An Interdisciplinary Masters Program in Microwave Communication Focused on Innovation

(Attracting and developing students' talent in challenging times)

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***Abstract* — An interdisciplinary format of a masters program in microwave communication has been designed and applied as a combination of engineering physics and innovation management training, taking into account latest research on worldwide requirements of business leaders. In addition, students are guided into strategic mentoring relations with academic staff and company managers for development of cutting edge talent.**

Keywords: M.Sc. degree education; curriculum development; microwave; innovation management

I. INTRODUCTION

Higher education in the area of microwaves: wave propagation, RF components and devices, antennas, wireless communication, etc. is among the most sophisticated and costly educational processes for many reasons. First of all, electromagnetic modeling of microwave structures is based on pure circuit approximation as well as on pure wave approximation, combined to a specific extent in each particular case (see for example well-known books in this area – [1, 3]. Therefore, students have to acquire sound knowledge both in the areas of electronics and electrodynamics. In addition, practice-orientated education in microwave physics and technology requires well-selected measurement equipment, components and devices, which are generally expensive and not easy to operate with. Moreover, modern RF design is based on utilization of circuit and structural (2-D and 3-D) electrodynamics simulators, which needs additional efforts for provision (licenses, upgrading) and training (computer classes, student seminars). Incessant development of research and modernization of key facilities, technical solutions and applied approximations in the microwave range also urges lecturers to continuously upgrade their own knowledge and skills.

All the above challenges are present worldwide. Along these lines, the aim of the present paper is to share our experience in organization, curriculum development and practical realization of a masters program in microwave communication that is focused on innovation [4]. The program has a wide enough but well-balanced profile, including three interconnected axes: 1) networks, software, channels; 2) devices, systems, signals and 3) networks and innovation management. This program has achieved continuous growth over the last eight years. Its attractiveness to high-scoring students has been significantly enhanced by convincing incorporation of training on the basics of personal and team management towards systematic search for, design and introduction of innovations. Corresponding studies include methods for overcoming inertia of thinking as well as generation, analysis and selection of new ideas. Overall approaches to achievement of high internal motivation and effective interpersonal communication are provided in the context of innovation processes.

II. M.SC.-DEGREE PROGRAM WITH WIDE EDUCATIONAL PROFILE IN THE AREA OF MICROWAVE COMMUNICATIONS, NETWORKS AND DEVICES

A. Structure of the M.Sc. Program

The schematic structure of the M.Sc. program is presented in Figure 1. The 1.5-year education is divided into 3 stages – introduction (1 month), education in 5 modules (1 year) and final practice, individual tasks and Master thesis (1/2 year). The introductory courses (Introduction to Wireless Communication [5], Applied Electrodynamics for M.Sc. Students and Modern Physics for Engineers) are essential for the launch of the education process. Students usually come from different higher education institutions and therefore have received different B.Sc. specialties and levels of training. A main goal of these courses is to align preliminary student knowledge in the area of physics, electrodynamics, technology and communications before starting the next stage of core professional education. It includes 7 compulsory and 7 elective courses (from 13 courses) distributed in 5 modules. These modules virtually reflect the necessary balance between the most important and inter-dependent directions (in our opinion) of practice-oriented education in wireless communication: signals, channels, networks, software tools, communication devises and systems. One or two compulsory courses in a given module present the main concepts, ideas, basis and applications. The other elective courses (usually with state-of-the-art upgrade within 3-5 year intervals) provide additional knowledge and experience in the corresponding module (see the presented course titles in Figure

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1). Single courses/lectures (delivered by leading specialists on single occasions) on particular communication topics are also planned (for examples – Air Force Meteorology Data Networks; Metamaterial Antennas, Telemedicine Networks, etc.). The final stage of student education is trainee practice (in companies and/or university labs), work on an individual task and a final project – Master thesis (usually connected with the individual task). The presented M.Sc. program structure is optimized for 15-25 students per year. Our experience has shown that students easily accept this structure, do not lose their interest during the whole period of education and continuously update their professional orientation after each taken course.

B. Special Aspects of the Education Process

Let us consider some specific aspects of the education process in the presented M.Sc. program. First of all, the big number of the elective courses can not be delivered by lecturers from a single department. They usually cover most of the compulsory and some of the elective courses. In spite of being the host of the M.Sc. program, the Faculty in Physics of Sofia University "St. Kliment Ohridski" employs lecturers from other faculties and higher education institutions and (which is crucially important for the actual education process) – leading specialists directly from cooperating companies. Thus, the lecturers' team is quite interdisciplinary and is capable of providing the necessary theoretical basis, additional practical skills as well as access to state-of-the-art information and technology. All courses presented in Figure 1 are combined with laboratory and/or computer exercises, textbooks and manuals of specifically developed structure for individual work. This is important prerequisite for inclusion of a course into the curriculum. The courses happen in a sequence of preliminary chosen pairs. This allows students to be more focused and achieve higher final scores.

C. Cooperation with Business Organizations

Lecturers' long-term experience and their observations on graduated masters' professional realization have shaped the following extended framework for cooperation with business organizations as future employers which goes beyond established patterns.

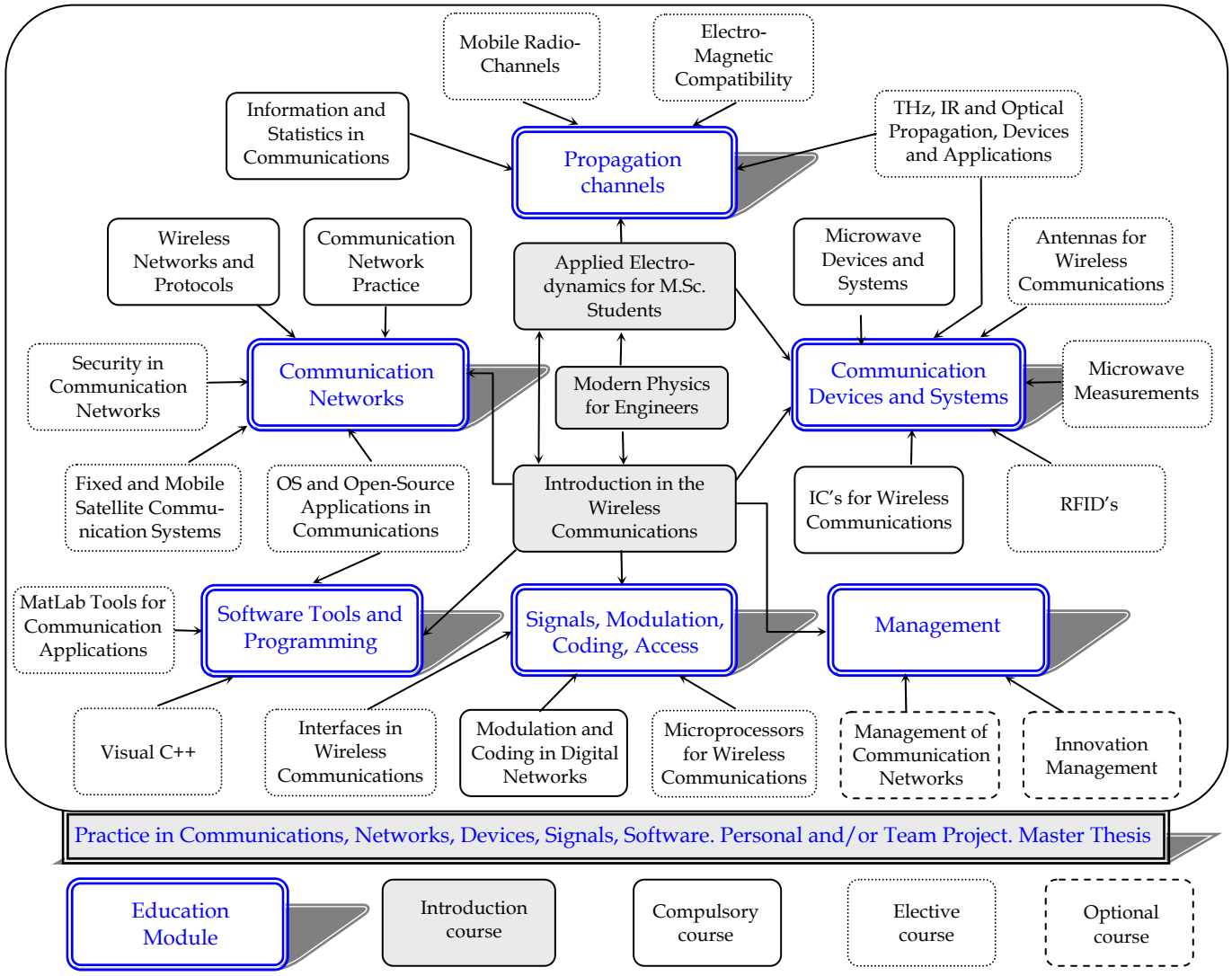

Figure 1. Schematic structure of the MSc program: education modules, courses and relations between them

First of all, permanent exchange of information takes place between academic staff and companies on the one hand about students with particular interests and skills and, on the other hand, about needs for professionals with special qualification in a certain innovative area. Alongside with this, applying modern human resources management methodology, suitable candidates are directed towards initial contacts with corresponding companies. Facilitation is also provided on reaching mutual agreements about future professional realization. Furthermore, students' specialization is customized according to company requirements through selection of adequate academic curriculum and provision of specialized practical training in work environment arranged as (non) paid training or part-time employment ("on-the-job training").

A key success factor for future professionals in the above process is to get acquainted with and subsequently internalize the corresponding corporate culture. Although this is usually understood as feasible only after starting full-time employment, our observations have shown that, if it happens beforehand then choice of employment is more motivated and loyalty is higher.

Especially when innovative companies are concerned, by maintaining constant informal interaction with lecturers and future managers, students are guided into a strategic mentoring format for development of cutting-edge professional skills. It will be shown in the next section that such skills are not necessarily connected with high degrees of technical knowledge and experience.

Let us give an example of a successful advanced educational initiative between a business company and an academic institution. A small high-tech antenna company in Bulgaria (< 70 employees) permanently needs 1-3 specialists per year with relatively full basic knowledge in the area of modern antenna and RF design, microwave measurements, system design, satellite communications, etc. Unfortunately, young people with such a wide field of knowledge graduating from ordinary B.Sc. and M.Sc. university programs are not easy to find and the company under consideration has big difficulties to employ new specialists and experiences a high rate of attrition among them to other companies with narrower areas of necessary knowledge and skills. To cope with this state of affairs, the company delivers every year in the academic institution a 1-year Post-graduate Advanced Microwave Educational Program parallel to the corresponding M.Sc. program with topics close to the company profile (some of them included in a M.Sc. curriculum as elective courses). Starting with approximately 20 students and finishing with ~8-12 students after intermediate selection, company management can eventually choose 1-2 well-trained future employees (5-10 % from the total number of trained students). These young employees are typically very loyal to the company and none of them has quit. The benefit for the rest of the graduate students is the possibility to find good jobs in other companies. This form of company-supported education is rather effective, especially when it is combined with the described M.Sc. program. It has been functioning since 2001 and more than 100 students have been trained so far.

III. Innovation Management

As a latest stage in the program development, a course in innovation management was introduced in 2009. It was designed according to the results of the worldwide survey [6] on talent strategies for innovation. Fig. 2 shows the ascertained key skills for innovation where creativity and ability to collaborate appear to be the most important. They are immediately followed by the ability to learn quickly, the ability to solve problems and by self-motivation. And all of them are followed by the high degree of technical knowledge. Such a structure of findings is clearly indicative that development of cutting-edge innovation skills should start as early as possible.

Along these lines, our innovation management course starts with an overview of innovation as a key to success in modern science and business. Importance of the human factor is considered in the context of innovation-driven organizational

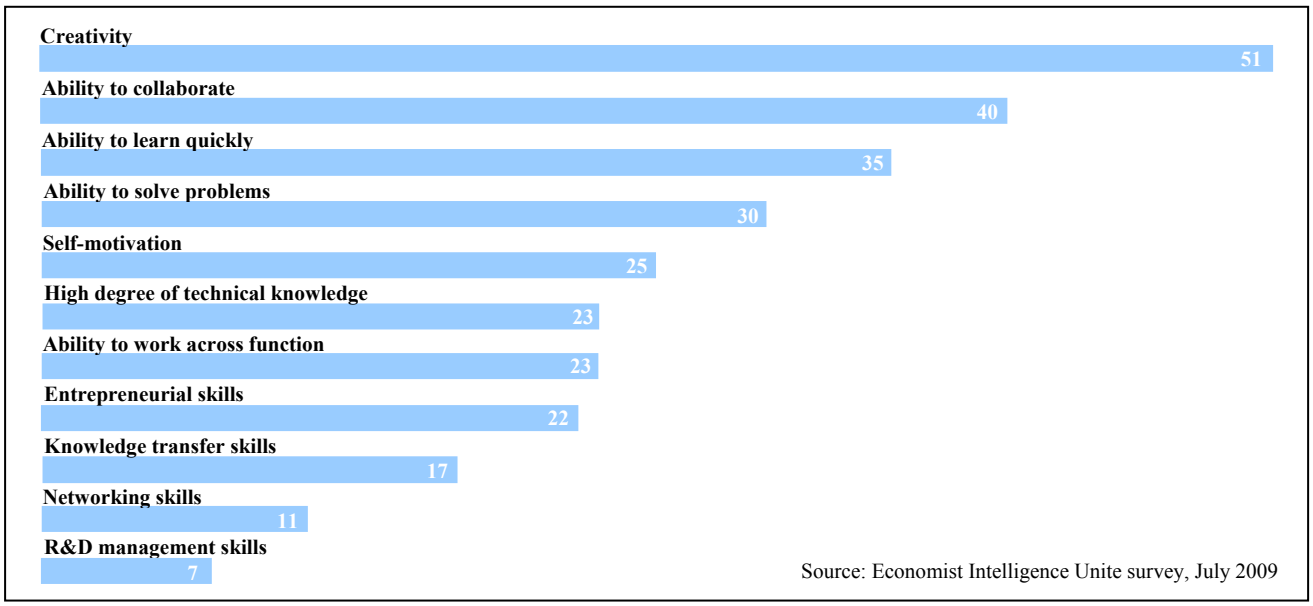

Figure 2. Key skills (in %) for innovation according to [6]

structures. Collaboration and knowledge management are especially highlighted as areas of continuous personal and team development.

This extended introduction is particularly meant to take students out of the box of purely technical thinking and expand their attention towards business-related topics. The course continues with approaches to overcoming barriers to corporate creativity, which appears as prejudice, inertia of thinking, indifference, opposition to change and ineffective communication.

The course continues with a particularly dynamic section about human creative capacities and their enhancement. Linear and non-linear thinking processes are considered as well. A practically all known methods of generation of new ideas are practiced and applied to real problems in combination with effective assessment and selection of feasible solutions.

The concluding topics are connected with basics of teamwork, effective interpersonal and corporate communication (especially presentation of new ideas) as well as motivation management.

IV. Analysis of the M.Sc. Program History

General conclusions about attractiveness to students of the applied content and methodology can be derived from historical analysis of the presented M.Sc. Program "Wireless Networks and Devices" which started in 2002.

Different stages of development according to the number of participating students are shown in Fig. 3. The interval from the start in 2002 to 2005 is generally connected with rapid expansion of mobile networks in Bulgaria.

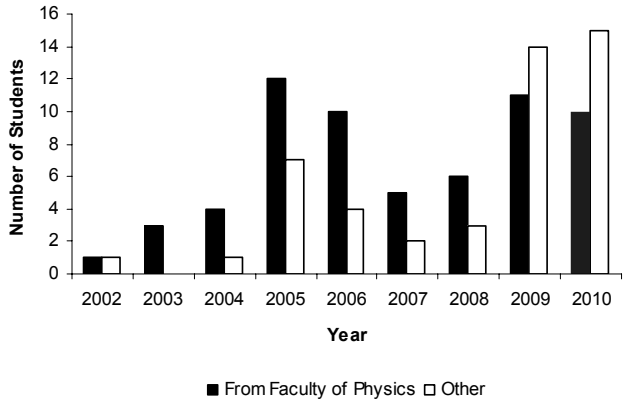

Figure 3. Number of students participating in the program.

Decline from 2005 to 2007 can be attributed to a local social and economic turbulence that happened just before country's accession into the EU. Growth of participation between 2007 and 2009 can be explained with overall positive tendencies due to actual EU membership. Decline in 2010 compared to 2009 is an obvious result of the world financial and economic crisis. This is because the majority of M.Sc. students are employed and it is arranged for them to take their courses after hours. As this country is currently recovering from economic recession, lower student participation numbers can be directly attributed to financial difficulties and/or longer working time.

In general, reasonably excluding the two starting years and focusing on the interval 2004 – 2008, a more or less stable ratio between the numbers of students from the hosting Faculty of Physics and from other higher education institutions is observed even within the considerable "market" fluctuations. Later on, regardless of the crisis effects, the ratio is significantly reversed with a still growing number of other students, which means that the program is already particularly attractive due to its interdisciplinary content and focus on innovation.

V. Conclusion

Interdisciplinary approach to M.Sc. education in microwave communication, incorporating a wide spectrum of modern practical skills in engineering physics and innovation management has proved to be attractive to students regardless of negative social and economic tendencies. It can further be developed along the lines of flexibility and optimization of its components as well as cooperation with business organizations for establishment of life-long personal efficiency and creativity programs. Moreover, similar approaches can be designed and introduced in other areas of academic education that are related to strategic innovation.

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