S. and some other countries is not direct. The Belgian program is not a 4-year bachelor's degree. The 5th year of education within this program is not identical in its structure to a pure master's degree—it is a full 5-year program of engineering education. Good Belgian students have entered (and still enter) directly, with no difficulties, into a Ph.D. program in a good foreign school; and good students from abroad with a B.Sc. degree may benefit from courses offered in the Belgian 5th-year program.

The Belgian legal framework defines engineering education within the universities as a "2+3" curriculum. To enter into a university engineering school, the student has—according to the law—to successfully pass an *entrance examination*. For most students, it is limited to the program of high school mathematics. In Belgium, it is, however, legally possible for a student who never went to any school in his or her whole life—which is rather extreme case—to enter into a university engineering school. However, the student has to successfully pass a "complete" entrance examination which, besides mathematics, also covers a first language, second language, history, geography, physics, etc. This is the case for a few students every year. Being legal, the entrance examination implies that a student may pass the examination in one university, of his or her own choice, and have the right to enter into any school of engineering in the country, again by choice. This happens regularly.

The first two years are essentially devoted to basic sciences, with a trend toward "applicability": physics, mathematics, chemistry, computer use, and some introduction to humanistics. The curriculum is common to all the departments, regardless of the future choice of the student (except, however, for the engineers in architecture, who have a quite different program). When successfully completed, a degree of *candidate* is obtained. This degree is essentially a "pass" toward higher education, although, when the author was a student, the degree was one of those with which one could head a railroad station. This always brought up quite a rewarding feeling. The degree of "candidate" is legal, which implies that the student has the right to enter another engineering school after the first two years, with almost no formalities.

When entering the third year of study, and for the last three years of his or her curriculum, the student chooses a Department, for instance, Electrical Engineering. Throughout these last three years, however, the student still has some courses on nonelectrical subjects, like thermodynamics, mechanical engineering, industrial law, etc. During the fifth and last year of study, the student works out an engineer's thesis which is equivalent, depending on the school, to a load varying from 1/4 or 1/2 of the annual load. In most cases, the subject is related to Ph.D. theses, and the student cooperates with a Ph.D. student, who also offers advice and some supervision. This system is quite satisfactory for both.

Belgium has a legal framework for the organization of engineering studies, with the right for the student to pass the entrance examination in one school and enter in another one, or to change schools after his or her first two years of engineering education. All the Deans of Engineering meet regularly. Belgium is a small country where everybody knows everybody. Hence, the general structure of *basic* education within the Electrical Engineering departments is essentially the same, regardless of the university. For instance, in every Belgian university, one will find rather good basic courses on electromagnetic theory, on transmission lines, as well as a first course on radio, or HF, or microwaves. The differences appear at a more advanced level, where education depends more on specific research themes and local expertise, which is the case for microwaves. The transnational tradition of Belgium has induced a number of student exchanges, even before they have obtained their engineer's degree.

One problem is common—funding! Microwaves is an expensive field, and universities in Belgium do not offer adequate funding, even for purely educational expenses. So, funding has to be obtained from other sources. Sources are available on a rather competitive basis: the National Fund for Scientific Research, the Services for Programming Scientific Policy, the Institute for Research in Industry and Agriculture, regional funds, administrations, European contracts, international agreements, bilateral contracts with specific companies not necessarily national, etc. As a result, a research staff financed by a university is, if successful, generating a total staff which may be 3 or 4 times larger. Most of the good research teams within Belgian universities are some sort of a small or medium enterprise, with the permanent difficulty of creating and maintaining research permanence and research jobs.

III. Specific Description

In all seven Belgian universities, the student will find good basic courses on electromagnetic theory, transmission lines, and on basics in radio, HF techniques, or microwaves. The seven universities have, of course, developed expertise in specific areas in the general field of communications. Four of them have specific programs in microwaves. In the other three, the groups close to microwaves—optics, communications, and microelectronics—have developed their expertise in other areas: the University of Brussels (*Université Libre de Bruxelles*) has put the accent on microelectronics applied to communications, with some specific microwave activity on noise characterization and measurements; the University of Liège (*Université de Liège*) has developed more theoretical aspects of communications and modulation systems, including spatial communications; while the School of Engineering of Mons (*Faculté Polytechnique de Mons*) mainly concentrates on optical fiber communications with, for instance, a specific course on optical communications. This illustrates the fact that, because of the small size of the country and the proximity of all the research teams, which induces friendship among the leaders of those groups, "internal" competition is quite naturally absent, particularly to avoid duplication of costly experimental facilities. In what follows, the reader will find information on the four specific microwave programs, with the accent on the link between education and research.

University of Brussels (Vrije Universiteit Brussel—VUB, Prof. A. Barel)

The main research activity of the EE Department of VUB is the development of new measurement techniques using advanced signal processing methods and tools. The long-term objective of the department is the realization of its IMMI project (Interpretation by Measuring, Modeling, and Identification). Some other smaller research projects are also carried out in the department. In the research project, measuring is considered to be a complex process consisting of three main steps: the design of an experiment, the definition of a model for the problem, and the estimation of the parameters involved in the model. The IMMI technique is divided into three layers. The first layer consists of the basic measurement techniques, strongly dependent on the application field. It is the implementation of the measurement task of an instrument. The second layer consists of the identification tools, with links between measurement and information technology. The third layer consists of the interpretation of the measurement results by using a knowledge-based system. In the project, the goal is to incorporate a large amount of fragmentary and heuristic knowledge to solve the difficulties automatically, to accommodate new knowledge as it evolves, and to use knowledge to give a meaningful explanations of the observed behavior.

The team interested in microwaves is in the group called Electromagnetism, Microwaves, and Optical Fibers. Its main point of view is to assist microwave engineering by a large amount of computer-aided simulation and design systems. In hyperthermia, they produced a method for the automatic acquisition of SAR patterns of applicators; the SAR is determined by processing adequately the time impulse response of the temperature measured in a glass bulb scanned through a liquid phantom above the applicator. RF-coils are designed for special applications, in particular, for nuclear magnetic resonance and imaging, spectroscopy; a study is in progress which takes into account the interaction of the antenna with its load, the biological tissue, modeled by a stratified medium including 2 or 3 embedded lossy layers. Measurement set ups are being developed for measuring the dispersion and the attenuation of superconducting microstrips over the range 45 MHz–26 GHz. The department offers a course on HF, UHF and microwave techniques.

University of Ghent (Universiteit Gent—RUG, Prof. D. De Zutter)

At RUG, the team involved in microwave research is a group of about 20 people. It is a part of a large entity, the Laboratory for Electromagnetism and Acoustics (LEA), which has a total staff of about 90 percent. The engineering program at RUG has a strong emphasis on electromagnetic theory, due largely to the fact that the LEA was founded by Prof. J. Van Bladel, who has a long-time international reputation. A strong basic course on Principles of Electromagnetic and Acoustic Wave Theory is mandatory for the electrical engineering degree which provides training in numerically solving EM problems (integral equation, finite difference time domain, and finite element methods) together with training in the design of HF circuits.

The main activity of the microwave team is the modeling and characterization of high-speed and high-frequency analog active and passive devices for communication applications. The modeling activity covers the quasi-static and full-wave modeling of various kinds of waveguides ranging from metallic to fully optical ones, in each case embedded in a planar stratified medium. It also covers open planar microwave circuits embedded in a multilayered structure. A planar structure simulator including microstrips, striplines, and slotlines, together with via-holes between the different metallization layers, is being developed, where a mixed potential integral equation is solved using the method of moments combined with Galerkin's procedure. Also, the group is active in the modeling of multiconductor waveguides and devices, and a lot of effort has been spent in the modeling of dispersive waveguide structures with nonlinear loads and drivers. The group specializes in complex measurements problems for boards, connectors, and packages using an in-house-designed board probing station.

It should be mentioned that the group has acquired an international reputation for its work in hyperthermia, which started quite a while ago. It led to medical applications and to instrumentation. Quite recently, a four-channel hyperthermia system has been inaugurated at the hospital of the university, at 433 MHz. A substantial effort has been put in the noninvasive measurement of temperature distributions, resulting in the possibility of measuring temperature maps with a thermal resolution better than 1°C and a spatial resolution better than 3 mm. Recently, the research has been extended to the field of biological effects of electromagnetic fields, by calculating the internal em field due to a typical dipole antenna, radiating near the head of a mobile radio operator.

The LEA of RUG has a rather unique "LEA design" team of about 10 engineers, which is a professionally equipped laboratory where 5th-year engineering students, PhD. students, as well as people from industry can be trained in the design and prototype development of high-speed electronic, microwave, and optoelectronic systems. It covers a complete design task, from the study of the problem, the system concept, and the development of an industrially acceptable prototype or demonstrator set up. The facility includes a faradized room for precision high-frequency measurements, a clean room for monomode fiber and naked chip handling, and the possibility of handling semiconductor lasers and submicron technology chips. Microwave equipment goes up to 26 GHz.

University of Louvain (Katholieke Universiteit Leuven—KUL, Prof. A. Van de Capelle)

The curriculum offered by KUL has, in the third year of study, a compulsory course on electromagnetic wave propagation and microwaves for all students registered in Electronics. It is completed with some introductory training on a software package modeling transmission lines and planar microwave circuits. Those students who choose communications as an elective field are submitted to further microwave education, which is centered on design capabilities, in a course entitled "Components for Telecommunication Systems: Microwave Techniques, and CAD Techniques for Antennas and Microwave Circuits." Time is available for a design project, consisting of the design, optimization, layout, realization, and testing of a passive or active microwave circuit with given specifications. The evaluation by a team of four teachers replaces the classical examination.

Microwave research is developed within a group devoted to telecommunications and microwaves. KUL is well known for its work on the analysis and design of microstrip antennas (single elements, arrays, dual patch antennas, and backfire antennas). It first developed the transmission line model, with very fast computing, then a second model based on the mixed potential integral equations, with a better accuracy at the expense of computing time. Software for antennas with multiple dielectric layers and multiple layers of patches is now available, also yielding the analysis of arrays. Fast near-field measurement techniques for the radiation pattern are investigated. A small linear phase-steered array and a 7-element pyramidal antenna with switched elements has been developed, and broadbanding of passive microstrip antennas is being investigated.

The expertise acquired at KUL in the field of antennas can readily be seen when looking at the available equipment. Sophisticated antenna measurements can indeed be made (up to 26 GHz) using two anechoic chambers.

Microwave activities are also related to elements other than antennas. The study of MMIC's with HEMT's is a new field of research in the group, focusing on modeling and design, with initial accomplishments on the passive elements. Work is also progressing on high-Tc superconducting microstrip resonators and filters. The first target is to develop several types of microstrip resonators—rectangular, S-shaped, and circular—and to establish a model for superconducting microstrip lines. Then, various types of filters will be designed and tested using a cascade of resonators. There are also microwave system studies, related to secondary surveillance radar, as well as global positioning. This is done in cooperation with the Royal Military Academy.

University of Louvain-la-Neuve (Université Catholique de Louvain—UCL, Prof. A. Vander Vorst)

In the third year of study at UCL, a course on electromagnetics and a course on transmission lines are compulsory for all EE students. Courses on microwaves, and on the design of microwave active circuits, as well as a seminar on telecommunications and microwaves, are optional in the fourth and fifth years of study, respectively. The engineer's thesis is equivalent to a half-time throughout the year: the student is forbidden to take more than half a load of courses.

Teaching and education are influenced by the fact that UCL has a long tradition in microwave research: the Microwaves Laboratory started its activities around 1965. This contributed to assembling a rather wide experimental microwave facility, which is used by the students. It extends into the millimeter range: a vector analyzer is available up to 110 GHz. Atmospheric phenomena have been modeled at frequencies up to 300 GHz. Three themes are investigated: circuits (passive and active), atmospheric transmission, and bioelectromagnetics. Ph.D.'s as well as engineer's theses are developed in the three areas. In general, they have a strong experimental basis. The Laboratory is a group of about 20 people.

In the field of microwave circuits, UCL has a facility for measuring the performances of circuits up to 110 GHZ, a homemade facility to make its own circuits up to 40 GHz, a homemade software for synthesizing passive circuits up to 40 GHz, and an optimization software for active circuits. A student can design his or her circuit, have it laid out on Rubylith by a cutter placed on a plotter, and get the actual circuit in a few days, so that he or she can start measurements and check the performances with respect to the specifications. Linked with the microwaves course, there is a miniproject on the design of a passive microstrip circuit, followed by the realization of the circuit, the measurement, and the evaluation of the results. Associated with the course on the design of active circuit, there is also a project which is similar but more ambitious. This offers to the student a practical training, in real life, which associates him or her with the research developed in the Laboratory. The activity, indeed, is in developing and evaluating models at centimeter and millimeter wavelength, on microstrip, slot line, coplanar waveguide, and fin line, with a main tendency to widebanding. Lines and transitions between various sorts of lines, as well as amplifiers, oscillators, and mixers, are modeled and tested. Multilayer planar structures, including anisotropic layers, are also modeled, not only for microstrips. The theory on which the work is based combines variational principles, spectral analysis, and conformal mapping. Research has started recently on multi-GHz lightwave communication systems, with the emphasis on ultrawideband devices and systems.

In the field of atmospheric transmission, the Laboratory has been the Belgian participant to the Orbital Test Satellite project of the European Space Agency in the years 1978–1983, and is now the participant to the Olympus project, at 12.5, 20, and 30 GHz. It operates two earth stations, at the PTT and at UCL, elaborating statistics, and also analyzing and modeling rapid atmospheric phenomena. The main tendencies are to investigate at millimeter wavelength, up to 100 GHz, especially on scintillation, and on depolarization by ice crystals. The model developed for scintillation, based on dielectric inhomogeneity of the turbulent atmosphere, is presently tested by Ph.D. students and engineering students to evaluate the impact of the turbulent atmosphere on actual communication links, to yield bit error rates. Diffraction studies are also going on to evaluate interferences between horizontal links and slant paths due to knifes and screens between 1 and 100 GHz.

Students are also involved in research on microwave bioelectromagnetics. The main interest is in the study of the transmission between the peripheral and the central nervous system, and how it is affected by electomagnetic fields. The research is mainly experimental. The peripheral nervous system is excited by injecting microwaves at 2.45 GHz into acupuncture points. Reproducible and quantitative results of pharmacological and electrical changes in the brain are obtained. Students interested in that area take an optional course on physiology at the university.

IV. Conclusions

The Belgian system of microwave education has some specificities. Engineering education in all the universities is based on a rather strong 2-year program, devoted to basic science. Then, in the EE departments, the student is submitted to good basic courses on electromagnetic theory, transmission lines, and propagation for another 3-year period. After that, the student has quite a bit of freedom in selecting either optional courses (for instance, in microwaves) or a subdegree within EE (for instance, on communications). The number of different microwave courses within a given university is not very large. The specific topics are influenced by the nature of the research in which expertise has been developed in each specific university. Part of the freedom of the student is in the selection of the laboratory where he or she will work out the engineer's thesis, which is a significant part—both qualitatively and quantitatively—of the curriculum and education he or she is gaining. In most cases, this associates him or her with Ph.D. students or research engineers, and hence with scientific and technical research or with real-life microwave engineering. The microwave education programs are strongly based on design and testing training.

Acknowledgment

The author is very grateful to his colleagues from the various universities, who gave him adequate and precise information in a very short period of time—Prof. A. Barel (VUB), Prof. M. Blondel (FPM's), Prof. D. De Zutter (RUG), Prof. A. Van de Capelle (KUL), and Prof. J. L. Van Eck (ULB). Their cooperation was essential in writing this paper.

André Vander Vorst, photograph and biography not available at the time of publication.