CAPACITY BUILDING

SPECTRUM MANAGEMENT TRAINING PROGRAMME (SMTP)

Report

Telecommunication Development Sector

Spectrum management training programme

December 2014

The report present the spectrum management training programme prepared by the Human Capacity Building Division within the Projects Support and Knowledge Management Department (PKM) of the International Telecommunication Union (ITU) Telecommunication Development Bureau (BDT). Substantive inputs to the report were provided by Dr Arturas Medeisis.

Please consider the environment before printing this report.

Foreword

I am delighted to present the *Spectrum management training programme report.*

This comprehensive report is the framework for the Spectrum Management Training Programme (SMTP) developed under the ITU Academy. It outlines the study modules of the programme, provides an overview of each module, as well as identifies target audience and course duration and it recommends various combinations and progression paths within the proposed study modules, leading to professional certification.

This document will be important to those who would like to work with ITU in delivery and accreditation of this training product, and establish partner relationships.

This report can be accessed at https://academy.itu.int/component/k2/item/1077-smcp

I hope that you will find this report useful and informative.

Brahima Sanou
Director
Telecommunication Development Bureau

Executive summary

The purpose of this report is to offer a conceptual framework for a comprehensive set of study modules that could make up a spectrum management training programme. Such a programme would be a novel undertaking by ITU with the aim of offering its Members a solid system of staff training in the theory and practice of modern spectrum management (SM).

This report provides a framework for the development of a high-quality SMTP, including educational materials and resources for face-to-face training, active distance learning and self-paced knowledge refreshment. Importantly, the report recommends various combinations and progression paths within the proposed study modules, leading to various levels of professional certification.

Based on an overview of the current situation, the SMTP can successfully create a unique and credible niche, complementing the existing professional SM training options and promoting the harmonization of SM practices. To that end, the SMTP should be broad in scope and international in character, with tutors and participating institutions of the highest quality, in order to ensure the value of the programme and the reputation of its diploma. It should strive to establish itself as the global "gold standard" for SM training. An essential differentiator for SMTP would be formalized assessment of learning outcomes in terms of professional skills and qualifications obtained, supported by the award of a diploma representing a recognized academic level, such as Master of Science.

The following main options may be considered:

- **Option A**: the SMTP becomes an international course offered by a consortium of participating universities under the aegis of the ITU Academy and leading to a Master's degree offered to graduates upon successful completion of the course.
- **Option B**: the SMTP becomes a professional training course organized solely by the ITU Academy, perhaps delivered through ITU training facilities and/or the ITU Academy platform under the aegis of the centres of excellence (CoEs), with the possibility of being driven by ITU staff, ITU-R study group experts and/or ITU-D experts, and with possible cooperation of ITU-R industry partners or CoE partners. Upon completion of the training (which would include passing all assessment tests), trainees would receive a professional "Master of Spectrum Management" certificate awarded in the name of ITU/ITU Academy.
- **Option C**: a combination of Options A and B. That is, the SMTP becomes an international university-level Master's course offered by a consortium of participating universities, but organized in collaboration with ITU-D/ITU-R external experts (lecturing for example on actual case studies) and ITU-R industry partners, especially for practical sessions and laboratory exercises, under the aegis of the ITU Academy. This course would lead to the award of a university Master's degree for successful graduates.
- **Option D**: the SMTP might become a guide for self-study and training through practical experience, in which case ITU and the ITU Academy would develop the training material, offer counselling opportunities for students, and ultimately assume responsibility for the professional examination, i.e. the testing of knowledge and skills to an established standard. For the latter task ITU would need to develop and administer the final assessment tests for each module.

The justification for these different options, and their respective advantages and drawbacks, are described in the report, together with the proposed structure, content and duration of the study modules.

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1 Background and justification

The role of an SMTP in modern spectrum management

Wireless technology now drives the development and diversification of information and communication services for governments, industry and the public. The wireless sector is believed to contribute several per cent of GDP to national economies, and the social impact of new wireless services -- from smart phones and mobile Internet to RFID tags and wireless car keys -- cannot be overstated. However, this rapid evolution of wireless services depends on one crucial asset – the radio spectrum, a limited resource of strategic importance. The judicious apportionment of spectrum and supervision of its efficient use have therefore never been more important than in the dynamic world of today.

However, the traditional and rather well-researched technical aspects of efficient spectrum use are now often overshadowed by economic and legal considerations, as nations grapple with liberalization, globalization and the effects of free trade, not to mention the global economic downturn.

As a result, spectrum management specialists today must possess both specialized technical skills and a clear understanding of the legal and economic issues involved. The tools of the trade are constantly expanding and now encompass anything from traditional electromagnetic compatibility formulas to the theory and practice of real-time spectrum auctions. Such broad and varied professional requirements contrast strongly with the knowledge base of the typical university or technical college graduate. Even graduates who have majored in telecommunications engineering have a limited understanding of real-world spectrum use, not to mention the manner in which it is administered; the need for additional specialized training in SM is obvious. Today the national radio spectrum agencies and major wireless operators in need of professional spectrum managers have no choice but to train new recruits on the job, often simply through the "follow-me" examples of more experienced colleagues. While this approach can work in large organizations with many employees and a wealth of accumulated experience, it still takes a long time to reach the desired level of performance and too often the results reflect an institutionally biased perspective on the issues. In younger and smaller organizations, such as regulatory agencies in many developing countries, opportunities for acquiring the necessary qualifications are limited or non-existent.

Formal academic certification upon successful completion of the course would increase its appeal immensely. If the course were calibrated to a Master's degree level of sophistication, many employers would find it suitable for on-the-job training since most prospective participants will already have an undergraduate degree. To prospective students, employer acceptance of the course would eliminate the need to quit working in order to improve their career prospects. To employers it would offer a clear benchmark reference, simplifying and giving certainty to the process of recruitment while at the same time facilitating the mobility of SM professionals. And if the proposed course were also to have a clear modular structure with associated university credits, at least some of those modules could also be used to complete a bachelor's degree for those employees who do not already have one.

Overview of existing spectrum management study resources and courses

In this section, currently available options for spectrum management (SM) training will be reviewed in order to identify potentially useful existing features that can be combined to design a unique SMTP.

- ITU-R handbooks: ITU-R has developed more than two dozen handbooks[1], some rather general, others quite specialized, including dedicated handbooks prepared with external publishing partners. All these handbooks are valuable sources of theoretical and practical knowledge for spectrum managers. However, they are not substitutes for in-class learning, nor are they necessarily suitable for use as course textbooks, as they were intended to be reference sources better suited for occasionally looking up specific answers, rather than as continuous didactic

[1] www.itu.int/pub/R-HDB. See also section 8: references 1 to 4 and 24.

presentations of material unfamiliar to the students. Nevertheless, the ITU-R handbooks are likely to prove essential in establishing the scope and content of the SMTP, and useful to students in self-paced study.

- Books published outside ITU: The literature of SM is expanding but still limited. The problem with most such books is that, like the ITU-R handbooks, they were not conceived as academic course textbooks but as reference sources for professionals. And while certain older volumes tried to take a holistic view of SM (such as F. Matos' classic or the later book by D. J. Withers), most recent books tend to focus on a specific aspect, such as spectrum markets and economics, national approaches, the introduction of new technologies or specific services.[2].

SM courses

The shortage of professionally-oriented SM courses at academic institutions has led to the emergence of on-the-job training options. The pros and cons of some of these options are considered below.

ITU seminars and centres of excellence (CoEs)

ITU Radiocommunication Bureau (BR) and Telecommunication Development Bureau (BDT), directly or through the regional ITU CoE partners, organize seminars and workshops with the aim of disseminating knowledge of best practices, policies and processes in SM. The most notable examples include radiocommunication seminars and regional development forums. The advantage of such events is that they are usually tailored to the needs and realities of a specific region. There are also benefits in addressing a narrow set of issues regarded as topical at the time, such as the successful planning of analogue/digital switchover in television.

But while such workshops spread SM "know-how" in a timely manner and promote regional discussion of topical challenges, occasional events cannot be a substitute for a comprehensive and formalized programme of training in SM.

Another disadvantage is that such workshops generally do not include any evaluation of the effectiveness of knowledge transfer and retention (even though certificates of participation may be awarded). The mere fact of participation cannot be used to judge the level of professional qualification attained.

Therefore, in order to differentiate the SMTP from existing ITU seminars and workshops and offer significant additional value, the new course must cover a full range of topics and include formal assessment and attainment certification procedures on completion.

United States Telecommunications Training Institute (USTTI)[3]

Founded about 30 years ago, USTTI has become a respected source of professional training in ICT-related fields including SM. USTTI provides instructor-led training in the United States, mainly for citizens of developing countries working in ICT industries and regulatory agencies. Tuition is free, thanks to financial support from the United States Government and to donations of time and expertise, tours of facilities, presentations and other services from industrial and institutional partners. However, except for a few travel grants awarded by USTTI on a competitive basis, students and their sponsoring organizations (if any) must cover the costs of travel and subsistence during the training.

USTTI SM offerings in 2012 consisted of:

- a "radio frequency management" module taught by the National Telecommunications and Information Administration (NTIA) (two weeks);
- a "spectrum management in the civil sector" module taught by the Federal Communications Commission (FCC) and Comsearch (two weeks);

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2 Useful examples are listed in the references section. See especially references 5 to 10.

3 United States Telecommunications Training Institute (USTTI) 2012 course catalogue: www.ustti.org

- a "radio spectrum monitoring and measuring" module taught by FCC and National Instruments (one week);
- a "practical applications of spectrum management and monitoring" module taught by TCI International (one week).

USTTI trainees may sign up for all modules offered in a given track, and for this reason all modules are conveniently scheduled back-to-back to allow one-time travel. Alternatively, students may opt to take one or more modules based on a specific interest, e.g. only spectrum monitoring for employees assigned to that function. It is also possible to combine some or all of the SM modules with modules in other tracks, such as those dealing with the development of various wireless technologies, telecom regulation and management, and so on.

Some strengths of USTTI SM course offerings compared with the envisaged SMTP concept:

- USTTI already has an established reputation for course quality and reliable delivery of professional training;
- the average duration of the courses (around two months), together with the intensity of full-immersion instructor-led classroom teaching, are usually sufficient to convey what is needed for participants to be able to operate in a professional context;
- students can self-tailor their course of study by combining modules from SM and other streams.

However, there are also some drawbacks:

- USTTI tailors its courses to the needs of developing countries, so course content is often skewed towards conveying the basics rather than towards rigorous state-of-the-art knowledge;
- the focus on developing countries also means that students in the classroom will be interacting with their peers from countries at a similar level of development, rather than sharing experiences with colleagues from more developed countries;
- the fact that this institution and nearly all of its tutors are from the United States inevitably biases the curriculum content toward United States-based models, policies and interests;
- the certificates awarded upon completion of the courses are only for participation, not for the attainment of a certain level of knowledge.

In conclusion, in order to complement USTTI offerings, the SMTP should be thoroughly international in its curriculum, course content, faculty and tutoring partners. It should provide advanced, state-of-the-art knowledge and aspire to higher professional levels in serving students from developed and developing countries alike. Its certification should be recognized as the "gold standard" in professional training.

Commercial SM courses:

A small number of advanced SM courses are offered by private companies. One example of this is the Spectrum Master Class offered by InterConnect Communications (ICC) Ltd[4]. The ICC Spectrum Master Class is an instructor-led course lasting one week that aims to offer a complete and well-rounded overview of SM from the basics (such as radio wave propagation and spectrum engineering methods) to the advanced (market allocation methods and modern policy trends), and including overviews of SM problems common to the most widely used radiocommunications services. Tuition is provided in a highly concentrated manner by a team of former SM professionals and experienced consultants in the field.

Advantages: this offering allows newcomers to the field to undergo a quick "crash-course" with a well-rounded "smorgasbord" of essential information. Learning from internationally recognized experts ensures access to some of the best professional know-how.

[4] InterConnect Communications Inc, Spectrum Master Class: www.icc-uk.com/spectrum-master-class.php

However, this offering also has drawbacks compared to the SMTP concept:

- the fee of around GPB 3 000 for one week of classes (including accommodation) is very high and a barrier to many potential students, even if it is affordable for some committed employers and institutions;
- concentrating so much information into such a short time-frame challenges the students' ability to grasp and retain the intricacies of the material presented;
- there is no formal assessment at the end of the course, and a simple certificate of participation does not guarantee that the desired proficiency has been attained.

In conclusion, the distinguishing features of the SMTP, compared with commercial SM courses such as the Master Class offered by ICC, would be a more thorough in-depth presentation of the material, perhaps interspersed with practical assignments to cement students' understanding, complemented by a formal examination and assessment at the end of the course to ascertain the attainment of a certain level of professional knowledge. If tuition costs are involved, the fees charged by commercial course offerings can be used as a benchmark for SMTP.

National SM training:

With such a limited choice of SM training options, and noting the drawbacks of existing courses, some national administrations adopt their own initiatives. Some larger administrations organize their own SM classes, which introduce students to the working practices in their countries against the backdrop of international SM[5]. Other administrations conclude agreements with private companies to offer their staff in-house tailored classes similar to the example cited previously[6]. In the latter case, the administration may seek a discount on the tuition fee, given the large class size, and also save on expenses (paying the travel and accommodation costs of a few foreign tutors is less than the cost of sending a larger group of students abroad).

Another type of initiative is seen in national/regional seminars dedicated to SM, such as the annual international congress organized in Colombia[7]. In concept and composition, such seminars are similar to the ITU seminars described above, but as they are locally organized, the scope and content of the presentations can be tailored very precisely to the audience's needs.

In conclusion, given their occasional nature and precisely tailored, localized scope, the existing national initiatives do not overlap with the idea of a formalized international SM course.

University-certified commercial professional courses:

Although this investigation could not identify any SM course offering formal certification, some similar professional courses that offer certification do exist: the telecom engineering courses offered by the Telecoms Academy, a unit of Informa Telecoms & Media Group[8] is one example.

The Informa Telecoms Academy offers several tracks leading to university certification, thanks to a partnership with the University of Derby corporate division. Students may choose among different combinations of physical classes (each up to one week in duration) followed by a work practice assignment or a complete remote training course lasting nine months and consisting of a series of nine modules (some are compulsory, others optional), with formal assessment upon completion. When students successfully

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5 See NTIA Spectrum Management Training: www.ntia.doc.gov/spectrumtraining/spectrum-management-training-course

6 InterConnect Communications Inc, Spectrum Master Class: www.icc-uk.com/spectrum-master-class.php

7 2nd International Congress on Spectrum, Agencia Nacional de Espectro, Colombia: http://congresoanecie.cintel.org.co/

8 www.telecomsacademy.com/

complete these tracks they may receive a Postgraduate Certificate in Advanced Telecoms Management, which constitutes 60 British university credits at Level 7 (corresponding to the first year of a Master's-level university course). For comparison, in order to receive a full Master's degree in the United Kingdom a student needs 180 credits.[9] In other words, upon receiving the Informa Telecoms Academy certificate, someone wishing to receive a full Master of Science qualification could then continue earning more credits at Derby (or another) university until reaching the required number of credits to receive a Master's degree.

The advertised fees for various courses at the Informa Telecoms Academy suggest that it would cost around 8 000 euros to achieve the 60-credit university certification.

In conclusion, the Informa Telecoms Academy represents an option whereby a professional course might be certified as part of a University postgraduate diploma. This could be considered as an option for SMTP as well, depending on course size, duration and negotiated agreements with one or more partner universities.

Professional certification:

Apart from university certification, it is also possible to award a professionally certified and industry-recognized diploma. A noteworthy example close to the field of SM is the Wireless Communication Engineering Technologies (WCET) professional certification of the Institute of Electrical and Electronics Engineers (IEEE), a professional association of engineers in electrical and related fields that is based in the United States but global in scope[10].

The essence of the WCET approach is to establish benchmarks for measuring professional qualifications in the field of wireless engineering and then to conduct tests to determine whether or not a practising professional has surpassed that level. The focus of WCET is thus more on developing and running the tests than on the training needed to reach the required professional level. Because the certification looks broadly at wireless engineering, the training aspect is secondary, as WCET seems to assume that the knowledge needed to do well in the test can be obtained by combining a university degree in the subject area with a few years of practical experience. This is similar to the way in which medical and legal professionals are certified, with tests of theoretical and practical knowledge administered after a few initial years of practice.

The WCET work package is thus mainly a guide to the examination process: the book outlines the subjects of the certification exam, describes the knowledge required for each topic, how the exam is organized and how the certificates are awarded. Since this process is organized and run by the IEEE Communications Society (ComSoc), credibility and international recognition for the certification were achieved rather quickly. Some larger employers, primarily in the United States, already require WCET certification as a precondition for hiring their senior wireless engineers.

The WCET professional certification scheme might be regarded as a suitable model. It should be easier to set up and administer, compared with what is needed to organize university degree certification or to create a longer and more comprehensive course than those offered by commercial firms. However, the easy way does not answer the need for more high-level training of SM professionals with an international perspective.

Overall conclusions from analysing existing training and certification options

SMTPs can successfully create a unique and credible niche, complementing the existing professional SM training options and promoting the harmonization of SM practices, if they meet certain defining criteria:

The programme should be broad in scope and international in character, with tutors and participating institutions of the highest quality, to ensure the value of the programme and the reputation of its diploma. It should strive to establish itself as the global "gold standard" for SM training.

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[9] University credits in the United Kingdom differ from those of most other European countries, which follow the so-called European Credit Transfer and Accumulation System ECTS. ECTS is discussed below.

[10] IEEE Wireless Communication Engineering Technologies Certification: www.ieee-wcet.org/

The programme should be comprehensive and well-rounded, addressing all theoretical and practical aspects of SM. It should offer a higher level of professional knowledge than is available from existing self-study resources or short courses.

An essential differentiator for the SMTP would be the formalized assessment of learning outcomes in terms of achieved professional skills and qualifications, supported by the award of a diploma representing a recognized academic level, such as a Master's degree.

Alternatively, the certificate awarded could represent partial completion of a university course of study with a certain number of transferrable credits that would count towards a full Master's qualification at some other institution of higher learning (university or college). This option could be especially useful for students taking only some of the study modules.

Yet another alternative would be to regard it as an independent professional (non-academic) qualification in the field of SM, like the WCET certificate offered by IEEE ComSoc. Consideration could be given to devising or sponsoring a professional certification programme for spectrum managers with the ITU certificate, which would be recognized by administrations and the wireless industry but without having ties to the world of academia.

Formal university credits system and the corresponding course dimension

Many European countries have chosen to follow the European Credit Transfer and Accumulation System (ECTS)[11]. This system was originally set up in 1989 in order to facilitate the recognition of study periods spent abroad by students. Since then it has become a widely recognized and unified system for evaluating the levels of university learning or other types of formal or informal continuing education.

A key feature of the ECTS system is that it is learner-based, i.e. the credits correspond to the average time it takes the learner/student to achieve certain learning objectives. Thus one ECTS credit corresponds to 25-30 hours of learning (the precise value depending on the country) and it is assumed that students taking a full-time formal educational course should be able to accumulate 60 ECTS credits in a typical academic year consisting of two semesters of 3-4 months' duration. On that basis, the first-level degree (Bachelor of Science) would normally require the collection of 180-240 ECTS credits (representing 3-4 years of full-time study), while the second-level degree (Master of Science) would require 90-120 ECTS credits (1.5-2 years of full time study). There is also a provision that a second-level degree may have an interim level with at least 60 ECTS credits. This might be used to refer to the kind of postgraduate diploma in a specialized field that is especially popular in the United Kingdom, and which in other countries has names like licentiate, polytechnic diploma, or MA[12].

The main distinguishing factor between the full Master's degree and the postgraduate diploma is often that the former is seen as more theoretical and research-oriented, and requires the writing of a thesis. The latter is seen purely as a diploma in applied sciences, and a thesis is not always required. As writing a thesis usually represents 30 ECTS credits, this could make all the difference between 60 and 90 ECTS credits, which is the minimum required for a formal Master of Science degree according to ECTS principles.

Overall, given the wide adoption of ECTS as a reference system in Europe and beyond, it seems logical to consider using this system when designing the SMTP programme. The only notable exception in Europe

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[11] See ECTS User Guide: http://ec.europa.eu/education/tools/docs/ects-guide_en.pdf

[12] Two examples of national Master programmes worth 60 ECTS credits may be found here:

- Master of Arts in International Relations, University of Groningen, Netherlands, www.rug.nl/let/onderwijs/master/globalgovernance/index
- Master Degree Programme in Project Management, Karlstad University, Sweden, www.kau.se/en/education/programmemes/SAIPL

that deviates from ECTS is the United Kingdom, which uses a system called CATS. However, this system is readily convertible to ECTS, with one ECTS credit corresponding to 2 English CATS university credits.

An additional advantage of using a European system is that it also provides a good example of derivative international teaching programmes by university consortia known as European Erasmus Mundus Master's Courses[13]. Erasmus Mundus programmes offer international education options in many specialized subjects, from food innovation to earthquake engineering, so it might be fitting for an international Master's course on SM to join this grouping. Most importantly, the Erasmus Mundus programmes and their students are eligible for European funding for programme organization and student scholarships. This funding is also available to students from non-EU countries.

As examples of the possible composition of such a European Master's programme, one may take two Erasmus Mundus programmes in subject areas nearest to SM:

MERIT - Master of Science in Research on Information and Communication Technologies[14]

This Master's programme is multi-track and research-oriented, based on a flexible curriculum spanning the ICT field. The programme is offered jointly by five technical universities in Spain, Belgium, Germany, Italy and Sweden.

MERIT students study full time for two years, in three 15-week semesters for classroom work and a fourth semester to write a Master's thesis. The total number of ECTS credits (120) should be spread equally between two of the participating universities. At the end, students are awarded a double MSc diploma issued by both the universities attended.

The MERIT course comprises three broad areas of knowledge, namely:

- microwaves, antennas, remote sensing and photonics;
- wireless and optical communication systems and networks; and
- multimedia signal processing.

The above three areas are then further divided into specialization tracks, making a total of nine tracks to choose from, with each track being offered by a different combination of participating universities (e.g. the Wireless Network Management track is offered by the Sweden Royal Institute of Technology (KTH) and the Politecnico di Torino in Italy).

EMIN - Erasmus Mundus Joint Master in Economics and Management of Network Industries[15]

This joint Master's programme is offered by a consortium with truly global aspirations, including five European universities (in Spain, France, the Netherlands, Italy, and Belgium), five universities from the United States, Brazil and China, and ten large companies (mostly energy networks).

The programme again consists of 120 ECTS credits and spans two years of study, with several possible paths, depending on the student's background (engineering vs. economics). The three semesters of studies are divided between the three leading partner universities, while the fourth semester (devoted to writing the thesis) can be spent in any of the global partner universities or companies. At the end of the process, the graduates receive multiple Master's diplomas from the three leading partner universities (in Spain, France, and the Netherlands).

It may thus be concluded that the international Master's programmes offered today by university and industry consortia tend to follow the format of two academic years in full-time study, earning 120 ECTS

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[13] See http://eacea.ec.europa.eu/erasmus_mundus/results_compendia/selected_projects_action_1_master_courses_en.php

[14] MERIT – Master of Science in Research on Information and Communication Technologies: www.meritmaster.org/

[15] EMIN – Erasmus Mundus Joint Master in Economics and Management of Network Industries: www.upcomillas.es/estudios/estu_mast_emin.aspx

credits. In general, it seems that the existing European Erasmus Mundus framework could be a good model for the creation of a university consortium to run an international Master's programme such as an SMTP.

As regards the eventual academic composition, ECTS load and duration of the SMTP programme, this would clearly be a subject for negotiation with the participating universities. However, ITU could also offer a shorter course which would be more suitable for on-the-job training. Conversely, any course going beyond one calendar year might be perceived as too long and distracting for a career-oriented professional.

Choice of immersion levels and professional specialization for the SMTP

One can assume that any on-the-job training programme would interest people with differing levels of work experience and differing current job requirements. It might therefore be appropriate to offer two different entry levels to the SMTP:

1. Basic level, for people with little or no prior work experience in SM.
2. Advanced level. For admission at this level the participant would need to have passed the basic level successfully or, alternatively, to demonstrate some practical experience in SM (e.g. at least one year) and pass an entry exam.

The time required to complete the programme would differ according to the entry level chosen by the student, but in both cases, the studies would lead to the same qualification diploma. This would make it easier to build brand recognition for the "Master's in Spectrum Management" (or whatever similar certificate is awarded by SMTP) if it were just one level, so that the industry would grow accustomed to the idea that an SMTP offers some specific guaranteed "gold standard" of professional qualification. This would be similar to the WCET certificate (described above) conferred on professionals to certify their proficiency in wireless communications engineering.

The possibility of joining SMTP directly at the advanced level raises an important issue. It would require a formal definition of the minimum work experience required, as well as some formal examination to assess the skills and competences acquired through professional employment. This would be critical, especially if the SMTP were to follow the path of formal university degree certification, because the ECTS framework allows recognition of the outcomes of informal learning such as those obtained through practical work experience[16]. In order to formally award learning credits for proficiency levels achieved through practical experience, the SMTP would need to establish some kind of assessment mechanism, such as a combination of interviews and examination, as part of admission to the higher SMTP level.

When speaking of basic or advanced levels in SM, one might generalize and say that the basic level of SM proficiency is more technically oriented, while advanced SM proficiency is associated with "soft", i.e. non-technical subjects and skills. This is because the engineering aspects of SM tend to be decisive at the most basic level of frequency planning and assignment, whereas advanced SM requires a greater understanding of strategy, policy and other non-technical considerations, ranging from the use of market mechanisms to the art of negotiation. This specific circumstance of the SM profession would be taken into account during the design of the SMTP curriculum and teaching modules. In academic parlance, this corresponds to the model in which a Master's degree represents a broadening of the initial knowledge base, rather than a deepening of one narrow focus.

Undoubtedly, some jobs in SM do benefit from specialization and a deep understanding of some specific topics (for instance, frequency planning for networks of broadcasting stations, or sophisticated electromagnetic compatibility (EMC) analysis in connection with co-existence of different services). However, certifying mastery of such a complex and diverse field as SM cannot be based on proficiency in just a few of its constituent spheres.

Nevertheless, the role of professional specialization is important and may be supported by offering a wide choice of elective study modules, so that the student can focus on particular sub-fields according to his or her interests. It can thus be concluded that the overall composition of SMTP should be based on a

[16] See ECTS User Guide: http://ec.europa.eu/education/lifelong-learning-policy/doc/ects/guide_en.pdf

progression of mandatory modules which will advance knowledge from more technical subjects towards soft/non-technical issues, complemented by a diverse set of specialized elective modules.

2 The SMTP concept and programme outline

In the light of the options and circumstances described in Section 1, this study proposes the following general concept for designing the SMTP programme:

- Maximum duration of one calendar year for students taking the complete course, from the basic level through advanced level to course completion.
- If formal academic certification is desired, such as a university Master of Science qualification, the SMTP should be planned so as to offer the equivalent of 60-90 ECTS credits, including:
  - 20-30 ECTS credits for basic-level modules, which may alternatively be granted for a minimum of one year of active professional experience subject to formal assessment of the professional competences acquired;
  - 20-30 ECTS credits for advanced-level modules;
  - 20-30 ECTS credits for the final thesis in the chosen area of professional specialization.

Assuming 25 hours of study for one ECTS credit, completion of the SMTP would correspond to 1 500-2 250 hours of study and work experience. The regional ITU centres of excellence and partner universities will need to play an active role in supporting the organization and coordination of SMTP activities.

Target audiences

The SMTP course would be designed for anyone wishing to enhance their professional knowledge while working in the field of SM, for example in a national regulatory authority or a company operating in wireless communications. The SMTP would be oriented towards the broadening of skills in the complex field of radio SM; it could thus be taken by any professional who has previously graduated with a first-level university degree (Bachelor of Science).

This being the case, students entering the SMTP may be from different institutional levels, from technical to managerial, and from different backgrounds (engineering, legal, economic, etc.).

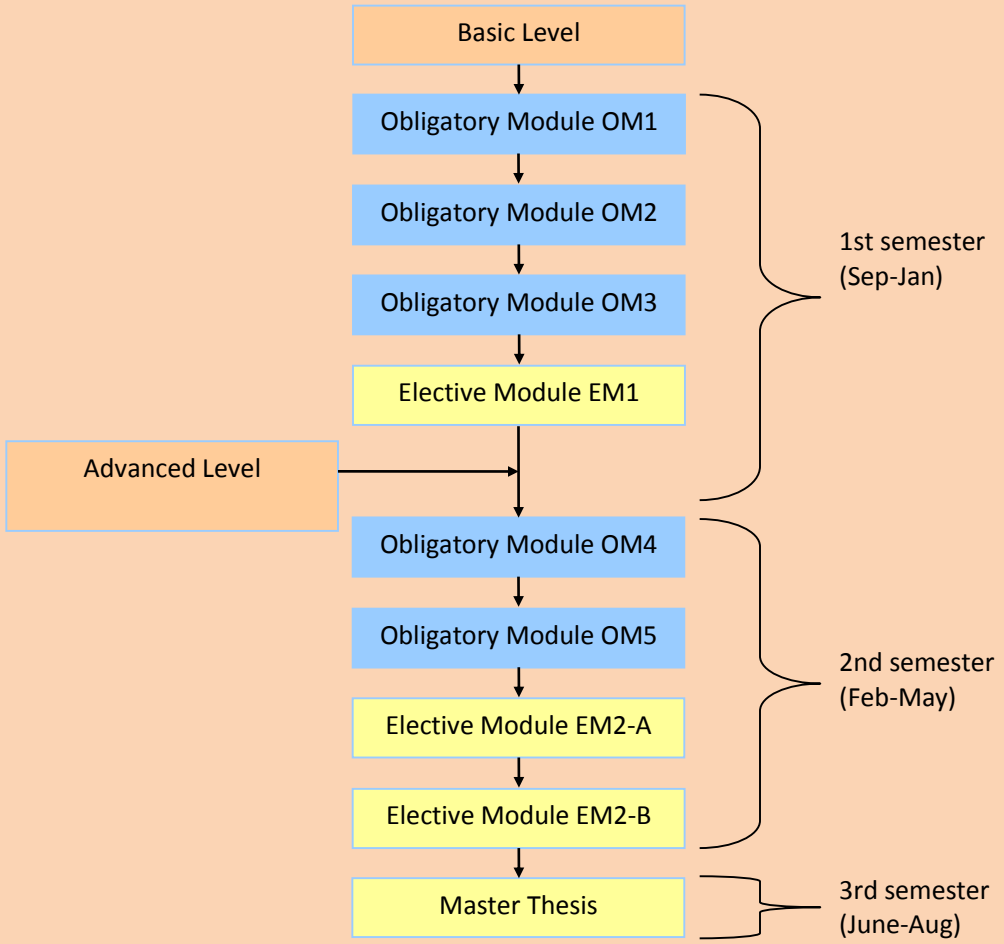
Those wishing to join at the advanced level would need to have at least one year of practical experience and pass an entrance exam to ascertain whether they have the required level of basic knowledge. The advanced level entrance exam would be essentially the same as the assessment taken on completion of the basic course by students starting from that level.

Course duration options

Since it is anticipated that the programme would be most attractive as an on-the-job training option for working professionals, the SMTP may consist of a sequence of modules spread over no more than one calendar year (September to August). Each study module could last for between four and five weeks, including the formal assessment at the end of each module.

As a point of departure, aiming for a course worth 60 ECTS, the SMTP might be composed of eight training modules, each worth five ECTS credits, complemented by a thesis worth 20 ECTS credits. To summarize this proposal, the overall course composition, duration and entry points are illustrated in Figure 1.

Figure 1: Proposed composition and duration of the SMTP



Source: ITU

Table 1 shows the proposed composition of the SMTP modules of OM1 to OM 3 with the elective modules EM1 options 1 to 6, followed by OM 4 and OM 5, with the elective modules EM2 options 1 to 4.

Table 1: SMPT obligatory and elective modules

Obligatory modules	Elective modules	
OM1: Legal basis and regulatory framework of spectrum management		
OM2: Spectrum engineering fundamentals		
OM3: Wireless telecommunication technologies	**EM1**:	• Option 1: Spectrum monitoring • Option 2: Enforcement and type approval of equipment • Option 3: SM for satellite systems • Option 4: SM for HF systems, science, maritime and amateur services • Option 5: SM for aeronautical and radiodetermination services and military systems • Option 6: Computer-aided spectrum management
OM4: Economic and market tools of spectrum management		
OM5: Strategic planning and policies for wireless innovation.	**EM2:**	• Option 1: (Legal Specialization): Advanced spectrum authorization regimes • Option 2: (Legal Specialization): Socio-economic impact of spectrum regulation; competition and consumer protection • Option 3: (Technical Specialization): Terrestrial TV broadcasting planning and digital transition • Option 4: (Technical Specialization): Opportunistic spectrum access and cognitive radio.

However, it should be noted that the modular structure of the SMTP, especially with the choice of elective modules, is well-suited to allow constant updating of the modules initially proposed as well as development of new specialized (elective) modules.

The overall design concept of the SMTP proposed above would have the following benefits:

1. The sequential flow of modules provides multiple benefits through:
    a. being a convenient way to combine study options with daily work commitments, as students would need to focus on only one study topic at a time;
    b. simplification of logistics, by minimizing the coordination needed between different partner institutions: only the organization managing a particular study module would be responsible for daily operations in any given time period;
    c. predictability of time commitments for teaching staff (assuming each tutor is assigned the same module in successive years and each module is offered annually in the same time-frame);

   d. clear break-points in the sequential flow can be used as different entry points; in the case of multiple sets of study paths and/or certification levels, the breaks allow different combinations of entry and exit points. This option is discussed in more detail below.

2. Module durations of four to five weeks seem a reasonable compromise, being sufficiently short for focused study of one topic but long enough to give instructors flexibility in planning their syllabuses. The suggested four to five week duration also allows for a succession of many different modules to fit within one year. Periods of self-directed study may coincide with holidays, major industry events, work-related travel, and so on.

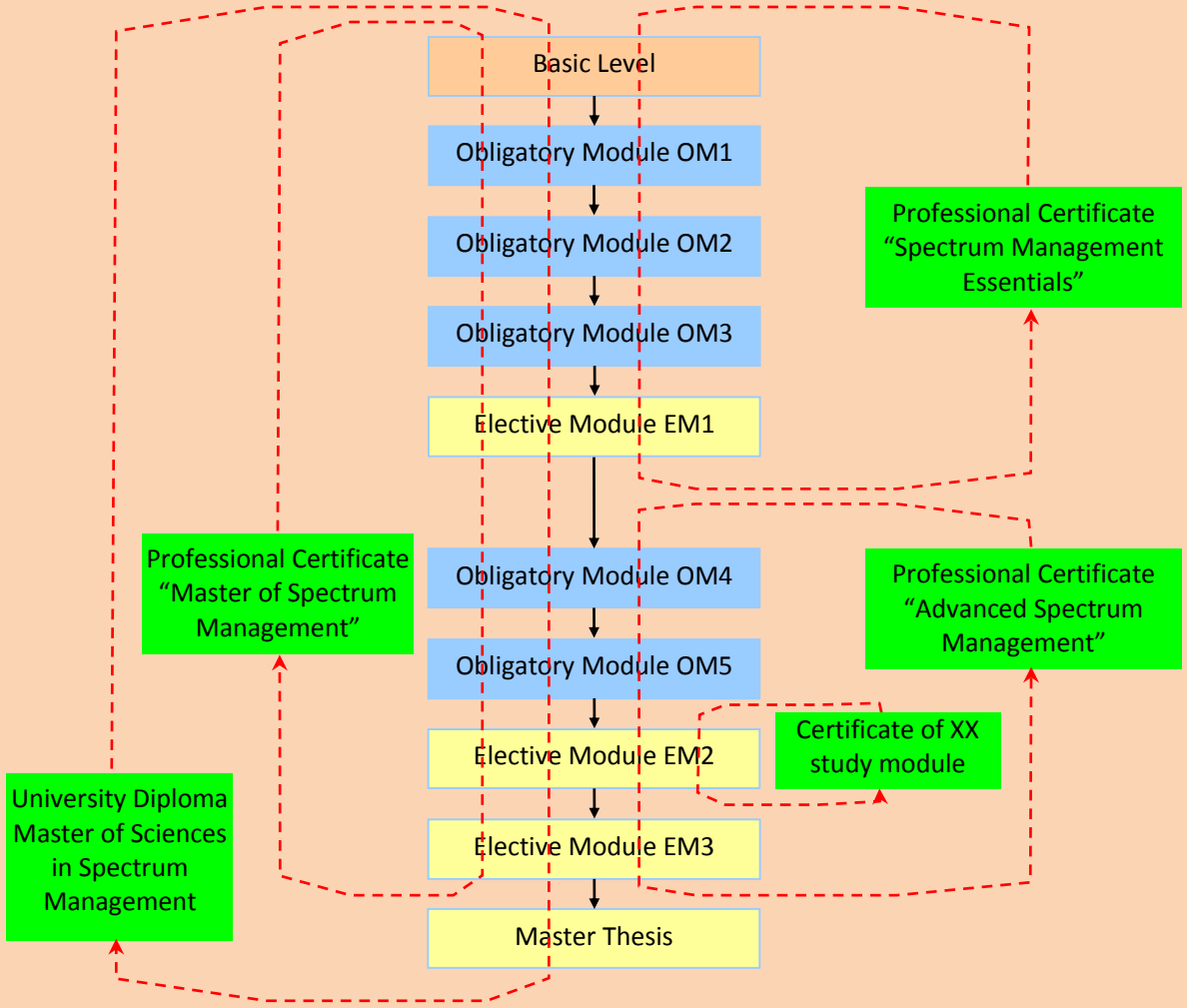
3. Another notable feature in the above design is the different proportion of obligatory and elective modules in basic vs. advanced levels. This is proposed because the basic level should be broad in scope and is therefore formed mostly of obligatory modules offering knowledge in subjects that must be known by any SM professional. The advanced level, on the other hand, may involve more specialized study and therefore has a higher proportion of elective modules.

Noting the above principles and observations, the SMTP design concept recommended in this report would appear to provide a robust yet versatile course structure that can be easily adapted to the composition of the consortium of participating institutions and to any later modification of the objectives. For instance, as was discussed before, different options can be chosen to pursue various SMTP certification objectives and as a result, the delivery format of the course may need to be changed while using the same overall design as described above. The following main options may be considered:

- **Option A**: the SMTP becomes an international course offered by a consortium of participating universities under the aegis of the ITU Academy and leading to a Master of Science degree awarded to graduates upon successful completion of the course. This objective may be realized by implementing the structure described in Figure 1.
- **Option B**: the SMTP becomes a professional training course organized solely by the ITU Academy, possibly delivered through its training facilities and/or the ITU Academy platform under the aegis of the centres of excellence, with the possibility of being driven by ITU staff, ITU-R study group experts and/or ITU-D experts, and possibly with the cooperation of ITU-R industry partners or centre of excellence partners. The overall structure of the course may still follow the concept described in Figure 1, except that there would be no need for the third semester and Master's thesis. Upon completion of the training (including passing all assessment tests), the trainees would receive a professional "Master of Spectrum Management" certificate granted in the name of ITU/ITU Academy.
- **Option C**: a combination of Options A and B. That is, the SMTP becomes an international university Master's course offered by a consortium of participating universities, but is organized in collaboration with ITU-D/ITU-R external experts (e.g. lecturing on actual case studies) and ITU-R industry partners, especially for practice and laboratory exercises, under the aegis of the ITU Academy. Such a course would lead to a university Master's diploma for successful graduates.
- **Option D**: the SMTP could become a guide for self-study and training through practical experience, in which case ITU/ITU Academy would develop the training material, offer student counselling opportunities, and ultimately assume responsibility for the professional examination, i.e. the testing of knowledge and skills to an established standard. The latter task would involve the development and administration of the final assessment tests for each module. With this option, the composition described in Figure 1 could still be used, but only as a description of the subjects (and respective teaching material sets) that have to be completed through self-study and final assessment as a condition for obtaining professional certification.

These options are just the main ones, as further derivations are also possible, e.g. by allowing certain combinations. For example, completion of the entire course as proposed in Figure 1 might lead to a university Master's-level diploma whereas completion of only part of the course could lead to the award of a professional certificate of some level. This concept, with examples of intermediate certification paths, is illustrated in Figure 2.

Figure 2: Possible derivative options for university or professional, full or partial certification levels



Source: ITU

From Figure 2 it should be obvious that the proposed course structure, comprising general and specialist modules, allows a large enough number of combinations and thus provides for different types of certification, knowledge attainment levels and specializations. The ultimate set of training paths offered may be decided once the objectives are agreed and negotiations take place with all parties involved in the SMTP teaching consortium.

The detailed matrix of study tracks and module combinations is shown in the Annex.

Course delivery options

Given that the SMTP is conceived as an advanced training programme, it can rely on a substantial amount of instructor-led self-study ("e-learning"). Most people get accustomed to self-study during their undergraduate years, and the self-discipline thus acquired could be used to significant benefit in postgraduate on-the-job training. Self-paced e-learning (under the supervision of an instructor and with ad hoc consulting services) is easier to adapt to the changing availability of time due to daily workload fluctuations in the student's primary job, and tutors may also focus more efficiently on advising those students and on those topics that are subject to the largest learning frictions.

Another important benefit of e-learning is linked to the assumption that students are likely to be working in departments or organizations actively engaged in SM. This means that prospective students may reinforce their understanding of the topics studied by drawing on institutional resources. For instance, they may consult with experienced colleagues who are working on a relevant topic, and use the specialized applications (e.g. automated SM systems, wireless planning software, and so on) available in their organization to acquire practical, hands-on experience along the educational path.

The vision of SMTP structure presented in Figure 1 is based on the assumption that obligatory modules would be primarily classroom driven, whereas elective modules would rely mostly on e-learning. The emphasis would be on actively teaching the well-established general subjects in class, drawing on reference materials, while the elective modules could rely more on self-paced e-learning, including in-depth research and study of specialized literature sources. The inherent flexibility of elective modules oriented toward instructor-led self-study would be especially useful if the student's organization required some special type of knowledge in a given subject. For instance, studying a particular technology may be tailored to the state of development and wireless standards adopted in a particular country.

Consequently, all modules might benefit from exploiting different delivery modes adapted by the tutor. For example, the time allocated to a module might be divided between:

- classroom teaching and physically attended seminars and workshops;
- practical exercises whenever possible (e.g. with monitoring equipment and software tools);
- instructor-led remote lectures (live or pre-recorded);
- self-study of textbooks and reference material;
- interactive seminars and discussions with tutor and peers using web tools.

Classroom instruction could be coordinated by the ITU Academy and conducted at ITU centres of excellence or at other partner institutions such as universities.

Partner institutions

The ITU Academy should become a convenient coordinating point for devising and then implementing the SMTP. However, it would need to involve skilled partners in preparing teaching content, decide how and what to test for in the certification procedure, design entry-level examinations that could confer academic credit for work experience, and eventually determine how to staff, deliver and manage the programme. While it may not be necessary to pre-define at the outset the types of partner institutions that might be considered for participation in the SMTP, suitable institutional partners could surely be found among the following categories:

- ITU BDT and BR departments as "founding fathers", together with the ITU Academy;
- ITU-R and its study groups;
- ITU-T and its study groups (e.g. those dealing with relevant technological standards);
- organizations participating in the running of the ITU CoEs in various regions;
- national regulatory authorities (NRAs), especially those that already have their own national SM training programmes and facilities;

- Regional telecommunication organizations (e.g. CEPT, CITEL, APT)
- Universities and research centres
- Organizations and companies which currently run educational programmes for SM (such as USTTI and others reviewed in Section 1 above)
- sector-specific industry associations (e.g. GSMA) and unions (e.g. broadcasting);
- companies prominent in the field of wireless communications, especially producers of SM software tools, radio monitoring equipment, and wireless network equipment manufacturers;
- other stakeholders.

All potential partners should be consulted in order to gauge their interest in an SMTP, both with regard to the possibility of their participating in training and with regard to the potential demand for SMTP-certified specialists. The level of demand will surely influence the number of students accepted onto the programme, which will in turn influence the budget and staffing requirements. These consultations will provide a better understanding of the types of institution that are interested in participating and their level of engagement, as well as the overall scale of the undertaking, which will help in forming the consortium.

Another important consideration in terms of support and participation should be the establishment of a large pool of well-qualified SM experts. These experts may be involved first of all in the process of developing the teaching content and assessment exams; some may continue their engagement in the delivery of the classroom-based modules and remote tutoring of students, as well as supervision of their progress and eventual Master's thesis.

3 SMTP obligatory modules

In this section, a set of proposed teaching modules is described according to the scheme shown in Figure 1 above. The content of each module could obviously benefit from further refinement, and the sequencing and overall configuration could also be reviewed for possible improvement.

There is certainly room for expanding the scope of the course with elective study modules covered in Section 4, in order to take advantage of proposals made by partner institutions based on their particular competencies, specializations and capacities.

3.1 OM1: The legal basis and regulatory framework of spectrum management

Module content

OM1 is an important introductory module that may be called "SM for beginners". The module should cover the following basic subjects and concepts:

- historical background and evolution of SM principles and strategies;
- ITU role and structure;
- ITU Radiocommunication Sector, BR and their respective roles;
- ITU Constitution and Convention, world radiocommunication conferences;
- ITU Radio Regulations;
- international regional cooperation structures in the area of SM;
- national legal frameworks relevant to SM (including internal frequency coordination processes);
- national frequency allocation tables;
- national regulatory authorities: typical structures and functioning;

- other national stakeholders involved in SM;
- frequency use authorization processes for various radio services;
- overview of BR software tools and automated SM systems.

Proposed delivery mode and duration

This module is very important as it will set the stage and context for the rest of the SMTP teaching. It is therefore important to start it on a high note with carefully orchestrated instructor-led teaching, e.g. as a full-time, five-days a week, lecture-based classroom presentation. This could be followed by three weeks of instructor-led e-learning with self-study of reference materials (primary documents whenever possible). At the end of the final week, an interactive seminar should be held to enable students to strengthen their knowledge and understanding by discussing and resolving problems based on real-life situations.

It might also be beneficial if students – particularly employees of national regulatory authorities - were required as part of completing this module to attend in person some SM-related international event (seminar, workshop or policy-making conference), such as an ITU-R study group/working party meeting, a radiocommunication seminar, a regional SM event (convened by, for example, CITEL, CEPT, ATU, or APT), a transnational frequency coordination meeting, or some similar event. Students could choose a suitable event themselves, in consultation with their employer organization, subject to approval by the module instructor or course coordinator.

Total duration: Four weeks.

Study objectives and assessment

Upon completing this module, students should understand the overall context and objectives of SM and its practical realization in a complex, multi-layered structure of international, regional and national levels. Students should understand the role and functions of the different stakeholders involved and the legal framework underpinning all the interactions. Finally, the students should understand the role and operational principles of authorization processes (licensing) for radio services.

As a part of the overall module assessment, students could be required to substantiate the results of their distance learning by writing a short essay of around 10 pages describing the institutional framework and functioning of SM in their country or the problems and solutions discussed at the international SM event they have attended. This work would be graded by instructor and given proportional weighting in the overall final grade for the module.

The module would conclude with an assessment that could take the form of a computerized test in which students answer a number of multiple-choice questions, covering all the subjects and concepts that have been studied.

Study resources

Some earlier multimedia-based versions of “SM for beginners” courses may be re-used as seed material for this module. The study resources for this module would be primarily reference documents available from ITU, such as:

- ITU Constitution and Convention.
- ITU Radio Regulations.
- ITU-R Handbook on National Spectrum Management.
- Other ITU-R handbooks and reports.

In addition, students may be required to review some actual documents being prepared by ITU-R study groups at the time of study, and/or the Final Acts of the most recent world radiocommunication conference (WRC), examples of regional cooperation documents in the field of SM, and so on.

3.2 OM2: Spectrum engineering fundamentals

Module content

This module should cover the following subjects and concepts:

- radio waves, antennas and propagation; physical differences among frequency bands;
- radio link budgets, minimum coupling loss (MCL) and similar formulas and units;
- spectrum space occupied by radiocommunication systems, measuring spectrum use efficiency;
- interference mechanisms and EMC of radiocommunication systems;
- planning frequency use for different services;
- cross-border frequency coordination principles and international agreements such as the Harmonized Coordination Method (HCM).

Proposed delivery mode and duration

This is another module of critical importance, as it would establish the technical foundation for understanding the problems addressed by the practice of SM. It is proposed that this module should start with instructor-led teaching, e.g. as a full-time, five days a week lecture-based class. This could be followed by three weeks of instructor-led e-learning and self-study of reference materials. During the self-study period the students should be given individual assignments to prepare a module project addressing some specific problem that would involve analysing and resolving a complex compatibility issue and planning frequency use.

In the final week, a series of interactive seminars may be held to review the results of the module, with students presenting their own projects for discussion with their instructor and peers.

Total duration: Four to five weeks.

Study objectives and assessment

On completing this module, students should understand the technical principles underlying the use of radio spectrum space by communications systems as well as problems related to the co-existence of different services and systems. The students must be comfortable with using decibel units and should be capable of performing the essential calculations of link budgets and MCL estimates.

The module assessment should include grading of individual course work (including the assigned project as well as its defence during the interactive seminar) plus the results of the final test. This final test should consist of a number of multiple-choice questions as well as problems requiring students to apply EMC analysis skills.

Study resources

The study resources for this module would be primarily the reference documents available from ITU and ITU-R reports and handbooks, complemented by text books as necessary, such as:

- ITU-R Handbooks on National Spectrum Management, radiowave propagation, and specific radiocommunication services.

- ITU-R Recommendations pertaining to spectrum use efficiency, planning and co-existence of various radiocommunication services.
- The SMS4DC User Manual.

In addition, students may be required to review recent documents related to the work of various ITU-R study groups, such as co-existence and spectrum sharing studies, as well as regional best practices, such as the HCM Agreement.

3.3 OM3: Wireless telecommunication technologies

Module content

The constant improvement and successful use of wireless communication systems is the objective of the spectrum manager's work. It is therefore important for every spectrum manager to have a solid understanding of wireless communication technologies, their operating principles and requirements. To that end, this module should cover the following subjects and concepts:

- the history and development of wireless communications;
- high-level review of essential building blocks of radiocommunications systems;
- wireless network architectures;
- spectrum access mechanisms, bandwidth requirements;
- technology case studies:
  - radio and TV broadcasting;
  - cellular mobile systems: Evolution from 1G to 4G and beyond;
  - satellite Communication Systems;
  - fixed services (radio relay links, PMP systems, etc.);
  - short Range Devices, WLANs/WPANs;
  - other (e.g. individual choice for self-study depending on the interests of a student and/or his or her employer).

Proposed delivery mode and duration

Like the modules discussed above, this important module would benefit from an instructor-led course format, i.e. full-time classroom lectures five days per week. This could be followed by three weeks of instructor-led e-learning and self-study of reference materials.

In the final week practical visits could be arranged to various companies and organizations that operate wireless networks in order to gain insights into the role of radiocommunications in business processes and get a feel for the technologies deployed. Depending on the composition of the SMTP partnership, such practical visits to prominent ICT companies in the consortium could be organized for an entire group of students at an international level. Alternatively, it may be left to the individual students to arrange such practical visits themselves at a national level, with the organizational help of their employers.

Total duration: Four to five weeks.

Study objectives and assessment

Upon completing this module, students should understand the evolution of wireless technologies, basic network configurations and requirements in terms of spectrum access. Students should also understand the working principles of selected types of wireless technology and systems, and how they are dimensioned

and planned. For instance, students should be able to derive by themselves a provisional estimate of how the power output of a broadcasting station relates to the service area, how many base stations may be needed to serve a given population and area, how many hops may be needed for a radio relay link to span a certain distance, and what channel bandwidth may be needed to deliver a wireless link of a given throughput.

As a part of the overall module assessment, the students could be requested to substantiate the results of their distance learning by writing an essay of around ten pages describing an example of technological requirements and a planned solution for a given technology in a specific area of their country. This work would be graded by instructor and account for a proportional part of the overall final grade for the module.

The module assessment should include the grading of individual course-work (written work and its defence during the interactive seminar) plus the results of the final test. This final test should consist of a number of multiple-choice questions as well as a number of problems that would require students to apply their understanding of basic wireless telecommunication planning principles.

Study resources

Delivery of this module might rely on a number of ITU-R handbooks, ITU-R Recommendations, ITU-D reports and handbooks on planning and spectrum use and the requirements of specific radiocommunications services and technologies.

In addition, the module (especially the self-study component) could rely heavily on the many literature sources describing wireless technologies.

3.4 OM4: Economic and market tools of spectrum management

Module content

This module should cover the following subjects and concepts:

- spectrum as a resource;
- ways of defining spectrum usage rights;
- spectrum liberalization;
- methods of incorporating economic forces and market mechanisms into SM;
- models of spectrum pricing and administrative incentive pricing;
- designing spectrum auctions, “beauty contests”, tenders;
- setting up rules for secondary markets in spectrum trading;
- re-purposing and re-farming spectrum bands;
- band managers, co-regulation and self-regulation.

Proposed delivery mode and duration

This module could be presented at the start of a new semester and the beginning of the advanced level of the SMTP, and consequently may involve a new intake of students. The introduction to this module should thus take into account the new students’ need for contextual orientation as to where and how these advanced SM tools fit into the overall context of SM. This could be done with instructor-led teaching over a full-time five-days-a week class, which could be followed by three weeks of instructor-led e-learning and self-study of reference materials. During the self-study period students should be given individual assignments to prepare a course project addressing some specific problem involving the development of a proposal for applying an economic/market-based SM tool. The final week could consist of a series of

interactive seminars in which students present the results of their individual projects and discuss them with their instructor and peers.

Total duration: Four to five weeks.

Study objectives and assessment

Upon completing this module students should understand the principles and reasons for using economic/market-based tools. Students must be able to differentiate between the various tools and identify the circumstances in which each tool or a combination of tools might be most appropriate. Finally, students must demonstrate their understanding of how to design the respective tools to suit different requirements and situations.

Assessment of this module should include grading of individual projects as well as their defence in the interactive seminar, plus the results of the final test. This final test may consist of a number of multiple-choice questions as well as problems requiring students to apply the analytical skills obtained in the area of economic/market tools for SM.

Study resources

Delivery of this module will rely on a number of ITU sources, such as ITU-R handbooks and recommendations related to the use of economic and market-based SM tools, BDT reports and guidelines.

In addition, the module (especially the self-study component) could rely heavily on the recent literature discussing the application of economic and market-based SM tools.

3.5 OM5: Strategic planning and policies for wireless innovation

Module content

This forward-looking module should equip students with essential skills to enable them to participate actively in the development of national policies for wireless technology in which SM constitutes a crucial part. The module should cover the following subjects and concepts:

- use of scenarios and other strategic planning tools;
- approaches to policy development and impact assessment;
- the role of standards (open and proprietary) in regulation and business;
- the art of negotiation;
- innovation management;
- evolutionary trends in radio technology.

Proposed delivery mode and duration

This module should teach students certain “soft” skills and must therefore draw heavily on instructor-led discussions, case studies and group work (brainstorming, role-playing, etc.) as well as interactive group seminars. This module could therefore start with two weeks of classroom sessions (ten days of lectures plus the intervening weekend, which can be used for team activities). That could be followed by two weeks of instructor-led e-learning and self-study during which students are required to prepare a group-written essay about some real-life situation and resulting in the development of a policy proposal to resolve the situation in the most beneficial way. This should include an impact assessment in order to validate the predicted benefit.

Total duration: Four weeks.

Study objectives and assessment

On completion of this module, students should understand the basic principles of strategic planning and innovation management. They should also have acquired negotiating skills relevant to stakeholder consultations and team work in policy development.

The overall module assessment should consist mainly of graded coursework (the various group exercises and the collectively written essay) and the results of the final test. The final test could take the form of a computerized test in which students answer multiple-choice questions based on the topics studied in this module.

Study resources

Delivery of this module will rely on a number of available literature sources on strategic planning, innovation management, technology forecasts and policy impact assessment.

4 SMTP elective modules

4.1 EM1: Option 1: Spectrum monitoring

Module content

This module will provide students with an understanding of the role and functions of radio spectrum monitoring. It is proposed that the module should cover the following subjects and concepts:

- the role of spectrum monitoring in the SM process; tasks of a monitoring service;
- the relationship between radio monitoring and other functional elements of the SM organization;
- how to set up a new monitoring service or improve an existing one:
  - What monitoring support is needed?
  - What monitoring facilities are needed to meet the requested monitoring support?
- ITU Radio Regulations, Recommendations, reports, and handbooks in relation to monitoring.

Proposed delivery mode and duration

Given that spectrum monitoring is dependent on the use of specialized equipment and facilities, this module requires hands-on immersion in the daily physical procedures of spectrum monitoring. Depending on the eventual format of the SMTP, this may be implemented in different ways.

- If the module is organized centrally, students may converge at some “best practice” spectrum monitoring organization or training facilities of a monitoring equipment manufacturer such as Rohde & Schwarz participating in the SMTP consortium, and during one week take part in a combination of introductory and theoretical lectures, followed by hands-on training and observation of how spectrum monitoring teams carry out their real life operations.
- Alternatively, students may have the introductory material delivered to them remotely, by distant lecturers using Internet video, before being assigned for a time to the spectrum monitoring departments of their own organizations, where they can observe and participate in work.

Upon completion of such combined introductory and practical immersion phases, students may be given time for self-paced study of reference materials and the completion of some assigned coursework, with counselling provided by the module tutor.

Total duration: Four weeks.

Study objectives and assessment

Upon completion of this module, students should be capable of clearly describing the role, function and basic techniques of spectrum monitoring, and have an understanding of the purpose and capabilities of different types of spectrum monitoring equipment. They should be able to demonstrate their ability to define monitoring tasks (checklists) and analyse their results (results list), as well as individually planning essential spectrum monitoring operations and measurements.

The assessment grade may comprise two parts: the grade awarded by the monitoring supervisor upon completion of the internship (e.g. based on the results of a hands-on test consisting of a set of tasks, such as carrying out specific measurements etc., at the end of the immersion period); and the grade awarded for a theoretical test upon completion of the module.

Study resources

The primary reference source for this module is the ITU-R Handbook on Spectrum Monitoring (2011). It may be further reinforced by a number of ITU-R Recommendations on the subject, as well as operational manuals for specific types of equipment. The SMS4DC Manual may also be used as a reference guide on linking automated SM systems to the monitoring software.

4.2 EM1: Option 2: Enforcement and type approval of equipment

Module content

This module will provide students with an understanding of the role of enforcement in SM and the role of the standardization of radio interfaces and national type approval of radio equipment. The main topics to be covered may include:

- the role of enforcement in the operation of SM organizations and supervision of spectrum users;
- typical national arrangements for enforcement, role and functioning of inspectorates;
- the roles of standardization and type approval (including declarations of conformity) of radio equipment;
- different national and international levels and regimes of type approval;
- the role and functions of type approval labs.

Proposed delivery mode and duration

Enforcement and type approval activities have two important components: the legal background and the supportive practical activities. Students therefore need to understand both these aspects. It may therefore be recommended that students start this module by studying the legal considerations. This part of the module may be arranged as self-paced study of training material and reference documents, with counselling provided by a module tutor. After completion (and assessment) of this part, the students' understanding of the theoretical material could be reinforced by practical immersion in daily activities of enforcement and type approval.

- If the module is organized centrally, students could meet for a week-long internship at some "best practice" NRA and take part in its enforcement and type approval activities.
- Alternatively, students may be assigned to the enforcement (inspectorate) and type approval departments of their own organizations for a time, where they could observe and participate in the work.

Total duration: Four weeks.

Study objectives and assessment

Upon completion of this module, the student should be capable of clearly describing the role and functions of enforcement, have an understanding of different type approval regimes and the functions of national type approval labs, and demonstrate understanding of the practical operational aspects of enforcement and type approval.

The assessment grade may comprise two parts: a grade based on a remotely administered theoretical test, and a grade awarded by the supervisor for the practical internship.

Study resources

The reference sources for this module are the various ITU-R handbooks and Recommendations, ITU-D country reports, as well as operational guides and similar reference material from different standardization organizations.

4.3 EM1: Option 3: Spectrum management for satellite systems

Module content

This module will provide students with an understanding of the management of radio spectrum related to satellite communication systems. The main topics to be covered might be:

- overall principles of SM for satellite systems;
- different types of satellite systems and their respective SM considerations;
- different types of Earth station;
- overview of the ITU Radio Regulations and Appendices pertaining to satellite systems;
- overview of ITU BR operational procedures and software for notification and recording of assignments to satellite systems.

Proposed delivery mode and duration

SM for satellite systems is an intrinsically international task in which ITU plays an essential role. It may therefore be recommended that completion of this module should require attendance at one of the regular ITU seminars addressing this subject. Physical attendance at the seminar could then be complemented by self-paced completion of a theoretical course, with consultation provided by module tutors, as well as some coursework assignments, e.g. to review independently some case study in SM for a particular type of satellite system.

It would also be beneficial for students to visit a large Earth station, such as a satellite network hub or teleport.

Total duration: Four weeks.

Study objectives and assessment

Upon completion of this module, the student should demonstrate an understanding of SM procedures for satellite communication systems as well as the respective roles of NRAs, satellite operators and ITU BR in that regard. Students should develop basic skills in using the relevant reference material (Radio Regulations and Appendices) and the ITU BR software for managing and recording assignments to satellite systems.

The assessment grade may consist of two parts: a grade for the theoretical test administered remotely and a grade awarded by the supervisor for completion of the assigned coursework (case study).

Study resources

The reference sources for this module are the various ITU-R handbooks and Recommendations, as well as operational guides for software and similar reference material from the ITU pertaining to satellite communications.

4.4 EM1: Option 4: Spectrum management for hf systems, science, maritime and amateur services

Module content

This module will provide students with an understanding of specific aspects of managing radio spectrum use by the above mentioned systems and services. Specific topics might include:

- managing diurnal and seasonal spectrum use by broadcasting and other systems in the HF bands;
- HF broadcasting schedules;
- spectrum requirements and protection of the operation of science services (including the special problem of defining the spectrum access rights of passive services whose stations may not be licensed);
- spectrum requirements and planning of assignments for maritime services;
- spectrum bands used by radio amateurs and their administrations.

Proposed delivery mode and duration

This module could be delivered as an instructor-led e-learning module. In order to reinforce understanding of the material, students may be given individual coursework assignments, e.g. to try resolving, at least on paper, some real-life SM-related problem occurring in the systems and services that are the module focus.

In addition, students completing this module could attend one of the ITU workshops on the subject.

Total duration: Four weeks.

Study objectives and assessment

Upon completion of this module, the student should demonstrate an understanding of spectrum requirements and the specific procedures for managing spectrum for HF systems, science, maritime and amateur services. The students should develop basic skills in using reference material from ITU (including relevant ITU-R study groups) and other institutions, including stakeholders in the respective fields (including IMO, URSI, IUCAF, and IARU), and in the procedures for managing and recording assignments to stations and systems of such services.

The assessment grade may comprise two parts: a grade for the remotely administered theoretical test and a grade given by the supervisor for completion of the assigned coursework.

Study resources

The reference sources for this module are the various ITU-R handbooks (such as the ITU-R Handbook on Amateur and amateur-satellite services) and recommendations, as well as operational guides for software and other relevant material from ITU and elsewhere.

4.5 EM1: Option 5: Spectrum management for aeronautical, radiodetermination and military services

Module content

This module will provide students with an understanding of specific aspects of managing radio spectrum use by the above systems and services. Accordingly, the following topics could be covered:

- SM for aeronautical services and cooperation with civil aviation authorities;
- interference between aeronautical and broadcasting services;
- SM for radiodetermination services;
- SM for military systems and cooperation with national defence authorities.

Proposed delivery mode and duration

It is recommended that this module be delivered as an instructor-led e-learning module. In order to reinforce understanding of the material, students may be given individual coursework assignments, e.g. to try to resolve, at least on paper, some real-life SM-related problem in the systems and services concerned.

It would also be beneficial if students could visit and acquire hands-on experience of real systems installed and used at their nearest airport and/or military facilities.

Total duration: Four weeks.

Study objectives and assessment

Upon completion of this module, the student should demonstrate an understanding of the spectrum requirements and specific procedures for managing spectrum for aeronautical and radiodetermination services and military systems. Students should develop basic skills in using the respective reference materials from ITU (including relevant ITU-R study groups) and other institutions, including stakeholders in the respective fields (such as ICAO for aeronautical services), and in the procedures for managing and recording assignments to stations and systems of such services.

The assessment grade may comprise two parts: a grade for the remotely administered theoretical test and a grade awarded by the supervisor for completion of the assigned coursework.

Study resources

The reference sources for this module are the various ITU-R handbooks and recommendations, as well as operational guides for software and similar reference material pertaining to the subject services from ITU and elsewhere (such as Annex 10 of the ICAO Handbook).

4.6 EM1: Option 6: Computer-aided spectrum management

Module content

This module will provide students with an understanding of the role and functions of automated SM systems and various other computer-aided SM tools. It is proposed that the module should cover the following subjects and concepts:

- the role of computer-aided tools in the SM process;
- automated SM systems: role, structure, functionalities;
- specialized computer-aided SM tools, such as those used for:

- EMC analysis;
- frequency planning and assignment;
- e-applications and publicity (www interfacing).

Proposed delivery mode and duration

Given that understanding computer-aided tools normally requires some practical experience of using such tools, it is recommended that this module should require some hands-on practice. Depending on the eventual format of the SMTP, this may be implemented in different ways.

- If the module is organized centrally, students may converge at some "best practice" SM organization such as an NRA that makes extensive use of advanced computer-aided SM tools, and over a period of one week take part in a combination of introductory and theoretical lectures followed by hands-on training and observation of the use of computer-aided tools in daily SM practice.
- Alternatively, students may have the introductory material delivered to them remotely, by distant lecturers using Internet video, before being assigned for internships to the relevant departments (i.e. those which operate computer-aided SM tools) in their own organizations, where they can observe and participate in their work.

Upon completion of such combined introductory and practical immersion phases, students may be given time for self-paced study of reference materials in consultation with a module tutor, and some assigned coursework.

Total duration: Four weeks.

Study objectives and assessment

Upon completion of this module, student should be capable of clearly describing the functionalities of various computer-aided SM tools, and demonstrate their ability to use such tools themselves for a defined set of essential SM tasks.

The assessment grade may comprise two parts: a grade awarded by the supervisor upon completion of the internship (e.g. based on the results of a hands-on test consisting of a set of specific tasks at the end of the practical work component), and a grade for a theoretical test upon completion of the module.

Study resources

The primary reference source for this module is the ITU-R Handbook on Computer-aided Techniques for Spectrum Management (2005) and the SMS4DC manual. It may be further reinforced by a number of ITU-R Recommendations on the subject as well as operational manuals for specific software tools (including commercial automated SM systems or public tools such as SEAMCAT).

4.7 EM2: Option 1: Advanced spectrum authorization regimes

Module content

The purpose of this advanced-path module is to provide students with an understanding of the ways in which the licensing of radiocommunication stations and services has been changing over the past century and the future trends in this important aspect of regulation. This module should be seen as a logical extension to the material provided in module OM4.

The topics to be covered in this module may include:

- apparatus vs. service (concession) licensing;
- class licensing and "commons";
- light-licensing;
- real-time authorization schemes (LSA, etc.);
- future trends.

Proposed delivery mode and duration

It is recommended that this module be delivered as an instructor-led e-learning module, including a live (web) seminar moderated by the module tutor to discuss the latest trends and review selected case studies. In order to reinforce their understanding of the material, students may be given individual coursework assignments, e.g. to analyse their respective national spectrum authorization practices and the evolution thereof, or to evaluate the recommendations of regional bodies like CEPT or the European Commission Radio Spectrum Policy Group.

Students not employed by an SM authority might be required to arrange a visit to their own NRA and familiarize themselves with its SM procedures.

Total duration: Four weeks.

Study objectives and assessment

Upon completion of this module, the students should demonstrate familiarity with the subject of authorization of radio spectrum use and the various forms it can take in practice, as well as an understanding of where the different forms of authorization may be most appropriately applied. Students should demonstrate basic skills in designing the essential elements of authorization frameworks, such as the minimal/typical requirements to be included with authorization of a specific type, the time-frames involved, and similar considerations.

The assessment grade may comprise two parts: a grade for the remotely administered theoretical test and a grade awarded by the supervisor for completion of the assigned coursework and participation in the concluding seminar.

Study resources

The reference sources for this module are the ITU-R Handbook on National Spectrum Management and various reports and Recommendations, as well as the external literature on the subject. Extensive use can also be made of documents from regional telecommunication organizations (e.g. CEPT, CITEL, APT).

4.8 EM2: Option 2: Socio-economic impact of spectrum regulation; competition and consumer protection

Module content

The purpose of this advanced-path module is to provide students with an understanding of the role of competition and consumer protection laws in the overall regulation of wireless service provision. This module should be seen as a logical extension to the material presented in modules OM4 and OM5.

The topics to be covered in this module may include:

- defining wireless markets and market segments;
- the role of competition, evaluating its intensity and impact;
- estimating the socio-economic impact of SM decisions;

- *Ex ante* vs. *ex post* approaches to the regulation of competition;
- supervision of markets, enforcement;
- consumer protection.

Proposed delivery mode and duration

It is recommended that this module be delivered as an instructor-led e-learning module, including live (web) seminars moderated by the module tutor, to discuss the latest trends on the subject and review selected case studies. In order to reinforce their understanding of the material, students may be given individual coursework assignments, such as analysing the socio-economic impact of some proposed SM decision in their own country.

It may also be recommended that students arrange study visit to their respective national market supervision authorities and/or consumer protection agencies and familiarize themselves with the activities of those bodies in supervising wireless communication markets and consumers.

Total duration: Four weeks.

Study objectives and assessment

Upon completion of this module, students should demonstrate familiarity with the subjects and definitions of wireless markets, competition and consumer protection, and show that they are able to apply general principles of socio-economic impact analysis to the proposed regulatory measures.

The assessment grade may comprise two parts: a grade for the remotely administered theoretical test, and a grade given by the supervisor for completion of the assigned coursework and participation in the concluding seminar.

Study resources

The reference sources for this module are to be found in the ITU-R Handbook on National Spectrum Management and various reports and Recommendations, as well as the external literature on the subject.

4.9 EM2: Option 3: Terrestrial tv broadcasting planning and digital transition

Module content

The purpose of this advanced-path module is to provide students with an understanding of the role of regional and international agreements in planning frequency agreements for broadcasting, and the problems and strategies involved in migrating from analogue to digital broadcasting (both radio and television). The future of broadcasting in light of the expansion of broadband and socio-economic arguments for alternative uses of the UHF spectrum will also be explored.

Topics to be covered in this module could include:

- technical considerations and socio-economic objectives of terrestrial TV broadcasting;
- digital TV technology and the choice of DVB-T transmission standards;
- international conferences on band planning and their deliverables;
- international and national processes of negotiating and planning allotments/assignments for TV broadcasting;
- scenarios for the analogue to digital switch-over.

Proposed delivery mode and duration

It is recommended that this module be delivered as an instructor-led e-learning module, including live (web) seminars moderated by the module tutor, to discuss the latest trends on the subject and review selected case studies. In order to reinforce understanding of the material, students may be given individual coursework assignments, e.g. to develop a strategy and elements of a technical plan for a (simplified) case of TV broadcasting development/digital switch-over in (a part of) their country, or an analysis of UHF band coexistence between incumbent users and potential new service offerings.

A visit to a local broadcasting station (studio and transmitting facilities) could also be a requirement for completion of this module.

Total duration: Four weeks.

Study objectives and assessment

Upon completion of this module, students should demonstrate familiarity with the subject of strategic and technical planning of terrestrial digital TV broadcasting and the policy issues of socio-economic optimization of band allocations. Students should demonstrate basic skills of analysing international agreements on the subject and carrying out national planning in support of digital TV broadcasting (or planning in support of DTV and cellular mobile band sharing).

The assessment grade may comprise two parts: a grade for the remotely administered theoretical test and a grade from the supervisor for completion of the assigned coursework and participation in the concluding seminar.

Study resources

The reference sources for this module are to be found in relevant ITU-R handbooks and various reports, Recommendations and other documents (including RRC-06 deliverables, national delegation reports on WRC-07, and so on) as well as BDT reports and guidelines on the subject. Another important reference source may be found in documents of regional broadcasting organizations (e.g. EBU, ABU, CBU, ASBU, and WBU). The significant body of external literature on DVB-T may also be used.

4.10 EM2: Option 4: Opportunistic spectrum access and cognitive radio

Module content

The purpose of this advanced-path module is to provide students with an understanding of the emerging paradigm of opportunistic spectrum access (OSA), also called dynamic spectrum access (DSA). This module should be seen as a logical extension of the material in modules OM3 and OM4. It could also be beneficially combined with elective module EM2-Option 1 (Advanced spectrum authorization regimes).

The topics to be covered in this module could include:

- concepts, implementation and regulatory challenges of software-defined radio (SDR) and cognitive radio (CR);
- SDR/CR standardization and conformance testing for reconfigurable radios;
- limits and requirements of spectrum availability determination for OSA-based applications;
- autonomous vs network-connected CR;
- location awareness and automated (policy-controlled) frequency selection;
- authorized/licensed shared access vs license-exempt secondaries;
- OSA case study: TV “white space” devices.

Proposed delivery mode and duration

It is recommended that this module be delivered as an instructor-led e-learning module, possibly complemented by a live (web) seminar moderated by the module tutor, to discuss the latest trends on the subject and review selected case studies. In order to reinforce understanding of the material, students may be given individual coursework assignments, e.g. to propose a vision and tentative design of a regulatory/technical framework for implementing OSA in their country.

Total duration: Four weeks.

Study objectives and assessment

Upon completion of this module, students should be able to demonstrate an understanding of the concepts and emerging technologies of CR, reconfigurable radio and OSA.

The assessment grade may comprise two parts: a grade for the remotely administered theoretical test and a grade from the supervisor for completion of the assigned coursework and participation in the concluding seminar.

Study resources

These will include newly produced ITU reports on the subject, policy documents from regional organizations (such as the EU and CEPT), and national documents (most notably from the United States and United Kingdom). Reference sources also include the numerous recent books and articles on the subject.

5 Setting up the course and preparing syllabuses: Possible contributing institutions and experts

Universities

If the idea of conferring a university degree upon completion of the SMTP is adopted, partnerships will need to be established with suitable teaching partners. It will be important to find a lead university willing to act as the diploma-issuing institution (or primary diploma-issuing institution, if more than one institution is involved).

Table 2 provides a list of universities which could be contacted with a proposal for them to become a lead university for the SMTP. This list is deliberately limited to universities in Western Europe because they are accustomed to the ECTS framework and international multi-university courses. Choosing a prominent Western European university as the diploma-issuing institution would enhance the image of the programme and foster truly global recognition of the degree awarded. The universities in Table 2 were chosen from the top 100 world universities[17] and have strong credentials in the field of telecommunications. The listing order corresponds to the university world rank.

[17] Times Higher Education. The World University Rankings 2014-2015: European region: www.timeshighereducation.co.uk/world-university-rankings/2011-2012/europe.html

Table 2: Universities that could be asked to become an SMTP diploma-issuing institution

University	Department	World ranking 2014
École Polytechnique Fédérale de Lausanne, Switzerland	School of Computer and Communication Sciences	34
King's College London, United Kingdom	Telecommunications Institute	43
Delft University of Technology, The Netherlands	Department of Telecommunications	42

It should, however, be stressed that the suggested list is entirely arbitrary and should not be regarded as exhaustive or as somehow limiting ITU in its search for suitable university partners. In particular, the world ranking of any candidate institution should not be regarded as an essential consideration, since the ranking process itself, which attempts to gauge the performance and comparative reputation of some 20 000 institutions of higher education worldwide, inevitably involves some uncertainties.

As regards other universities that might be engaged across the world to join the SMTP consortium and teach some specific modules, it would appear futile and meaningless to try to list them all or offer anything more than a limited and highly arbitrary "snapshot" selection.

Instead, it is recommended that the other partner institutions be identified in either or both of the following ways:

- through coordination by the selected lead university, which is likely to have its own network of global partners and "sister" universities with well-established and functioning collaborative links;
- in consultation with ITU CoEs in the different regions. In such cases, it may be logical to arrange for the respective on-site lecturing to take place at the CoEs, with the involvement of teaching staff from local universities, administrations and industry, as appropriate.

Whichever route is chosen for selecting other participating universities for the SMTP consortium, the eventual partners may offer to teach some particular module(s) and grant certificates/credits for completion of a given module. Depending on the ultimate composition of the consortia and the overall teaching and examination arrangements, the other partnering universities could even consider joining as co-sponsoring institutions for the diploma granted at the end of the course.

Experts to develop the programme syllabuses

The universities and/or CoEs, together with any other SMTP teaching consortium partners (as discussed in Section 2.4), will certainly wish to have a hand in shaping the final teaching programmes and the respective teaching and examination materials. However, in order to ensure a uniformly high quality of different modules, and strong professional and international foundations, it may be recommended that a team of international experts in different sub-fields of SM should be appointed for the purpose of developing:

- syllabuses for the respective modules:
  - list of topics that need to be covered;
  - apportionment of the instructor-led/self-study time needed to complete the study topics, from the overall time (ECTS credit-based) allocated to a given module;
  - list of ITU and other international study materials, textbooks and similar references to be used by tutors and students; and

- associated sets of module completion/examination requirements:
  - minimum set of knowledge and skills to be obtained upon completion of the module;
  - proposal for formal assessment of knowledge/skills acquired, through a combination of examination and practical tests.

It is recommended that the experts responsible for developing module syllabuses should be selected from among the ranks of existing BDT experts and ITU study group leaders in the specialist SM topics. As regards the required number of experts, it may be noted that:

- the proposed initial complement of the SMTP consists of 14 different modules;
- the list of elective modules is very tentative and could easily be expanded with the offer of some (two to three) additional specialized modules; and
- the topics of some modules are sufficiently close to allow some experts to cover at least two related topics.

It is recommended that the team responsible for developing the syllabuses of SMTP modules should consist of approximately ten experts from different sub-fields of SM, as tentatively proposed in Table 3.

Table 3: Proposed composition of the team of international experts to develop SMTP syllabuses

Subject areas	Allocated SMTP modules from initial list	Number of expert
Spectrum regulation and planning	OM1, EM1-3, EM1-4, EM1-5	3
Spectrum engineering and technical innovation	OM2, EM2-3, EM2-4; EM1-6	2-3
Economic, legal and market aspects of SM	OM4, EM2-1, EM2-2	2
Wireless technologies, policies for wireless innovation	OM3, OM5	1-2
Spectrum monitoring and enforcement	EM1-1, EM1-2	1-2
	Total:	**10**

Note that in Table 2 the proposed division into subject areas and respective attribution of SMTP modules is very general and could easily be adjusted, as can the associated number of experts per area, depending on the skill-sets of the experts finally selected.

Time required

Developing and setting in motion such a complex undertaking as the SMTP would inevitably take significant time, require many hurdles to be overcome and many unknowns to be resolved, as well as involving negotiations with the prospective teaching consortium partners. This process may take one or two years, from the initial decision until the first class of students is enrolled. The most crucial factor determining the time-frame for necessary preparations would be the decision as to whether to involve universities and offer a university degree at the end of the course, or make the SMTP a professional development course delivered through the ITU Academy and CoEs.

A university-led course would clearly take longer to organize, as the universities tend to be conservatively-minded institutions with many formal layers created to safeguard the formal credibility of their teaching programmes. It would therefore require extra time for them to embrace the SMTP concept and weave it into their formal teaching structures and diploma/certification arrangements.

On the other hand, choosing the route of an ITU Academy/CoE-led professional course may be easier and faster to get up and running, given that in such a case ITU would maintain full control of the proceedings.

Another important element of the course initiation process would be the phase of developing the syllabuses for the constituent modules. It could be recommended that this phase be initiated immediately after taking the principal decision to establish an SMTP. It is estimated that developing syllabuses and examination requirements would involve about one man-month for each module. Given that the working team would be made up of several experts, each working with one or two modules at most, this phase of work may be completed within two to three months (allowing for some extra time for mobilization of experts and eventual review/adoption of their deliverables).

Once the syllabuses for all the modules and the composition of the teaching consortium are established, the work could proceed toward fixing the module delivery options and developing the actual teaching material for classroom lectures, e-learning (multimedia) and laboratory exercises. This phase would take longer, as developing teaching material for each module may require one to three man-months of work. However, the development of different modules could run in parallel, potentially shortening the overall time required for completion of this phase to around half a year.

Last but not least, it would be important for overall timing to consider the issue of the language of instruction for teaching (and testing) the SMTP students. It is recommended to start with one language, such as English, while aiming eventually to expand to include other official ITU languages as well.

6 Principles of student assessment and grading

As mentioned previously, some kind of formalized assessment of learning outcomes and the professional knowledge and skills attained will be a critical element of the SMTP. It will therefore be necessary to ensure that each study module has an associated examination procedure. This could be a set of questions to be answered, problems to be solved, analyses to be written, or practical tasks to be carried out. If the SMTP is developed as a university affiliated, academic credit-based course, the type and scope of a module examination would ultimately be defined by the university responsible for the module.

For class-delivered instruction, the examination and practical tests could take place at the end of the instruction period. For e-learning modules and modules involving combined teaching modes, the examination could be organized remotely, using online tools.

It would thus appear necessary to complement the syllabus of each SMTP module with the outline of a vision for the formal assessment of students upon completion of each module. Depending on the type of material taught in a given module, the formal assessment could take one or more of the following forms:

- examination, typically to be completed within a prescribed time interval, using electronic (online) tools with multiple-choice questions;
- written report/coursework showing solutions to assigned problems obtained using the analytical and computational skills acquired while completing the module;
- written essay about the analysis of a problem issue, demonstrating the student's background research and analytical skills, understanding of contextual issues and possible sensitivities involved in resolution;
- results of practical (hands-on) proficiency tests, such as in practical use of certain SM tools, radio monitoring equipment, and so on;
- grading of the student's participation in seminars.

Regardless of the form or combination chosen, each submission should be graded on the chosen scale with some grade to be considered as the minimum pass grade (e.g. 5 on a scale of 10). In the case of an examination, the grading would be based on a straightforward computation of the relative proportions of passed and failed questions. For other forms of assessment, the grading would be the responsibility of a tutor.

As was discussed in the previous section, it is proposed that the international experts charged with developing detailed syllabuses for different modules should also be required to propose the most fitting method or combination of methods of final assessment. This would ultimately be reviewed and substantiated/confirmed by the institutional partner (university, CoEs or other institution) that assumes responsibility for teaching a particular module. The grading scale and choice of pass grade would need to be confirmed with the institutional partners, as this may concern their usual practice and certain statutory principles governing requirements for the award of a formal qualification.

If the overall structure of the SMTP outlined in Figure 1 is accepted, special consideration will need to be given to the design of the admittance assessment as a prerequisite for bypassing the basic level and entering the course path at the advanced level. This assessment may be arranged as a multi-part exam, with subsections associated with each of the obligatory modules (OM1-OM3) and a proportional selection of questions reflecting the material presented in the basic level elective modules (EM1 Options 1-5).

Provision should be made at the end of the programme for a final assessment.

- In the case of the university-affiliated SMTP delivery option, the final evaluation would take the form of the Master's thesis defence, during which students would have to demonstrate their overall proficiency in the subject of SM and their deep understanding of their chosen professional specialization. Students passing this evaluation would receive a Master of Science diploma with the usual supplement listing grades received for all the individual study modules completed.
- In the case of the SMTP as a professional certification course, the final evaluation would involve a process whereby the student's grading for all the individual modules is reviewed and some aggregate evaluation made as to whether or not he or she passes the entire course. The aggregate evaluation may assume different weighting factors for different modules (for example, higher ones for some compulsory modules and lower weightings for the elective modules). The precise values of weighting factors and the ultimate aggregate passing grade need to be decided by the ultimate authority issuing the certificates, e.g. the ITU Academy.

It may be observed in conclusion that the SMTP would benefit from having an examination board made up of prominent SM experts, who would be responsible for vetting and supervising the examination processes, including where appropriate a defence of the Master's thesis.

7 Conclusion

Based on its overview of the current situation, the report concludes that the SMTP can successfully create a unique and credible niche, complementing the existing professional SM training options and promoting the harmonization of SM practices. To this end, the SMTP needs to be broad in scope and international in character, with tutors and participating institutions of the highest quality in order to ensure the value of the programme and the reputation of its diploma. It should strive to establish itself as the global "gold standard" for SM training.

An essential differentiator for the SMTP would be its formalized assessment of learning outcomes in terms of professional skills and qualifications acquired, supported by the award of a diploma representing a recognized academic level such as Master of Science.

The following main options may be considered:

- **Option A:** the SMTP becomes an international course offered by a consortium of participating universities under the aegis of the ITU Academy and leading to a university Master's degree awarded to graduates upon successful completion of the course.
- **Option B**: the SMTP becoming a professional training course organized solely by the ITU Academy, perhaps delivered through training facilities and/or the ITU Academy platform under the aegis of ITU CoEs, with the possibility of being driven by ITU staff, ITU-R study group experts and/or ITU-D

experts, and possibly with assistance from ITU-R sector industry partners or CoE partners. Upon completion of the training (including successful passing of all assessment tests/exams), trainees would receive a professional "Master of Spectrum Management" certificate granted in the name of ITU/ITU Academy.

- **Option C**: a combination of Options A and B: the SMTP becomes an international university Master's course offered by a consortium of participating universities but organized in collaboration with ITU-D/ITU-R external experts (who would, for example, lecture on actual case studies) and ITU-R industry partners, especially for practice and laboratory exercises, under the auspices of the ITU Academy. Such a course would result in the award of a university Master's-level diploma to successful graduates.
- **Option D:** the SMTP could become a guide for self-study and training through practical experience, in which case ITU and the ITU Academy would develop the training material, offer student counselling opportunities, and ultimately assume responsibility for the professional examination, i.e. the testing of knowledge and skills to an established standard. For the latter task ITU would need to develop and administer the final assessment tests for each module.

The justification for the different options and their respective advantages and drawbacks are described in this report, along with the proposed structure, content and duration of study modules.

In addition, the report recommends the following principles for composing the SMTP course:

- Modular structure with a set of obligatory and elective modules; the proposed complement of the modules and possible study tracks are shown in the annex to this report.
- Use of the ECTS study credits systems as a well-known student-centric system of describing the amount and worth of study completed, which then opens up the possibility of transfer and accumulation of credits between teaching institutions towards the completion of a formal educational degree.
- Establishment of an international team of experts charged with developing detailed syllabuses and assessment principles for particular modules. This phase may take up to three month and could be carried out in parallel with the search for institutional partners to make up the SMTP teaching consortium.
- Development of content in English (initially) with the possibility of expansion to include other official languages of ITU.

Depending on the chosen implementation option, setting up the SMTP may take one to two years.

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Abbreviations and acronyms

ABU	Asia-Pacific Broadcasting Union
APT	Asia-Pacific Telecommunity
ASBU	Arab States Broadcasting Union
ATU	African Telecommunications Union
BDT	Telecommunication Development Bureau (ITU)
BR	Radiocommunication Bureau (ITU)
CATS	Credit Accumulation and Transfer Scheme (United Kingdom)
CBU	Caribbean Broadcasting Union
CEPT	European Conference of Postal and Telecommunications Administrations
CITEL	Inter-American Telecommunication Commission
CoE	centre of excellence (part of ITU system for the dissemination of knowledge and good practices)
CR	cognitive radio
DSA	dynamic spectrum access
DVB-T	digital video broadcasting - terrestrial
EBU	European Broadcasting Union
ECTS	European Credit Transfer and Accumulation System
EM	elective module
EMC	electromagnetic compatibility
EU	European Union
FCC	Federal Communications Commission (United States)
GDP	gross domestic product
GSMA	Global System for Mobile Communications Association
HCM	Harmonized Coordination Method (European framework agreement for cross-border coordination)
IARU	International Amateur Radio Union
ICAO	International Civil Aviation Authority
ICT	information and communication technology
IEEE	Institute of Electrical and Electronics Engineers
IMO	International Maritime Organization
ITU	International Telecommunication Union
ITU-D	Telecommunication Development Sector (ITU)
ITU-R	Radiocommunication Sector (ITU)
ITU-T	Telecommunication Standardization Sector (ITU)

IUCAF	Inter-Union Commission on Allocation of Frequencies for Radio Astronomy and Space Science
LSA	licensed shared access
MCL	minimum coupling loss (an EMC evaluation method)
NRA	national regulatory authority (for telecommunications)
NTIA	National Telecommunications and Information Administration (United States)
OM	obligatory module
OSA	opportunistic spectrum access
PMP	point-to-multipoint
RFID	radio frequency identification (e.g. of items on sale)
RRC	regional radiocommunication conference
SDR	software-defined radio
SEAMCAT	Spectrum Engineering Advanced Monte Carlo Analysis Tool
SG	study group (ITU)
SM	spectrum management
SMS4DC	Spectrum Management System for Developing Countries (a software tool distributed by BDT)
SMTP	spectrum management training programme
URSI	International Union of Radio Science
USTTI	United States Telecommunications Training Institute
WBU	World Broadcasting Unions
WCET	Wireless Communication Engineering Technologies (professional certification programme of IEEE)
WLAN	wireless local area network
WPAN	wireless private area network
WRC	world radiocommunication conference

Annex: Matrix of study tracks and their respective module combinations

Track option	Time Frame												Certificate awarded
	September	October	November	December	January	February	March	April	May	June	July	August	
Full course (University diploma course option)	OM1	OM2	OM3	EM1	Holidays	OM4	OM5	EM2-A	EM2-B	Master Thesis		Defense	MSci Dipl
Advanced Level (University diploma course option)					Entry Eval	OM4	OM5	EM2-A	EM2-B	Master Thesis		Defense	MSci Dipl
Full course (Professional certification course option)	OM1	OM2	OM3	EM1	Holidays	OM4	OM5	EM2-A	EM2-B	Final Eval			Professional certificate
Advanced Level (Professional certification course option)					Entry Eval	OM4	OM5	EM2-A	EM2-B	Final Eval			Professional certificate

Legend:

OMx	Obligatory module
EMx	Elective module
Eval	Evaluation: Entry, Final, Master Thesis Defense
Holidays	Holidays, also time for finalization of modules not completed during the semester

OM1:	Legal Basis and Regulatory Framework of Spectrum Management
OM2:	Spectrum Engineering Fundamentals
OM3:	Wireless Telecommunications Technologies
EM1-1:	Spectrum Monitoring
EM1-2:	Enforcement and Type Approval of Equipment
EM1-3:	SM for Satellite Systems
EM1-4:	SM for HF Systems, Science, Maritime and Amateur Services
EM1-5:	SM for Aeronautical and Radiodetermination Services and Military Systems
EM1-6:	Computer-Aided Tools for SM

OM4:	Economic and Market Tools of Spectrum Management
OM5:	Strategic Planning and Policies for Wireless Innovation
EM2-1:	Legal sub-track: Advanced Spectrum Authorization Regimes
EM2-2:	Legal sub-track: Socio-Economics; Competition and Consumer Protection
EM2-3:	Technical sub-track: Terrestrial TV Broadcasting Digital Transition
EM2-4:	Technical sub-track: Opportunistic Spectrum Access and Cognitive Radio

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