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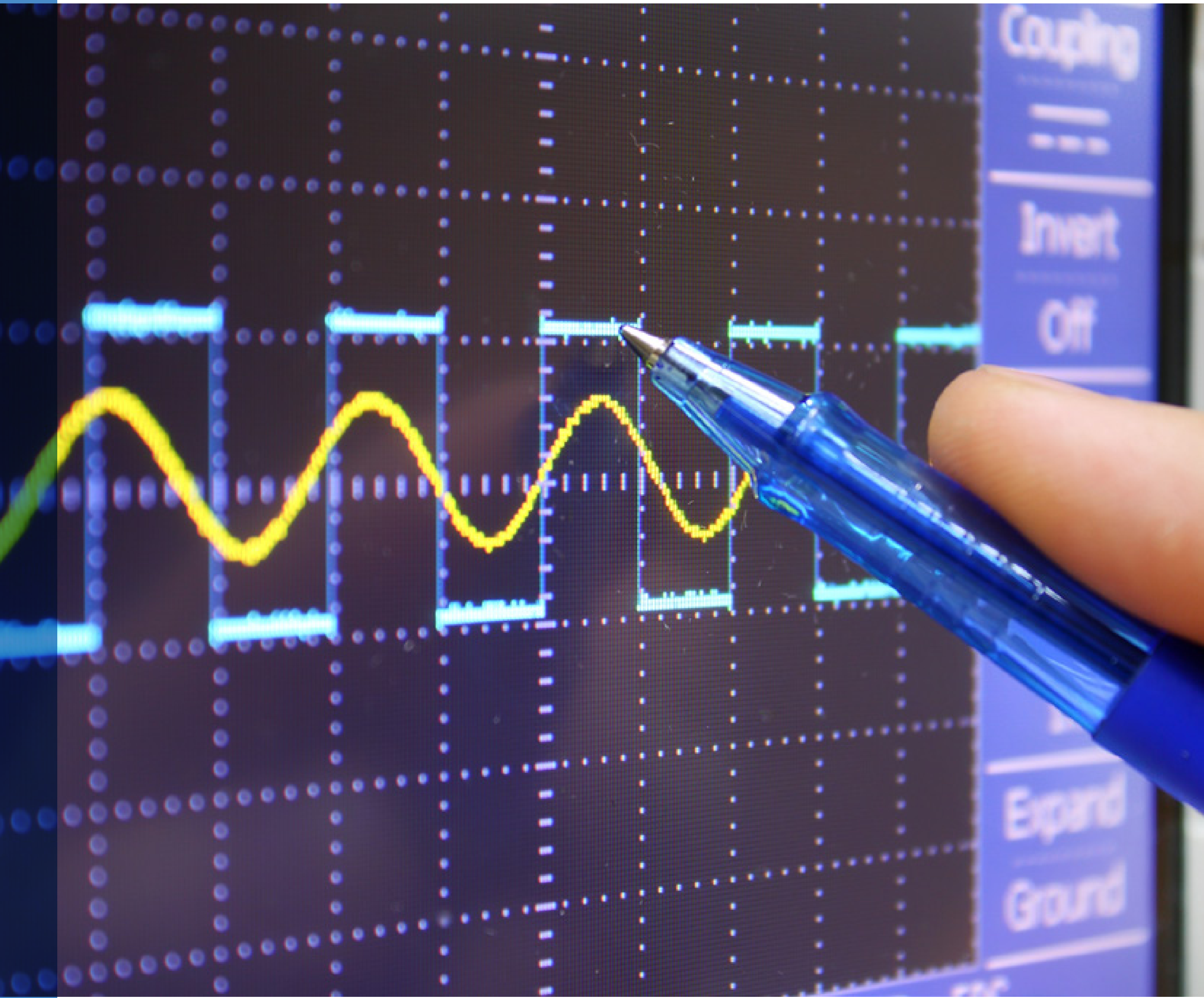

Handbook on Computer-Aided Techniques for Spectrum Management (CAT)

Edition of 2015

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Preface

The present 5th edition of this Handbook – Computer Aided Techniques for Spectrum Management (CAT) is the result of substantial efforts invested by experts – volunteers that offered their excellent knowledge and experience on Spectrum Management matters in the service of the ITU constituencies.

It is intended for the use by Administrations of Member States and Sector Members as well as those individuals whose work is related to the Automated Spectrum Management processes. The Handbook consists of five (5) Chapters and eleven (11) Annexes that offer basic guidelines as to the Automated Spectrum Management System and its implementation.

Description of computer techniques (Chapter 2) and spectrum management data and database management (Chapter 3) are complemented with principles of electronic information exchange (Chapter 4) that includes a number of relevant case studies. The examples of automated spectrum management procedures conclude the core texts of the Handbook (Chapter 5).

Annex 1 contains spectrum management data that can be used for specifying national needs for frequency assignments and notification data.

Various models of how to implement the Automated Spectrum Management and Spectrum Monitoring processes are given in Annexes 2 to 11.

François Rancy,
Director, Radiocommunication Bureau

Foreword

The present Handbook on Computer Aided Techniques for Spectrum Management (CAT) should be seen as a complement to the other two ITU products on the related subject, i.e. the publication of the Handbook on National Spectrum Management (edition 2015) and Handbook on Spectrum Monitoring (edition 2011).

The CAT first edition was published in 1983 and was subsequently updated in 1990, 1999 and 2005. Throughout this period, the topic of national spectrum management has evolved and became the central hot spot in the activities of all telecommunication administrations. This is particularly true for developing countries where dramatic development of ICT technologies and their wide application led to a heavy increase in related spectrum usage.

This has made the question of an efficient and automated spectrum management process a priority for each administration. The Rapporteur Group was established by ITU-R Working Party 1A and endorsed by SG 1 in June 2011 in order to review the outdated texts and to prepare this new version of CAT Handbook.

It was chaired by the Rapporteur of the Rapporteur Group, Mr. Sultan A. Al Balooshi of United Arab Emirates, as well as by Mr. Andrey Lashkevich of the Russian Federation and Ms. B. Sykes of the United States of America during some meetings.

The key elements required for spectrum management have been reviewed and successfully updated with a view to make this publication user friendly. The user-reader may find basic material and numerous models for the efficient implementation of Automated Spectrum Management projects that may assist him/her in reaching the objective – implement Automated Spectrum Management as soon as possible.

Sultan A. Al Balooshi,
Rapporteur, WP 1A CAT Rapporteur Group

CHAPTER 1

Introduction

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1.1 Background

The use of computers in the spectrum management process has become crucial for most administrations that are faced with the ever-increasing use of the radio frequencies. Several aspects of this process, such as frequency coordination, administrative procedures (registration and issuing of licences) and notifications of assignments to the ITU according to the Radio Regulations, are crucial in the establishment of a computer-automated process. The first aspect to be considered is the establishment of a national body and associated regulations.

Recognition of these needs by the administrations led WARC-79 to approve Recommendation No. 31 that, followed by CCIR Decision 27-2, specified that a Handbook on “Spectrum Management and Computer-Aided Techniques” should be prepared and revised periodically. The first edition of this Handbook was produced in 1983 and revised twice (1986 and 1990). It was later recognized that, due to the complexity of the two subjects and the fact that spectrum management organization and associated computer-aided techniques were different disciplines, they should be dealt with in two separate Handbooks. As a consequence, decisions were taken in this respect by Radiocommunication Study Group 1. Based on these decisions and on the guidance established by Resolution ITU-R 12, the Handbook on National Spectrum Management was published in 1995 and updated in 2005 and in 2014 with emphasis on organizational and technical aspects rather than those related to the use of computers. This Handbook on Computer-Aided Techniques for Spectrum Management, originally published in 1999 and revised in 2005 and in the present edition, supplements the above-mentioned Handbook and offers state-of-the-art views on the possibilities of automation of various aspects of the spectrum management process. In general, the Handbook on National Spectrum Management provides only an introduction to automation, whereas this Handbook is much more detailed and provides substantial advice as to how to automate spectrum management operations.

1.2 When automation of the spectrum management process is needed

The first question that is raised when automation of the spectrum management process of a country is considered must be: “Is it really needed?”. The definitive answer in every case is “Yes”. However, if an automated spectrum management system is not properly designed, it could be a burden rather than a solution to an administration.

For any automated spectrum management system to be successful, several areas need to be addressed and clearly articulated by the administration proposing such a project. The areas that should be considered and the questions that should be answered include:

– Existence of a regulatory infrastructure for spectrum management. This means that a spectrum management authority and its supporting units are in place and effectively operating. These include, but are not limited to, legislation, regulations and operational policies and procedures.

– Definition of scope and project objectives for applying a computer-aided spectrum management system. Why is automation being considered? Have new directives been issued requiring that resources be redirected to other functions within the administration's mandate? Is automation seen as a tool for coping with an increasing workload? What portions of processes or tasks within each spectrum management unit are to be considered for automation? Are some manual processes better left untouched?

– Determination of available internal and external resource allocations. An assessment must be made as to what financial and human resources will be required and dedicated to the project. Also, will it be necessary to obtain special funding authority?

– How is the system to be developed or implemented, by in-house resources, by contract, by purchasing available software, or by a combination of these? Does the administration possess the necessary regulatory and technical experts or will it require assistance?

– What limits or boundaries, if any, are to be imposed in automation development? Will the magnitude of the project dictate its development over many phases or years?

– Development of work plans and schedules showing project phases, tasks and status reporting milestones. The use of any graphical illustrations, such as Gantt charts, for the work plan and scheduling should be considered.

– Definition of user specifications. Needs and requirements of the end users must be clearly defined to ensure their proper translation to detailed design specifications. The scope of the spectrum management functions that should be automated and the extent to which each will be automated must be clearly defined. Any contract to be awarded must contain a clear and comprehensive statement of work.
– Identification of operational requirements. Each task or activity contains its own operational requirements that must be easily interpreted into a sequence of steps such as flow charts or pseudo codes.
– Establishment of functional and technical specifications. These specifications chart out the development of the system and are the basis of the detailed design.
– Availability of organizational and procedural documentation of existing systems and operations. System developers will need access to this documentation as they will invariably need to become themselves quasi-regulatory/technical experts before the translation of existing operations and procedures can begin.
– If contractors are to be considered, their performance history must be examined. Does the contractor have the requisite skilled or experienced system developers to see the project through to completion and implementation? Previously delivered contracts should be reviewed to determine or assess any related experience that can be applied to the proposed contract.

The items listed above are for the guidance of an administration in considering the decisions on the establishment, design, development and implementation of a computerized spectrum management system.

1.3 The benefits of automation of the spectrum management process

Computer-aided techniques have become commonplace in administrations in order for them to be able to manage data and to perform the necessary technical analytical studies associated with spectrum management. Furthermore, technological developments have led to the continuous reduction in the cost of computer systems, in particular of powerful microcomputers, thus making the application of computer-aided techniques to spectrum management a practical solution.

To maximize the benefits of the introduction of computer-aided solutions for spectrum management, the first step should be to evaluate the application of computer systems to a specific spectrum management situation. The various types of existing computer hardware and software available should be analysed. Their use should be embedded in a clearly defined structure with well-defined functions of national spectrum management.

Once this is done, administrations may benefit from such an integrated system through timeliness and effectiveness of the following tasks:

– verification of the compliance of frequency assignment requests with the national and international tables of frequency allocations and their associated footnotes;
– verification that a set of equipment (transmitter, receiver and antenna) proposed to be used in a certain radio link has previously been submitted and passed the appropriate certification process or meets other mutual recognition agreement standards;
– more accurate and optimized response to frequency assignment requests, through the selection of appropriate channels taking into account details such as terrain characteristics;
– automatic and decentralized on-line issue and renewal of licences with invoices (law must allow for electronic signatures);
– appropriate treatment of radio monitoring data (see ITU Handbook on Spectrum Monitoring (edition 2011));
– the establishment of a more expeditious and fully documented, timely billing of customers for their use of the spectrum;
– more accurate preparation and electronic submission of notification forms to be sent to ITU, in view of the automatic data validation process which can be implemented;
– the availability of electronic exchange of data between administrations or between an administration and the ITU (see Recommendation ITU-R SM.668);
– increased transparency and data availability to users inside and outside the administration.

The total number of data elements to support all these functions is rather large. The objectives of the national authority largely influence the need for many of the data elements. For example, the amount of data required to achieve meaningful and valid EMC computation grows with the state of congestion of the spectrum. They are related to the density of radiocommunication equipment in use in a country and thus to the infrastructure of the country. This can lead to hundreds of fields of data for all files according to Annex 1. However, in many cases the required data may be reduced to a limited number of basic data elements.

The Telecommunication Development (ITU-D) and Radiocommunication (ITU-R) Sectors of the ITU have been cooperating since 1998 in a joint activity to assist developing countries with their national spectrum management functions. This activity was established by Resolution 9 of the World Telecommunication Development Conference 1998 (WTDC-98) and revised by WTDC-02 and WTDC-06. ITU-D and ITU-R established a joint group of spectrum management experts from developed and developing countries to identify the specific needs of developing countries. The work is done in stages using questionnaires, circulated to all administrations, to obtain detailed information on national spectrum practices and the use of the spectrum in frequency ranges identified as having particular interest to developing countries. At WTDC-10, Resolution 9 was further revised to address the national technical and economic approaches to spectrum management and spectrum monitoring, as well as to continue the development of the Spectrum Fees (SF) Database, incorporating national experiences, and to provide additional guidelines and case studies, based on contributions from administrations. At WTDC-14, Resolution 9 was again revised in order to i) report on national technical, economic and financial approaches to, and challenges of, spectrum management and spectrum monitoring, taking into consideration development trends in spectrum management, case studies on spectrum redeployment, licensing processes and best practices implemented in spectrum monitoring around the world, including consideration of new spectrum-sharing approaches; ii) continue the development of the SF Database, incorporating national experiences, and provide additional guidelines and case studies, based on contributions from administrations; iii) update the information available in national frequency allocation tables and make the Resolution 9 and ICT Eye portals complementary; iv) compile case studies and collect best practices regarding national uses of shared spectrum access , including DSA, and study the economic and social benefits arising from the effective sharing of spectrum resources; and v) continue to gather the necessary information on activities carried out by ITU-D Study Groups 1 and 2, ITU-R Study Group 1 and relevant BDT programmes.

A report on the first stage of the work was published by the ITU during 2002, including a database. Among the findings from the first questionnaire was the need for assistance in setting up of computerized frequency management and monitoring systems – a need which this Handbook is intended to help address. During 2002 the joint group began its work on the second stage of the report, with an additional responsibility to complete the database of information on methods that administrations are using to calculate fees for use the spectrum. This work was completed and the report published in 2004. The third stage was implemented during the period 2006-2010 and resulted in the publication of the Report on Resolution 9 (Rev. Doha, 2006) titled "Participation of countries, particularly developing countries in spectrum management 2010"[1]. In addition, Guidelines for the establishment of a coherent system of radio-frequency usage fees were also published[2]. The implementation of the fourth stage was completed and presented at WTDC-14[3].

Many ITU-R activities have been automated. The Terrestrial Radiocommunications System (TeRaSys) and the Space Network System (SNS) of the Radiocommunication Bureau (Bureau or BR) are the computerized tools used by the Bureau to process the frequency assignment/allotment notices submitted by administrations. The systems also maintain the Master International Frequency Register, as well as the frequency assignment and allotment Plans. This data is available in electronic format on the web. The data is thus readily available

[1] The ITU Report on Resolution 9 (Rev. Doha, 2006) is available at: http://www.itu.int/pub/D-STG-SG02.RES09-2010.

[2] ITU Guidelines for the establishment of a coherent system of radio-frequency usage fees are available at: http://www.itu.int/pub/D-STG-SG02.FEES-1-2010.

[3] The ITU Report on Resolution 9 (Rev. Hyderabad, 2010) is available at: http://www.itu.int/pub/D-STG-SG02.RES09.1-2014.

in the defined format for national use for enquiries or in a database. Also available in electronic form every two weeks is the BR International Frequency Information Circular (BR IFIC) with information on notified and recorded terrestrial and space assignments/allotments on DVD. BR IFIC is disseminated on two separate DVDs, for terrestrial and space services respectively.

In addition, the BR maintains and updates the database of coast and ship stations accessible through Maritime mobile Access and Retrieval System (MARS), the database of available frequencies/frequency bands for use in emergency situations and summaries of monitoring results received from administrations in the context of the regular and special monitoring programs.

1.4 Steps to acquire automation of spectrum management

The transition from a manual or semi-manual spectrum management operation to an automated one involves many considerations. Several factors should be taken into account before starting the transition to an automated system:

– there is an infrastructure that should be analysed, planned and carried out before starting an automated system. Some of the steps required for this planning are: a study of the methods that can be used to adapt established manual procedures to an automated system, including the possible acceptance of the new procedures by users; training of the core of specialized staff for carrying out the automated task; consideration of the source of funds required for automation; and consideration and analysis of the level of data to be made available to the automated system;

– the changeover from a manual to an automated process will initially create new types of challenges and requirements;

– the initial period of system development and implementation may be costly. The user should realise that it requires time before he/she can receive all the advantages and financial benefits of an automated system.

Each administration uses a unique set of documents (licences, application forms, allocation plans, invoices, etc.) in its spectrum management operations. These documents may be in paper or electronic form. In order to effectively transition to an automated spectrum management system, it is absolutely essential that these existing documents be considered carefully in order to meet the specific needs of the administration for spectrum management and to provide the requested output formats. A successful transition between the existing and the newly implemented automated system is critically dependent on the scheduling of the transition period and the effort invested in meeting these specific requirements and converting the necessary documents for use by the new system. These requirements should form part of the contractual framework for the necessary partnership between the administration and the contractor so important for a successful implementation.

Annex 1 of the 2011 ITU Handbook on Spectrum Monitoring provides a discussion of the procurement process for acquiring a spectrum monitoring system, but much of the discussion also applies to acquiring automated spectrum management systems. That annex discusses topics to be considered before issuing a tender, including planning a system and developing its specifications. It includes an outline of a representative tender document, and suggests requirements for site surveys, training, maintenance, documentation, and system acceptance – all of which are steps in the process of acquiring automation for spectrum management activities.

Formal project management is very important to the successful acquisition or development of an administration's automated spectrum management system. Project management establishes a work breakdown structure, which serves to decompose a project into essential work packages and cost components. Project management also divides a project into several sequential phases, which may include establishment of the project and selection of the project manager, establishment of the system concept, development of system specifications, implementation of the project, acceptance testing and project operation. Successful project management maximizes the chance of the success of the acquisition or development of an automated spectrum management capability.

In any tender process, it is recommended that the administration provide access to potential contractors to the input and output requirements and other appropriate information, so that the transition effort may be properly estimated and provided for in their offer. The administration should also properly estimate and ensure the availability of its own personnel required as a part of the transition effort. This will allow for a more stringent evaluation of the contractor's capabilities as well as make any guarantees more enforceable.

Many contractual problems have occurred in such projects in the past. Arguments over contractual provisions only leave both parties with bad feelings. It is best to design a transition process that recognizes the significant effort needed by all parties to ensure the process works smoothly. Finger pointing breakdowns do little to move the parties towards a successful conclusion. For these reasons, it is important to adhere to a formal process to document the existing data collection processes and data sources as follows:

– Identify the type and format of all existing data, including operational and management data, such as general administrative data (department, region codes, fee rules, workflow steps, types of licences, types of equipment certificates, types of holders, etc.) as well as general technical data (types of services, types of stations, types of equipment, types of mobiles, frequency plans, protection ratios, off-channel rejection curves, etc.).
– Define a detailed strategy to migrate the existing data including a list of the data to be migrated, the format and timetable for delivery of the data by the administration, the timetable for conversion of the data by the contractor, the tests that will be used to verify that the conversion process has been successful and complete.

This shared responsibility should form part of the contracting agreement to avoid misunderstandings. Contract documents should outline the work to be carried out, the timing of this work and the nature of the responsibilities attributed to each party. The basic data and the operational data will have been defined, the data will be collected in the proper format by the administration, and will be provided to the contractor at the beginning of the transition period. The data provided by the administration should be valid and redundancies should be eliminated. The data from any manual records is often transcribed into an intermediate electronic format. This data can then be integrated into the new system, using scripts provided by the contractor, in compliance with the requirements document.

During the data migration process, the administration must rigidly note any modifications made to the original data provided to the contractor, since these changes will not be made by the contractor in the migration. The administration will need to use the new system to input these modifications, once the data has been successfully migrated and verified. The process works most effectively if the partnership of the administration and the contractor is well understood and adhered to by all parties.

While many functions of the spectrum management process can be automated, many cannot be automated. As an administration considers automation of its processes, it should expect the following facilities from automation:

– A system to facilitate processing of applications and licences.
– An accounting system to administer fee collection.
– Engineering analysis tools to allow analysis to avoid interference.
– Geographic maps and a geographic information system.
– A readily available and straightforward interface to spectrum monitoring facilities.
– A database facility to handle the spectrum data management.

For more details on facilities to be automated, see the most recent version of Recommendation ITU-R SM.1370.

A regulatory agency should not expect the following facilities from automation:

– Automatic assignment of frequencies.
– Automated frequency-site planning.
– Quality of service of cellular or broadcasting systems.

There are different ways to approach automation of spectrum management. A national spectrum management operation can be automated all at once, or just certain parts of an operation can be automated. Modularity is a very important consideration. Since spectrum management is ever growing and ever expanding, because of population growth and technological advances that give rise to new uses of the radio spectrum, a system needs to be expandable, flexible and modular so that it can grow as required over time.

The financial aspects of automating spectrum management must be considered by a regulatory agency. Automation costs money, and an administration must consider its requirements and the cost of satisfying these requirements. An administration should only acquire what it can afford. If it can only afford a limited initial capability, it should incrementally acquire its automated capability and ensure that the system is modular and can be easily expanded.

A regulatory agency should also consider the fact that spectrum management can be a source of self-financing for automation; specifically, fees for licences and renewals and fines for violations are a source of revenue that can fund the acquisition of automation of spectrum management procedures. Chapter 6 of the Handbook on National Spectrum Management) provides more detail on the economics of spectrum management.

1.5 Training and maintenance

Training is essential for any personnel who perform functions of spectrum management which are automated. Spectrum managers should be proficient in the use of computers, or they must be trained as computer users. Spectrum managers need to be trained on any newly automated functions in their operation. This training is best accomplished by relatively short courses, so that trainees are not required to absorb too much information at one time. Training is further accomplished by on-the-job training, and by help functions in the automated capabilities. Any automated capability should have context-sensitive help, so that when a spectrum manager is working with one screen or window in the system, the manager can immediately obtain help for that screen by pushing a help key. Further information on training is provided in Annex 1 of the Handbook on National Spectrum Management.

Maintenance of an automated system is greatly facilitated by the ability of a computerized system to include built-in test equipment (BITE) and to be able to perform self-tests of its operation to detect faults or failures, and display on computer monitor information about any problem. Any newly acquired system should include comprehensive BITE as an aid to corrective maintenance.

Preventive maintenance should be performed for hardware and software according to a regular schedule. Filters may need to be cleaned and replaced. Operating system software should be updated with releases to correct system vulnerabilities, and anti-virus software must be kept current.

1.6 ITU-R Recommendations and Handbooks

The following is a list of ITU Recommendations, Handbooks and other relevant references. This Handbook attempts to avoid extensive or detailed duplication of information readily available elsewhere, so these references should be consulted for further information regarding topics covered in this text. In every case, the most recent version of the Recommendation should be used.

There are several ITU-R Recommendations and other Handbooks which are important for automation of spectrum management:

Recommendation ITU-R SM.1370: Design guidelines for developing automated spectrum management systems.

This Recommendation takes into account Recommendations ITU-R SM.1047 and ITU-R SM.1413 (RDD) and provides guidelines including:

– Operational requirements
  - Applications processing
  - Frequency allocation plan/channel processing
  - Licensing processing
  - Fee and invoice processing
  - Report processing
  - Complaint processing
  - Reference tables processing
  - Security processing
  - Transaction processing

– Record keeping requirements
– Engineering requirements
– Border coordination
– Licensing fees and fee collection
– Monitoring
– Equipment approval process
– Report generation
– User interface
– Data processing requirements (including hardware and software)
– Documentation.

Recommendation ITU-R SM.1537: Automation and integration of spectrum monitoring systems with automated spectrum management.

This Recommendation notes that integrated, automated systems can process large amounts of information and measurements and draw to the attention of monitoring service operators that data which need to be further analysed by operators, so that these systems can aid operators in their work of supporting spectrum management.

Automation, through the use of computers, modern client/server architectures and remote communications, simplifies many of the duties and responsibilities of administration of the radio spectrum. Computerized equipment provides a means to perform mundane repetitive tasks rapidly and accurately, freeing service personnel for more demanding tasks. The use of databases and computer modelling streamlines spectrum management functions and can help prevent interference. Coupling of spectrum management and spectrum monitoring makes possible an integrated system, which can automatically use measured data from the monitoring system and licence information from the management database to detect frequencies of apparent unlicensed transmissions and other licensing violations for closer examination by the operator; thus the integrated system can perform automatic violation detection.

A complete integrated computerized national spectrum management and monitoring system relies on one or more data servers within a network so that workstations or clients throughout the system can access the database. Management system servers include a main server and, occasionally, one or more servers for a database extracted from the main database, and/or a database dedicated to an application or at a local command centre. Each monitoring station, whether fixed or mobile, has a measurement server and one or more workstations. Each station uses a modular architecture based on server and workstation computers interconnected via Ethernet local area network (LAN). All stations are linked over a wide area network (WAN). This fully integrated network should provide rapid access by any operator position to any of the server functions available in the system.

In addition the most recent version of the following ITU-R Recommendations and documentation may be consulted:

Recommendation ITU-R SM.668: Electronic exchange of information for spectrum management purposes

Recommendation ITU-R SM.1047: National spectrum management

Recommendation ITU-R SM.1413: Radiocommunication Data Dictionary for notification and coordination purposes

Recommendation ITU-R SM.1604: Guidelines for an upgraded spectrum management system for developing countries

Recommendation ITU-R SM.1880: Spectrum occupancy measurement

The ITU software and database publications are available at: http://www.itu.int/pub/R-SOFT and the ITU Catalogue of publications on-line can be accessible at: http://www.itu.int/pub/S-GEN.

1.7 Organization of the Handbook

The following Chapters of the Handbook describe in detail the areas of computer techniques, spectrum management data, computer communications and automated techniques for spectrum management. The work is organized as follows:

Chapter 2 – Computer techniques. This Chapter discusses background information on computer hardware, software, networking and implementation of automation techniques. It further addresses security matters as well as related services such as project management, training, maintenance and documentation. The Chapter concludes with a discussion on guidelines for choosing a computerized spectrum management system.

Chapter 3 – Spectrum management data and database management. This Chapter provides information regarding spectrum management data, including quality assurance, as well as guidance on the spectrum management database and database management systems.

Chapter 4 – Electronic exchange of information for spectrum management. This Chapter discusses the various methods of data transport, both electronic and non-electronic, and then considers issues in systems implementation, including providing case studies of information exchange.

Chapter 5 – Examples of automated spectrum management procedures. This Chapter provides examples of spectrum management procedures that can be automated, including computer-aided selection of frequencies, propagation analysis, equipment characteristics, and coordination distance calculations. The Chapter discusses the advantages of integrated systems.

Annexes – Annex 1 provides detailed tables of spectrum management data elements. The other Annexes provide summaries of automated spectrum management systems which are commercially available, focusing on the spectrum management functions which can be automated. The listing of these systems in these Annexes does not necessarily constitute a recommendation for their use.

CHAPTER 2

Computer techniques

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2.1 Introduction

The purpose of this Chapter is to present the different options available for administrations wishing to use computer systems for spectrum management.

This Chapter gives some information related to computer systems security.

It also gives some guidelines to assist administrations to choose computer systems designed for required spectrum management tasks.

2.2 Project management, training, maintenance and documentation

2.2.1 Project management

A formal method of project management should be considered by any administration wishing to implement an automated spectrum management system. Some reasons are:

– the project is technically complex;

– there are many constraints to be considered, especially the regulatory issues that will define limitations to the extensions to the project;

– usually the budget and time available are limited;

– several tasks and areas might be involved: LAN/WAN implementation or upgrade; servers' availability; monitoring capabilities integration; training; data acquisition and/or digitization; etc.;

– there are several functional boundaries which must be crossed: all functional areas should be involved.

Many references are available dealing with project management and the objective of this section is to highlight its main aspects. Project management training should be seriously considered before beginning the automation of spectrum management.

It is important to note that project management for this type of automation initiative, is not something that can be bought in a box or can be left to others. All managers involved, either contractors or spectrum administrators should have the required knowledge and skills to lead such projects.

2.2.2 Training

Training is critical for a successful system implementation and operation. Training should cover all system elements and focus on operation and maintenance, rather than design.

It should consist of academic type training as well as operational training on the day-to-day use of the system. The latter may consist of technical assistance and professional support.

The introduction of automation into the daily operations of an administration often requires the implementation of new processes and procedures, and the administration personnel may need to be supported in the early stages of the system implementation.

Periodic training sessions should be organized in the form of refresher courses for the operational system users in order to accommodate system changes; and for more in-depth training of new personnel dedicated to system operations. New personnel may be trained by the experienced system users. Indeed, an untrained person needs the support of an experienced user, or preferably a training session in order to take full advantage of the system.

2.2.3 Maintenance

Availability of the main system elements in the local market as well as the availability of appropriate warranty, maintenance and support are important considerations when acquiring a system. Upgrade capabilities and related cost may also be selection criteria. Availability of technical support is an equally important criterion.

It is therefore important to ensure that supplied systems offer a reasonable warranty period (usually one year), followed by a continuous maintenance contract that ensures the operational maintainability of the system through bug correction and reasonable functional changes such as regulatory and administrative changes. Training on system releases and versions should also form part of this ongoing maintenance.

2.2.4 Documentation

Documentation is critical to software development. It is very common to omit some documentation since it is expensive to the organization and tedious for the technical personnel to produce.

It must be understood that the lack of documentation is the major long term cause of failure of any automated system, since it might impose serious difficulties for later integration and/or expansion.

The documentation is usually composed of system, operational and maintenance documentation.

The system documentation should include a complete description of all components and functions and interfaces to allow easy replacement whenever needed.

For the DBMS, a complete database model description should be available, indicating relations and dependencies of all entities defined.

If one is considering an in-house development, the system documentation process should be done on a daily basis, each new function, interface or data structure should be properly registered on the documentation database. Several specialized software to facilitate the documentation process are available and could be used to accomplish this task more easily.

If one is buying an off-the-shelf package, it is reasonable to believe that all the documentation is already available and therefore, an initial version may be provided at the very beginning of the system integration. It is important to allow further additions on the integration of the new system within the existing process.

The operational documentation consists of user manuals required to operate the system. It may be available as printed material as well as context sensitive help, tutorials, knowledge base, and formal manuals that are designed to provide the end user with all the knowledge needed to make the best use of the available tools. Operational documentation normally consists of a set of reference manuals and does not contain spectrum management procedures. For instance, the assignment of a frequency depends on the specific requirements of each administration and is usually not described in the documentation.

The maintenance documentation is an extension of the system documentation that provides specific instructions about how the maintenance is carried out and logged. The content may vary according to the current maintenance contract but in general it should be complete enough so that operators have a good understanding on how to keep the system operating.

2.3 System security

Paper tools have their own risks like fire, water or losing papers. Computer tools also have risks. The purpose of this section is to present the main risks associated with computer tools.

2.3.1 Backup

A computer system and related databases may be lost at any time through fire or other risk elements. If the hardware can be replaced with only the inconvenience of re-installing all the applications and proper configuration, the database content may be definitely lost. A loss of power supply can also be destructive for the databases if the online storage media fails to save the live data. A common method to seek protection against such eventualities is to keep a copy of the databases in a location other than the location of the working databases. Most computer manufacturers and DBMS creators supply utility routines that enable the databases to be copied onto off-line storage media. Such copies should be made at regular intervals, daily or weekly, and stored at a different location. Then in the event of loss of data, recovery of the original database is simple and accurate and may be completed in a very short time. To prevent loss of the data entered into the working database between the time of the last copy and the time of the loss of the database, a log may be kept, on disk or tape, of all data entered into, or modified in, the database.

Several systems of disk information redundancy prevent disruptions of service. The most common is the RAID (redundant array of independent disks) system which prevents disk corruption and loss. An interesting feature of the RAID topology is the increase in the disk access efficiency that can have a positive impact on the general system efficiency. Several levels of RAID are available, each level having a different profile of disk access time and safety.

Another important feature of disk arrays is the hot-swap capability. This allows the replacement of any damaged disk without stopping the services. Hot-swap is also a desirable function for power supplies and other components that might be critical for the computer system operation.

2.3.2 Virus

A computer Virus is a malicious set of program instructions that are contained within a computer program and, when executed, propagates to other computer programs by modifying those programs to include the Virus instructions. A computer Virus normally performs two functions. The first function is to propagate to as many other computer programs as possible. The second function is to cause some unexpected action to occur. There is often a trigger that causes the unexpected action to occur. The trigger action can be a date, and the unexpected action does not occur before the trigger date. The trigger can be the execution of another program or any other function that the Virus programmer has instructed. One of the purposes of the trigger is to hide the Virus until the Virus has propagated to a number of other programs. Another purpose of the trigger is to cause unexpected action to occur at a time not related with the primary "infection". The unexpected action can be a relatively benign action such as displaying a message; can be malignant such as damaging or deleting programs, data files or entire directories; or the action can be destructive such as blocking the computer with no way to be able to use it further. Since a computer Virus remains hidden until the trigger event, the Virus can easily be introduced into additional computer systems. Additional computer systems can be "infected" when software is transferred between systems via communication means, networks, or exchanging media containing infected files. Computer systems attached to a computer network are particularly susceptible to be infected by computer Viruses. Some Viruses have been designed to specifically take advantage of the features provided on a computer network and to propagate to as many computer systems attached to the network as possible. Some Viruses have also been designed to specifically take advantage of security breaches included into the computer operating system to prevent detection and allow its rapid propagation. Users and system operators should minimize exposure to unknown programs and should test and remove any Virus program that is suspected to exist in a computer system. Users of computer systems attached to a computer network should be particularly careful about using unknown programs on their computer systems.

Computer "Worms" are similar to computer Viruses but do not contain a trigger. A computer Worm typically affects a computer system or a network of computer systems by consuming all the available resources (main memory and/or mass storage) of the system or network systems. Computer Worms can be specifically designed to propagate throughout a computer network. Computer Worms do not contain a trigger and it is important to recognize the presence of a Worm in the network and disconnect other computer systems from the network before the Worm can propagate to those systems. Many Worms, however, spread so quickly that it is impossible to notify other computer systems to disconnect from the network on time. Most of the time, the first infection of a Worm occurs by an infected email containing an executable file or a script file including the Worm code. Most of Worms are benign; they only consume resources without harming the computer and the data. However, some of them are very malignant and may be destructive.

A computer "Bomb" is similar to a Virus except that it does not propagate. A computer Bomb modifies the computer system to contain a trigger event. When the trigger event occurs, the computer system performs an unexpected action. The unexpected action can be relatively benign or can be seriously malignant.

Another threat in computer programs is the "Trojan Horse". This Virus is related to hacking (see section 2.3.3). The Trojan Horse is a computer program that appears to perform some desirable function but, in fact, contains a Virus, a Worm, or a Bomb, and can give access to the computer system to a foreign operator.

All these Viruses have as a principal goal to change any functional program into a Virus by replication. Computer Viruses are particularly malicious because they modify normal functional programs and files and propagate to other normal functional programs and files until the trigger event occurs. Thus, computer Viruses can quickly propagate to additional computer systems by seemingly trusted programs.

The major practices that can be used to minimize computer system exposure to a Virus are:

- Install a firewall to protect the computer system and have an up-to-date anti-Virus program installed and running with permanent detection function.
- Run only trusted programs, obtained from trusted sources.
- Do not allow anyone to upload, or run, programs, from an un-trusted source, on a computer system, unless the program has been subjected to rigorous testing that is designed to detect, neutralize and destroy computer Viruses. This type of test can be done by anti-Virus software.
- Isolate all programs of unknown origin.
- Conduct testing of suspect programs on an isolated computer. Computers used for this purpose should not be used to run other programs or be operated in a network. No computer disk used to test a suspect program should ever be used for any other purpose and should never be used on another computer system.
- Establish rigorous testing procedures, programs and regulations designed to test suspect programs for presence of viral infections and enforce regulations regarding use of the test programs and uploading of programs of unknown origin.
- Restrict access to the computer system to only those persons who require access to perform authorized tasks. These restrictions should also include other restrictions that limit the authorized user's capability to access files and to perform tasks to only that capability necessary to accomplish assigned duties.
- Do not open attached files in email from un-trusted sources.

2.3.3 Hacking

When an unauthorized person uses a computer system, especially from a distant location, this person is hacking the computer system. For manual systems, security from unauthorized access is relatively simple since it can be maintained at a high level by use of locks on the doors and files used to store documents. However, a computerized database is subject to a larger problem, especially when it is realized that some administrations may, because of economic or organizational reasons, share a computer with others users. To restrict access to the data, the software routines may be written in a way that it requires passwords to authorize access to the database and/or the programs that use that database. Passwords may also be applied to allow access to specific records in the database. Each terminal on a machine may have a unique code and the security can be extended in such a way that only specific terminals may access specified data and programs. Some terminals may also require a physical key or a magnetic badge to be inserted by a user before operation is permitted. These procedures may not be adequate for certain levels of security so that sharing is not possible.

Networked computers have the weakest security. An access to a part of a network can give access to all parts if the hacker has the necessary knowledge and passwords. Hackers use Trojan Horses to retrieve passwords sent along the network. The best way to avoid this security breach is to isolate the computer network. With this solution, no-one can access from outside the network, and only the authorized users can access the computers and the network.

A solution to prevent unauthorized access is to add to the network a specific program (which can be embedded into a router or in a computer) called a "firewall". This firewall filters all the communication and has rules to forbid access from unauthorized people. The firewall can also embed an antivirus program. The firewall is able to prevent Hacking and Virus attack.

Another solution is to use encryption. All the information sent through the network can be encrypted and only the application is able to decrypt the information. It is also possible to directly encrypt the databases to be sure that the disks are safe in case of robbery.

All these solutions can be used together to enhance the security.

2.4 Guidelines for choosing a computerized system

This section will present some best practices in order to migrate from a manual spectrum management system to an automated/computerized one.

2.4.1 Analytical considerations

The implementation of a computer system often brings more benefits than the associated cost. The benefits achieved usually result from consideration of four categories:

Category 1: Improved performance of repetitive tasks: the computer can perform a calculation or provide an item of information with consistency and accuracy over and over again.

Category 2: Increased volume of repetitive tasks: the computer can usually perform a task much more quickly than a human being.

Category 3: Human beings released for discretionary tasks: human beings may better utilize their talents to work at unique problems or to work at problems requiring judgment.

Category 4: Improved control method: the computer procedures impose a type of logical approach and provide a source of information that can improve decisions or judgments made by human beings; this also permits enhanced planning for future operations.

Benefits may be tangible and measurable such as saving of manpower, saving of working and storage space, saving of materials and equipment, decreased processing time, increased workload capacity, etc., or they may be intangible such as improved management and accessibility of information, better quality of results, improved service to users, etc.

Costs usually fall into four categories:

Category 1: Hardware cost: the cost of computer systems, peripherals and communication devices.

Category 2: Software cost: the cost of analysis, design, programming and testing of the software or the cost of licences for existing software.

Category 3: Installation cost: the cost of system installation, site preparation, conversion of the existing data and training.

Category 4: Operating cost: the cost of maintaining hardware and software, rental of equipment (or amortized purchase price) and space, and the cost of additional or more specialized personnel.

2.4.2 Identification of the needs

The first phase in the migration to a computerized system is to analyse the needs according to the operational requirements. What do we really want the computer to do?

In order to complete this analysis, it is mandatory to identify each task done by the administration and point out each process. For these processes, a choice must be made between computerize the process or leave it manual. For an adequate and efficient work, all data should be digitized. Some processes can be accomplished without the intervention of a user (like create an invoice, all calculations are performed by the computer and the invoice is printed by the printer), some others need the intervention of a user to interpret or launch the calculation even when all the calculation is made by the computer (like interpreting a coverage or adjusting the thresholds for interference calculations).

In many instances, an administration wishing to implement automated spectrum management techniques will have a working experience with certain manual techniques. Such experience usually results in an organization structured along service lines; i.e. there will be a unit with experience in broadcasting, a unit with experience in mobile services, etc. This disciplinary expertise should be taken into account when the operational structure needs to operate a computerized system, and during the design of the system. An integrated system can be designed so that the database contains detailed files, with particular data elements for specific services and in a way that particular processes are used for the assignment and recording of frequencies in specific services. Such a system would also contain data files with elements and processes common to the services necessary for comprehensive management. For example, a system could contain data files pertaining to the technical characteristics of land mobile service assignments and a particular assignment process for granting licences in the land mobile service. It could also contain general files of topographic data and administrative or financial data that pertain to a number of services, including land mobile, and processes for the use and maintenance of those data. The engineers and technical personnel experienced in land mobile would continue to operate in a similar manner within the new organization. Such considerations could lower the design and implementation cost, personnel relocation and training, and could lower the risks associated with the introduction of the automated techniques. Computerized systems and associated application software are meant to be a means to assist qualified personnel in achieving their tasks faster while accomplishing more rewarding activities in an automated manner rather than automatic systems that would impose solutions or results without understanding the real reasoning behind the applied routines.

This phase documents the processes of the administration and gives a clear picture of the ways computers could be used to make improvements.

At this stage, it is possible to create specifications and functional requirements for all the requirements of the spectrum management team.

2.4.3 System design

In general, the spectrum manager will not directly design, program and implement, or maintain the automated system. These functions are usually performed by computer specialists. However, the spectrum manager does bear a great responsibility for ensuring that the functions are performed adequately. The spectrum manager must play a major role in defining the requirements an automated system should satisfy, and then must become involved continuously in the automation process. The design of the system should be reviewed to determine that it will satisfy the requirements (several iterations of the design may be necessary before a satisfactory system emerges). Realistic data for testing of the system should be provided, the sufficiency of documentation and user-training should be monitored, and the operational system should be periodically reviewed to determine areas for improvements.

It is important that the system design allows for flexible and adaptable functionality in order to facilitate its future maintenance.

Web access is a major tool to increase the efficiency of data exchange as well as the transparency of the spectrum administration. In this context, Web access and the Internet can be used, among other applications, to do the following:

– notification to the ITU;
– information access to engineers who are responsible for the design of new links and stations;
– submission of new requests and projects;
– information access to pending requests and projects submitted to the administration for analysis;
– on-line billing;
– on-line licence issue and renewal;
– public access to regulations and information about the services in operation, including monitoring data and enforcement activities.

2.4.4 Selecting a company for the project realization

In general, the spectrum manager does not have the resources to achieve automation and to implement a computerized system. The spectrum manager usually chooses a company to perform this task. Two possibilities are usually available.

The first one is to choose a company to develop a custom system based on specific requirements of the spectrum manager. This solution would better fit the spectrum manager's needs, but this is usually very expensive and long to implement, because the contractor company has to perform a custom development for a quite complex system. The system tuning and testing phases can be very complex and expensive.

The second solution is usually cheaper. It consists in purchasing an already developed system: "Off the Shelf". This solution may not fit every possible requirement of the spectrum manager, but it is always possible to ask for minor adjustments/customization in the software solution to meet most critical requirements. If the amount of customization required by the administration is significant, the development and maintenance cost may become larger than the development cost of a custom system.

In any case, it is important to have a mutual (contractual) agreement between the parties for the adjustment and customization.

The main advantage of this solution is that the software purchased is proven, tested and can be demonstrated to determine if the requirements are met.

Some criteria may help better select the Contractor.

The first one is the quality of the services offered. The spectrum manager should pay attention to the quality of the procedures followed by the company to ensure that the service is adequately performed.

The second main topic is training of the personnel intended to use the computer system. The training must be long enough to cover all the parts of the system, from the basic use of the system to the most advanced activities, as well as system administration.

The third topic is warranty and post-warranty maintenance including preventive, corrective and evolving maintenance, where patches and new releases are made available. Application software must evolve to accommodate new technologies, new recommendations and regulations. This should cover as well computer platform upgrades, as computers rapidly become out of date due to fast technological improvements. It is recommended that system elements are chosen for which maintenance is easily available and reasonably affordable in the local market.

The last topic is data acquisition. This part should not be underestimated. The migration of the data from one system to another may be time consuming and great care must be given to this sensitive task. It is important to retrieve all available data and the format in which they are available. The most important element of a spectrum management system is its data. The conversion of existing data should be carefully considered in the migration to a computerized system. Methods must be designed to perform editing and validation during the data collection phase. If the existing data is in paper form, a data capture method must also be designed. One strategy is to convert the data to machine-readable form according to the existing paper format and then to use a computer program to convert to the desired format. This eliminates clerical errors in transcription and conversion, and is likely to decrease the time and costs of conversion. Where there is a large volume of existing data, more efficient entry into the new database can usually be obtained by organizing the existing data in accordance with the design of the new data files before beginning the operation. When the data is collected, the completeness of the data and its consistency must be carefully examined. Sometimes, information needed by the computer system is missing in the data collected (loss of data, data never given, etc.). This missing data must be filled in with default values initially and then completed at a later stage.

2.4.5 Selecting a computer system

The required power of the processor in a frequency management system is determined by several factors. These are the sizes and rates of transactions associated with data files, the complexity and rate of application of engineering models, and the desired response time for carrying out specified procedures. The volume factors (sizes and rates) are usually determined by an administration's geographical size and the state of development of telecommunications usage. The frequency manager must decide upon necessary response times in order to provide a satisfactory level of service to users and the administrative authority. The level of service must be provided within appropriate budgetary constraints. Although a powerful computer can process a large amount of data or perform lengthy, complex calculations in a short period of time, a slower and less expensive computer may be able to process the required amount of data or perform the required calculations within time constraints acceptable to the manager. Increased processing time will also reduce the hardware and software costs associated with more complex data storage/access methods.

The frequency manager may be required to utilize an existing computer system that is also serving other users, or he/she may be required to acquire a computer system for his/her specific task. In the first instance he/she will usually have access to a large general-purpose system. These systems are capable of performing large-scale data processing and solving complex engineering problems; however, the frequency management application will be required to co-exist with the other applications on the computer system. This could cause constraints on available storage and calculation time.

Computer usage usually expands and grows after the automated system has been implemented. An automated system is usually designed to alleviate a particular problem, and it is often found that the original problem had obscured other different problems. The incremental cost of solving these new problems is often small in comparison with the benefits obtained. A computer system should be designed to permit expansion due to the automation of additional applications, as well as to accommodate the normal growth expected from existing applications. A system should be designed with excess storage capacity, about 100% for the main memory and auxiliary storage, as well as with the ability to replace input/output devices with higher speed models or to add additional input/output devices without a major system overhaul. Where possible, central processors should be selected to allow for the increase of the processor capabilities through upgrades, while maintaining software performance.

The availability of the spare parts for all parts of the computer system should be taken into account. Parts must be quickly replaced in case of failure. If required spare parts are not easily available in the local market, a failure can have significant consequences.

The cost of the consumable parts should also be taken in consideration. Like ink cartridges for printers, they could have very different cost schemes from one manufacturer to another. It is important to look at these costs carefully before making a final choice. These consumable parts should also be easily available.

2.4.6 Conclusions

According to the system design and the operational requirements adopted, the main guidelines for a computerized system implementation are:

– *For hardware*: to purchase fairly fast computers with adequate memory and storage space, as well as relevant peripherals.

– *For software*: to purchase the most compatible "off the shelf" product fitting with most processes of the frequency management administration, and providing for table driven parameterization allowing for easy minor customization and adjustments to more specific needs, such as monitoring system interface.

Systems acquisition should take into account performance versus operational use and related cost, as well as the familiarity of the administration personnel with the chosen technology and the availability of its main elements in the local market together with appropriate training, warranty, maintenance and support.

CHAPTER 3

Spectrum management data and database management

TABLE OF CONTENTS

3.1 Introduction

The goal of using computer-aided techniques for national spectrum management is to be able to answer practical questions of national interest, such as:

– How many transmitters operate nationally in the 235-267 MHz frequency band?

– What effect would a new transmitter at a particular location be expected to have on a certain existing receiver using the same frequency?

– Whom should I contact about a suspected source of interference?

The type of questions to be answered determines the type of spectrum management information an administration must collect and maintain. If only administrative tasks are envisioned, it may only be necessary to maintain information regarding frequency assignments. In this case, only simple retrieval and manipulation of the data (such as sorting and counting) would be required, capabilities typically included in database management systems.

More likely, however, an administration will need to answer technical questions regarding, for example, levels of emissions from suspected interference sources. Effective use of the computer-aided techniques described in this Handbook requires the capability to retrieve the necessary technical data from a spectrum management database.

To control costs, administrations should carefully consider what data must be collected and maintained. Such decisions will be influenced by requirements from the ITU Radio Regulations (RR), Regional Agreements concluded under the auspices of the ITU as well as the requirements of regional organizations. The spectrum management databases used by various administrations may also serve as examples for administrations developing new systems.

The Radiocommunication Bureau (BR) maintains extensive administrative and technical data related to its various spectrum management activities, including advance publication, coordination and notification. Online sources, such as the record of ITU World and Regional Radiocommunication Seminars and Workshops can be found at http://www.itu.int/ITU-R/go/seminars. In particular, they provide detailed information on BR data requirements.

This Chapter describes administrative and technical spectrum management data, as well as the organization and maintenance of that data using a database management system. Annex 1 of this Handbook lists and describes the types of data usually required to answer spectrum management questions.

3.2 Spectrum management data: Entities, properties and relationships

Data can be usefully described in terms of *entities*, *relationships* between those entities and *properties* of those entities. Entities related to spectrum management include tangible transmitters, receivers, antennas and platforms, as well as intangible frequency allocations, frequency assignments, and many others.

Entities will generally have a variety of properties of interest in spectrum management. The properties of entities may be viewed as a data table having rows for entities of a similar type and columns for the properties.

Relationships between the entities provide information such as what type of transmitter is used at a particular station. Relationships are so central to the efficient organization of data that tables of data are known as *relations* and the usual type of modern database is the *relational database*.

The cardinality of the relationship between two entities can be any of three types:

– *One-to-one*: the relationship between stations and call signs is a one-to-one relationship because a station can have only one call sign and a call sign can be assigned to only one station.

– *One-to-many*: the relationship between a licence and the responsible party is a one-to-many relationship because a licence can have only one responsible party, while that party may hold multiple licences.

– *Many-to-many*: the relationship between frequency bands and radio services is a many-to-many relationship because frequency bands can have multiple allocated services and services can be allocated to multiple bands.

Understanding relationships helps to avoid a major problem in data maintenance: redundancy of data, or the existence of the same data in more than one place in the database. If, for example, the mailing address of an individual holding numerous licences were to be maintained as a property of the licences, the same address would appear under each licence held by that individual. A change of address for the individual would require updating each of the affected licences, requiring unnecessary effort and possibly leading to errors. If, instead, the mailing address were properly understood as a property of the licence *holder*, the relationship between the licence and the licence holder would indicate the proper mailing address for notices related to that licence.

The following subsections describe relationships and properties pertaining to types of entities of interest in spectrum management. Some provide definitions from the RR along with their corresponding margin numbers.

3.2.1 Frequencies and radio services (frequency allocations)

RR No. 1.16 *allocation* (of a frequency band): Entry in the Table of Frequency Allocations of a given frequency band for the purpose of its use by one or more terrestrial or space *radiocommunication services* or the *radio astronomy service* under specified conditions. This term shall also be applied to the frequency band concerned.

By this definition, frequency allocations are relationships between frequency bands and services, as designated in RR Article **5**. Arranged by frequency band, the allocations cover one or more of the three RR Regions and have either a primary or a secondary status. A system of footnotes qualifies certain allocations, for example, by limiting them to specified administrations, by limiting the level of emissions, etc.

The use of "country footnotes" in the international Table of Frequency Allocations of RR Article **5** is governed by relevant RR provisions and resolutions of World Radiocommunication Conferences (WRC) and indicates the administrations having national allocations that differ somewhat from those in RR Article **5**. Information on national allocations should be maintained in a form similar to the international allocations so that the two may be readily compared.

3.2.2 Frequency assignments and licences

RR No. 1.18 *assignment* (of a radio frequency or radio frequency channel): Authorization given by an administration for a radio *station* to use a radio frequency or radio frequency channel under specified conditions.

RR No. 1.61 *station*: One or more transmitters or receivers or a combination of transmitters and receivers, including the accessory equipment, necessary at one location for carrying on a *radiocommunication service*, or the *radio astronomy service*.

The definitions indicate that frequency assignments are one-to-many relationships between stations and frequencies or frequency channels. This information is especially important because frequency assignments represent national authorization to use frequencies.

Since frequency assignments are the basis of international coordination and notification, data maintained must be consistent with RR and ITU-R requirements. RR Appendix **4** and the Radiocommunication Data Dictionary (RDD, see the most recent version of Recommendation ITU-R SM.1413), lists frequency assignment data generally needed for these national and international procedures. RR Articles **4** and **20**, RR Appendices **30**, **30A** and **30B**, along with relevant WRC Resolutions (e.g. Resolution 49) and regional allotment plans, provide additional information on necessary data for frequency assignments.

In general, a one-to-many relationship exists between licences and frequency assignments. A licence has relationships with the associated frequency assignment or assignments, as well as the licence-holder.

3.2.3 Licence holders

The properties of licence holders will be exclusively or primarily administrative information, such as contact information. This information may need to be maintained securely, a capability of some database management systems.

3.2.4 Stations and equipment

The many-to-many relationship between stations and the equipment (transmitters, receivers, antennas, etc.) used at the stations is a key area in which redundancy should be avoided. While many extant data recording systems consider properties of the equipment to be properties of the frequency assignment, the entities must be kept distinct to avoid the redundancy pitfalls. Since an administration may use a particular model of transmitter (with its set of properties) at many stations, the properties should be recognized as those of the transmitter, while recognizing the relationship between multiple stations and that particular transmitter.

Handling data for antennas may be less obvious. While certain properties, such as the antenna pattern and bandwidth, may be common to all instances of a particular antenna, other properties, such as the antenna height and bearing (for directional terrestrial systems) are properties of the station.

Link budget equations indicate what properties should be included for equipment. Using the database and computer-aided techniques, the spectrum manager should be able to analytically predict signal levels that a monitoring station would measure. Properties related to the licence-holder's authorization to use the equipment at a particular station should also be maintained.

3.2.5 Geography of the administration and the surrounding areas

For the determination of emission levels distant from a transmitter, as needed when estimating interference power levels, a rough approximation considering only path length and antenna heights will prove inadequate over most terrain. Other factors, primarily terrain, but also structures and vegetation, must be considered to refine the analysis by more accurately predicting propagation loss. This information is required not only within one's country, but also in adjacent areas to facilitate coordination of frequency assignments. Administrations may encounter difficulties obtaining terrain and other data for adjacent administrations, but less detailed, widely-available data may be sufficient for coordination.

Terrain dependent models for propagation loss require samples of terrain elevation at many points along the path to determine the dominant propagation mode and the role of multi-path propagation. Geophysical properties such as ground conductivity and permittivity will also affect the propagation statistics at some frequencies.

In data terms, elevation and geophysical properties are properties of locations (the entities) within national boundaries. ITU-R Study Group 3 [4], which addresses radio wave propagation issues, has developed methods to collect and maintain such geographic data.

Building attenuation can also be a large factor in predicting signal levels, particularly in urban areas. A practical approach to inclusion of this factor is the collection of data on the density of structures as a property of geographic locations.

3.2.6 Levels of emissions (monitoring)

Many administrations routinely monitor emission levels for purposes such as ensuring operation of transmitters in conformity with national and international regulations and licence conditions, identifying sources of unauthorized emissions and interference, and measuring spectrum occupancy. Administrations may nominate Monitoring stations to participate in the International Monitoring System (see RR Article **16**). All pertinent information, including the types of measurements carried out by these stations in the Terrestrial and/or Space Radiocommunication services, are to be notified for inclusion in the List of International Monitoring stations (List VIII[5]). It should be noted that these stations are a cooperative group for sharing monitoring data on a regular or ad-hoc basis, such as by participating in the regular HF monitoring programme. The use of monitoring is described in detail in the ITU Handbook on Spectrum Monitoring maintained by ITU-R Working Party 1C.

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[4] See the ITU-R Study Group 3 web page at: http://www.itu.int/ITU-R/go/rsg3.

[5] See the description of the ITU List of International Monitoring Stations (List VIII) at: http://www.itu.int/go/ITU-R/ListVIII.

Monitoring data is a record of emission levels detected at a monitoring station at a point in time. As such, it represents properties of a monitoring station. Using computer-aided techniques, an administration can compare monitoring data to emission levels estimated, based on frequency assignment data to verify the assignment data and detect unauthorized operations, in compliance with the most recent version of Recommendation ITU-R SM.1537.

3.2.7 Licence fee schedules

Administrations often have a schedule of fees based on properties of licences, such as the number and type of transmitters, the number of frequencies used and the transmitter power.

3.2.8 Spectrum management events

Administrations may also wish to record the occurrence of events such as:

– interference complaints filed by licence-holders;

– violations of national or international radio regulations by a licence-holder;

– inspections of stations.

3.2.9 Spectrum management data

In a database of entities, properties and relationships, the data itself is an entity with properties. The properties of the spectrum management data of interest to the ITU are described in the most recent version of Recommendation ITU-R SM.1413.

3.3 Data quality

The quality of decisions using computer-aided techniques demands that the available data be reliable, a great challenge to administrations. Data reliability or "quality" describes how accurately data represents some aspect of the actual electromagnetic environment.

Data can be acquired from specialized providers, such as census organizations, mapping companies, military forces or government representatives. Other data, such as station information and antenna diagrams, must be collected and maintained by the national spectrum management organization.

3.3.1 Quality of contractor data

Determining the quality of data from an outside source can be very difficult. The following general guidelines can be given whenever trying to acquire data from a third party:

– clearly specify what data is required and how accurate quantitative data must be;

– ensure that the data is recent enough for the intended application;

– explore the possibility of obtaining data maintenance services (periodic updates) from the contractor;

– use contractors who specialize in the region and the type of data requested;

– where appropriate, obtain data from those who collected it.

3.3.2 Quality of data acquisition and maintenance

An administration must also ensure the quality of data it collects as part of its spectrum management activities. Various computer-aided techniques are available to help ensure the validity of the data collected.

3.3.2.1 Data filters

Data filters take advantage of redundancy in existing information and use other techniques to help prevent and detect errors in new data. Examples include:

– *Check digits*: Identification numbers (e.g. credit card numbers) often have one or more digits appended to the number for validation. Similar validation techniques can be used to identify errors in manual data entry.

– *Redundant geographic information*: Information about the location of stations and licence-holders often contain redundancies that can be used to identify errors.

– *Selection boxes*: Whenever applicable, drop-down lists can be used to ensure valid entries. The content of the drop-down list can be determined by entries for other data elements.

3.3.2.2 Access control and historical data

Access control – ensuring that only authorized personnel can write to the database – is critical to data quality. Unauthorized editing of data can have serious consequences, such as incorrect fees charged to licence-holders.

Maintaining a simple log of all revisions to the database, indicating the substance of the change, the time of the change and the person making the revision, will also help to ensure data quality. This simple method usually is enough for most applications but is of limited value for auditing purposes. The type of log maintained will determine how it may be used. For example a simple log file will not provide information about how spectrum was used in the past.

3.4 Spectrum management databases and database management systems

3.4.1 Spectrum management databases

A spectrum management database is a collection of spectrum management data. Early spectrum management databases were simple tables in a row-column format in which the rows represented frequency assignments and the columns contained data regarding properties of the assignments. For administrations envisioning only the simplest administrative tasks, such a database could be developed using nothing more than a basic spreadsheet application.

Since entities such as, for example, maritime platforms and satellite platforms have vastly different relationships and properties, administrations are likely to find that database systems based on the relational model better fit their needs. Relational databases consist of tables in row-column format, also known as "relations". These tables consist of rows of individual entities and columns indicating properties of the entities or relationships to other entities, described in other tables.

Some administrations may find the type of applications packaged with word processors and spreadsheets in business software adequate for their needs, though the relational capabilities of these applications are generally weak. More robust systems can be designed to meet an administration's particular needs, though such systems are more costly.

3.4.2 Database management systems

The database management system (DBMS) is a computerized system that maintains spectrum management data and makes it available to a variety of users. A well-designed, modern database will allow easy input and modification of data and provide useful "views" of data to users without the users having to understand the details of the DBMS, such as how the required data is organized in the database. The DBMS should also be designed to minimize redundancy across the database, provide validation of data, provide security for sensitive data, provide data backup to avoid catastrophic losses in the event of system failures.

When considering the design of a database management system, an administration should consider systems used by administrations with which they must often exchange data, as well as systems used by the BR.

The system design should be modular and flexible. One method of achieving a portion of this flexibility is to use table-driven functionality where the program operation can be determined by code values in the database. In this way, the system can be somewhat customized without the need for coding changes. Some examples of this are:

– Storage of screen prompts in the database so that the language of operation of the system can easily be changed.

– Storage of all user messages to facilitate the system's availability in multiple languages.

– Storage of fee parameters and fee values in tables to enable easy customization for different administrations.

A DBMS can be implemented such that files containing the reference administrative and technical parameters in a central location are replicated or "mirrored" at the user sites. This technique, while transparent to the users, improves response time.

3.4.2.1 Geographic information systems

Geographic information systems (GIS) can be integrated with the DBMS to help administrations to account for environmental effects (terrain, population, etc.) in spectrum management. They usually offer two-dimensional geographic information representation and often three-dimensional capabilities as well.

The ITU Digitized World Map (IDWM), available at http://www.itu.int/pub/R-SOFT-IDWM, includes databases for geographical (coastlines, seas, islands, lakes), political (country borders and regional boundaries), meteorological (rain and climatic zones) and technical information (ground conductivity areas, noise zones, allotment areas, maritime zones, broadcasting CIRAF zones and propagation zones). The IDWM resolution, however, is only 5 km, which may not offer adequate precision for some radio services.

The IDWM is comprised of two main parts: the IDWM database and the subroutines and link libraries. The IDWM may be incorporated into the administration's spectrum management applications and used for determining, for example, the location of a given point, the distance and azimuth between two points, the land and sea distribution along a path, the areas or zones distribution of a specific technical map along a path or retrieving geographical areas within a contour. More advanced spectrum management applications use integrated GIS for enhanced displays and better use of digitised maps. Many other mapping sources of varying capabilities, such as the GTOPO30 database and the NASA database, are available online.

The accuracy and consistency of geographical coordinates is important when using GIS applications. An administration should therefore employ a standard geodesic system, which could be any national or other widely-used system, such as the WGS84. Administrations may need to use multiple suppliers to provide all the required maps.

Data used by GIS systems is usually provided in raster or vector format. Clutter type, population density, ground conductivity, and refractivity layers are among data usually presented in raster format. Geographical and political boundaries, main rivers, roads and railways networks, and district limits are among data usually presented in vector format. GIS facilities include mechanisms for the storage and retrieval of the geographical and associated data, database maintenance tools and drivers for printers and plotters.

Usually, geographic spectrum management data, such as transmitter station locations or coverage areas, can be superimposed on the geographical data in real time. GIS manipulates data rapidly and displays maps and diagrams based on users' criteria. They are designed for use by either novice or experienced operators using a system of menus. Some use sophisticated modelling packages for particular applications, such as network coverage for broadcasting services, path profiles between desired locations, or visualization of the horizon.

3.4.3 Input to the database

An administration establishing or upgrading a national spectrum management database is probably doing so because it already has an abundance of data that it wants to manage more effectively. The significant task of initial data input can be simplified somewhat with advanced data input techniques (e.g. a graphical user interface) or by requiring licensees and equipment suppliers to provide data in an electronic form that is compatible with the database. Though administrations with only paper records will most likely need to enter data manually, those with an existing electronic data storage system should be able to use software to map the available data into the new data files, at a significant savings.

It is critical that an administration allocate sufficient resources to keep the database accurate and current. Further resources may be required to modify the database if new capabilities (such as maintenance of newly-required data) are needed.

To help maintain the accuracy of the data, validation checks should be part of the data input process. Basic validation checks flag invalid data, such as a frequency assignment application number in the wrong format or an equipment parameter outside an acceptable range, and provide an error message for the entry. More sophisticated systems could recognize, for example, incompatible equipment specified for use at a station.

3.4.4 Output from the database

Database output consists of information provided directly to the user via a query of the database, or provided to an application for use in analysis. In each case, the DBMS should be designed to give the user or application designer powerful query capabilities through an easy-to-use interface.

Though a relational database consists of tables stored in files, known as “base” tables, direct examination of these base tables would be of little use to most users. Instead, the users require “virtual” tables, known as “views”, which the DBMS displays to the user to answer the user’s question. As an example, a user may be asking, “What are the names and telephone numbers of all licence holders having ten or more HF licences?” The DBMS would identify the licences for HF systems based on licence and frequency assignment tables, identify the holders of those licences from the licence table, determine which licence-holders have ten or more HF licences and retrieve the names and telephone numbers from the licence-holder table. No actual table would be created based on this data, but a virtual table (view) would be displayed or printed for the user.

An administration’s continued and expanding use of its spectrum management database will suggest new, unforeseen requirements for views of the data. To accommodate this need for additional views, the DBMS should recognize all valid relationships between data.

CHAPTER 4

Electronic exchange of information for spectrum management

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4.1 Introduction

This Chapter provides guidance to spectrum managers in organizations who want to implement or improve electronic data exchange. It considers among other things the hardware, software, data storage media, data file format and dictionary, library, security, procedures, communications networks, and the personnel required to accomplish this task.

The term "spectrum management information" includes, but is not limited to, the information which is needed to carry out the following functions:

a) portraying frequency band allocations; national frequency plan;

b) national frequency assignments and allotments;

c) licensing and billing;

d) coordinating and/or notifying frequency assignments or orbital positions;

e) monitoring spectrum activity;

f) specifying equipment/antenna/system characteristics;

g) using and transferring analytical models; and

h) accessing regulatory documents.

The process of exchanging information via electronic or computer related means and transforming that information into a suitable form for automatic processing is commonly referred to as electronic data interchange (EDI). Further, it is implied that the exchanged data will convey information that must be understood by the receiving party. For successful information exchange, both the sender and receiver must adhere to agreed standards for the conversion and transmission or transportation of the data. These standards may be human or computer-related. The former may be understood as a common cultural or technical background and is rarely explicitly formulated. The latter is standardized as a set of accepted formats.

Electronic data exchange may be facilitated in a number of ways; from the use of physical media such as CD-ROM, optical disc, memory stick, to the use of electronic file transfer protocols that permit transmitting information via wirelines, fibre optic cables, or radio wave transmission media. The cost of implementation and the benefits available to administrations will depend on their existing computer facilities, their requirements, and their desired solution.

In employing an electronic system to exchange spectrum management information, a degree of efficiency and effectiveness is expected to be gained. Search and retrieval of documents or technical data are vastly improved. Response times associated with evaluating frequency coordination proposals are reduced or minimized. The time associated with the capture and submission of notification data to the Radiocommunication Bureau is also substantially reduced. These benefits permit improvements in efficiency and may result in savings in personnel time.

Electronic data exchange provides the ITU with the same benefits as administrations but on an international scale. To aid the exchange of data electronically, the ITU has established a network facility called TIES (Telecommunication Information Exchanges Service) which is a set of networked information resources and services offered by ITU without any charge to ITU Members (Member States, Sector Members, Associates and Academia) to support their participation in the activities of the Union. More information is available in the TIES home page (http://www.itu.int/TIES/).

For the Space services, in accordance with Resolution 55 (WRC-2000)[6], electronic filing is mandatory and users are expected to use SpaceCap to capture RR Appendix **4** information, GIMS to capture related graphical data and SpaceVal to validate these data elements. SpaceCap, GIMS and SpaceVal are distributed on each BR Space IFIC and also available for download from the space software website.

For details on how to prepare your electronic filings and submission of assignments/allotments to space services, see the ITU website at http://www.itu.int/ITU-R/go/space-support/.

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6 This Resolution was revised at WRC-12.

Today, electronic filings for the Space Services should be submitted by e-mail to the BR email address: brmail@itu.int. This will change in the future as the Resolutions 907 and 908 of WRC-12 instruct the BR to develop a modern and secure web service for electronic communication between the administrations and the Bureau. Users will be advised by Circular Letter when this new method of communication is in place.

For terrestrial services, in accordance with Resolution 906 (WRC-07)[6], submission of notice forms in electronic format is mandatory since January 2009. Submission shall be made via the secured ITU web interface WISFAT (Web Interface for the Submission of Frequency Assignments/Allotments to Terrestrial Services). Access to this interface is limited to TIES registered users (see Case Study 1 below) nominated by the notifying Administration as their official notifiers.

Case Study 2 below provides more details on the notification of frequency assignments/allotments to the Bureau.

4.2 Transport methods

When planning to electronically exchange spectrum management information, a number of alternative transport methods may be used. The challenge facing the spectrum manager is to select one method or a combination of methods that best satisfies the requirements. Making this selection requires considering a number of factors including the estimated costs, timeliness for accomplishing the task, accuracy of the information transferred, capacity of the information transfer medium, availability and reliability of the communications medium, availability and reliability of required hardware/software, security of information and availability of trained staff to assist in the execution of the procedures and operations.

From a data storage, transmission, or processing perspective there is no difference between the data files representing spectrum management information and any other data files. Consequently, the spectrum manager should draw on the experience gained by other managers who have successfully implemented effective systems and procedures for satisfying their electronic information exchange requirements.

The discussion below presents some of the major transport methods together with some factors that should be considered in selecting the appropriate methods to use.

4.2.1 Surface mail

Surface mail is the simplest exchange of data using postal or package/courier services. The data can be held in a variety of different media (CD-ROM, optical disc, memory stick, etc.). For a limited number of exchanges, with a limited number of recipients this method may prove to be highly efficient and cost-effective.

When considering this method, however, consideration needs to be given to the staff time and the materials costs for copying the data to the chosen transport media, packaging, and the costs of the postal, package/courier service. In some cases, the use of third party support for performing these copying and packaging activities may be cost-effective.

The sender should be aware of the postal or package/courier services' reliability and the likely time/location of the delivery when selecting the service provider.

4.2.2 Facsimile (fax)

Facsimile (fax) is a technology which permits the transmission of images from one machine to another using the public switched telephone network (PSTN). The sending machine may be a dedicated fax machine or a PC with fax image conversion software and a fax modem. The receiving machine reproduces the original image on a printed page, or in the case of a PC based fax modem, stores it in an image file. Since an image of the entire printed page is transmitted, faxes can be used to exchange both text and graphic information.

Fax image conversion is performed to set standards and therefore PC software will not achieve any greater resolution than a dedicated fax machine. The principal advantages of PC software over a dedicated machine include:

– no manual scanning/paper feed problems;
– PCs have a larger memory than dedicated fax machines and therefore larger files can be sent to a greater number of recipients (this can however become a disadvantage if it ties up a user's PC for any significant length of time);
– the information exchanged can be stored in an image file.

4.2.3 Electronic mail (email)

Electronic mail (email) is a technology that permits a message to be transmitted between computer systems through data and/or telecommunications networks. This transfer is accomplished without any requirement for human intervention. A number of multi-featured email systems are available on the market and new products are constantly emerging. Using email services offers certain benefits over the use of surface mail and facsimile; however, the factors discussed below in the implementation and use of email systems should be considered taking into account the inter-connection(s) with a data network(s).

The system's capability for establishing a message path to intended users is a critical element of any email service. Email services available to the users connected to a LAN may be adequate for coordinating local spectrum management activities, but the use of email services to coordinate regional or international activities will require access to communications servers that can be connected either through the PSTN or a backbone network such as the Internet. While a variety of methods may be used within a given LAN or WAN to establish a "connection" between computers, the protocol used on the Internet permits message transmission in a "store and forward" manner.

While most email systems permit sending identical messages to multiple addresses, software (known as listservers) can be used to manage electronic mailings. Listserver software is not included in standard email installations and the installation of some multi-featured listserver software may require specialized expertise to achieve full compatibility with existing email systems. However, if a requirement exists for frequent electronic distribution to an extensive list of addressees, a listserver can be cost-effective.

4.2.4 Remote data access – Bulletin boards, WWW servers, FTP sites and "Connections"

Remote data access is a set of procedures and technologies which permits users to:

– connect their computers (local) to other computers (remote) in distant locations and view, copy, delete, revise, or execute files/programs located on the remote computer;

– transfer (upload) files between the local and remote computers.

As was noted in the previous section, email services operate as store and forward systems; consequently, the message path between computers sending and receiving email messages need not be a continuous connection. Remote data access services operate as "on-line" services; this means that a continuous connection (referred to as a "login session") must be maintained while the user is using or exchanging data with the remote computer. Because of this need for continuous connection during login session, spectrum managers considering the use of these types of services need to examine the availability and reliability of the communications facilities (LANs, WANs, PSTN, Internet, etc.).

Various forms of remote data access services can be established using what are commonly known as "servers". These servers are comprised of computers and specialized applications software that offer various types of services (bulletin boards, World Wide Web, FTP) to users.

4.2.5 Standards compliance

Standards are required to enable a product manufactured in one country to be compatible with similar equipment in another country. In the area of telecommunications, there are a large number of sometimes very complex standards. These standards are related to both hardware and software and are required for the use and growth of complex networks. Without these standards, data could not be transferred between the thousands of nodes in networks whose various segments may be controlled by different organizations around the world.

In June 1992, an Internet mail standard was approved (MIME). MIME is an acronym for Multipurpose Internet Mail Extensions. This standard builds on the 1982 standard with additional fields for mail message headers that permit new types of content and organization for messages. MIME allows mail messages to contain:

– multiple objects in a single message,

– text having unlimited line length or overall length,

– character sets other than ASCII,

– multi-font messages,

– binary or application specific files,

– images, audio, video, and multi-media messages.

Efficient and effective use of the electronic information exchange methods requires strict adherence to approved standards. Where the information exchanges cross national boundaries, international standards are required. When specialized data files are to be exchanged, agreements need to be established between all the intended users of this data to assure reliable retrieval of the information. Failure to use accepted standards will make the intended electronic transfer of data unreliable.

4.3 Issues in systems implementations

The introduction of data exchange by electronic means can have a major impact on an administration's procurement and computer system operations. The extent of the impact is dependent on the existing levels of computerization, the type of electronic data exchange required including the BR notification and regional agreements, the administration's security requirements, and the level of personnel skills available. All these factors must be considered as they will determine the cost effectiveness of implementing a data exchange mechanism and the level of benefits that the administration can achieve.

The starting point for the introduction of electronic data exchange must be an assessment of both the existing computer system and what the administration wants to achieve in terms of electronic data exchange. The result of the assessment analysis, combined with infrastructure considerations, will provide the administration with an overall view of how much a move to electronic data exchange will cost including training, the potential benefits and the timescale required. One factor that may emerge from the analysis could be that the proposed method of data exchange is not achievable in the short term and that a programme of controlled change over a period of, for example, 1-2 years is more practical, cost effective and manageable.

4.3.1 Existing computer facilities

An administration's existing computer facility may consist of stand-alone computers, networked computers or both. Computers may have a simple operating system where the features available are largely dependent on the application software or a more powerful operating system with many intrinsic features. An administration's computers may have different operating systems or they may be located at a number of different sites within the country. The simplicity or complexity of an administration's computers or the diversity of their location is not a barrier to implementing electronic data exchange.

4.3.2 The administration's electronic data exchange requirements

The essential question for any administration implementing electronic data exchange is "What do we want to achieve?" Does the administration wish to exchange data solely with the BR, or in addition, with other administrations? Is there a requirement to exchange data with other sites in their country or in addition with foreign websites? Does the administration want to link the introduction of electronic data exchange of spectrum management information with the development of a networked computer facility using a LAN or WAN? Will the administration's requirements change with time?

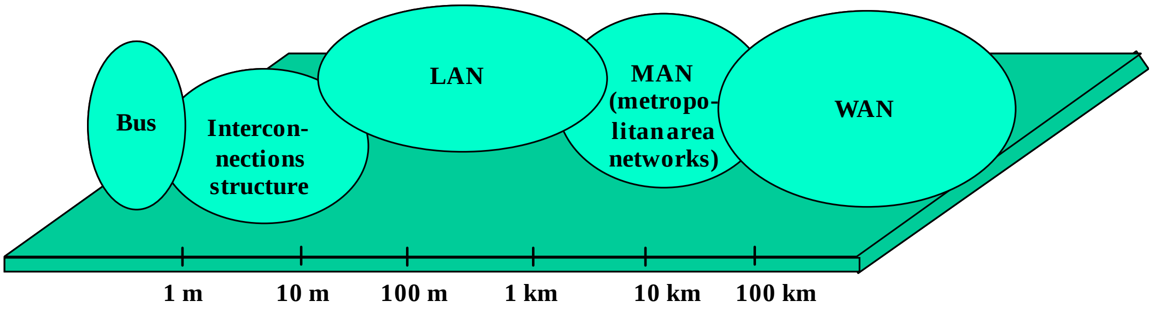
An administration's computing infrastructure will affect the implementation and operation of electronic data exchange. The extent of the impact will depend on the administration's requirements.

For electronic data exchange, it is necessary to implement in the national structure an information network allowing the files transfer from a computer to other computers, to link distant terminals to the central site, computers amongst themselves, and terminals such as workstations with servers.

Generally, five informatics network types are recognized depending on the maximum distance between the furthest points:

FIGURE 4.1

The different kinds of informatics networks



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The following list contains typical factors requiring consideration: the layout of the building can affect network costs; the number of sites to be connected in a country and that country's topography and national communications system, will determine the type of communications network needed; the cost of communicating via the PSTN or/and Internet varies considerably from country to country and therefore may be of primary importance to one administration and insignificant to another. Skilled personnel who understand the communications and network requirements are essential for implementing any network solution.

Moving to electronic data exchange does not require any major computing skills. However, it is essential to implement security measures appropriate to the value of the data and system (e.g. virus protection).

The following guidance will help to secure the spectrum data network:

– The system manager must control the access rights of the users for all the different elements of the system: management at the computer network level and the access to the system. This management needs to allow the definition of several access levels according to the user tasks and also the user's creation, modification, and deletion privileges.

– The manager should have the capacity to verify the network utilization of each authorized user. A data information storage and access network control system needs to be implemented to allow this supervision task.

– At the network level, it is necessary to implement up-to-date techniques to control external intrusions by means of informatics tools such as firewalls, anti-virus, etc. These tools must prevent non-authorized accesses.

– At the system level, the data has to be protected vis-à-vis operators. The authorized user, in accordance with his rights has access only a part of the global data according to his privileges. The system manager should have at his disposal the tools to define the accreditation level and the ability to grant or revoke these rights.

– The data servers should include physical data safeguard methods (such as disk redundancy using RAID techniques) as well as periodic backup on external media (back-up each night or each week). Data restoration tools must also be available with the goal of restoring the system.

– Finally, the accesses at the WAN network have to be secured and the data encryption considered.

As the electronic data exchange mechanism becomes more sophisticated then potentially more benefits accrue to the administration. However with this increase in sophistication and benefits, there is a corresponding increase in the complexity of the installation and the cost of both implementation and maintenance.

In a stand-alone computer facility and with today's elaborate modern software, most users do not need to acquire computing skills beyond those necessary for using the application software. The support required to maintain these computers can therefore be provided either by the users or by specialist computer support staff. Administrations are more likely to have specialist support services if they already have either local or wide area network systems or if any of their computer systems are running some of the more powerful operating systems such as UNIX. More extensive computing facilities are also likely to have more highly developed system security arrangements. If an administration already has these facilities in place, it may be easier for them to implement more sophisticated electronic data exchange systems, since the impact on their existing computer systems operations may then be small.

4.3.3 Procurement

All administrations will have an approach to procurement, whether the selection of the hardware and software is made by specialist support staff or in collaboration with the spectrum users. Procurement can be based on standardization around a particular brand of software, hardware or on the desire for the best possible solution to meet individual work requirements. The more elaborate the electronic data exchange system becomes, the more software and hardware is needed to meet the administration's needs. However, care needs to be exercised in selecting software or hardware since not all network or communications software is necessarily compatible. There may also be additional problems with some application software and operating systems. Identifying the potential problems and successfully implementing electronic data exchange may therefore require the administration to take a pragmatic approach to procurement by selecting the best overall fit of software and hardware to meet the administrations' needs. Successful implementation may also mean acquiring experience in data communications.

4.3.4 Managing change

It is necessary for administrations to consider how they will manage the transition to their required standard of electronic data exchange. If the transition is considered to be significant, the implementation of one or more pilot schemes is highly recommended (perhaps with more than one type of software) to gain experience. This approach also allows in-house personnel time to gain new skills and experience under controlled conditions, without the pressure of working on an operational system.

The selection criteria for the computer systems is very important, especially the software (both operating system and application software). Software is efficient for many reasons; speed, user-friendly interface for the programmer and end-user, customer support, etc. If software is extensively used, one can usually assume that the product works reasonably well. There is also a good probability that if additional staffing is required, trained personnel may be available if the product selected is in wide use.

4.4 Case studies

The following case studies are examples of the existing and planned use of electronic data exchange by the ITU and a number of administrations. They are intended to demonstrate both the variety of information that administrations wish to exchange and the potential benefits for administrations and the BR.

These case studies range from document exchange, which is the simplest but most common form of electronic data exchange, to the more elaborate and complex requirements of coordination.

The example in the monitoring environment perhaps best typifies the need for electronic data exchange as well as the need for international agreement on the format. This example shows how as the quantity of monitoring data collected increases, the most suitable method of handling it is for it to be directly loaded into a computer for analysis. It is also an indication of how remote automated monitoring equipment may be accessed from other distant locations.

Case Study 1: Document exchange via ITU-TIES for ITU-R meetings

a) *TIES services*

The ITU Telecommunication Information Exchange Services (TIES, see at http://www.itu.int/TIES/) is a set of networked information resources and services offered by ITU without any charge to ITU Members (Member States, Sector Members, Associates, and Academia, see at: http://www.itu.int/en/membership) to support their participation in the activities of the Union. Most of these services are available via the World Wide Web. One of the main goals of TIES is to help make ITU activities, such as telecommunication and radiocommunication standardization work, more rapid and efficient. Another goal is to make a wide range of ITU information available to all interested parties. In general, ITU information is public with no need for prior registration. ITU electronic publications are available for on-line purchase, by annual subscription or free of charge on-line, according to the case.

b) *Information for TIES registered users*

TIES membership allows, through the Internet, access to ITU-R information resources including TIES restricted Study Group documents (Contributions, Temporary Documents, etc.). "TIES registered users" may also be able to access set up mailing lists with FTP server web pages and/or share point sites with share folders for exchanges of informal working documents between or during meetings.

More information is available on the TIES Frequently Asked Questions web page (http://www.itu.int/TIES/faq.html).

c) *Electronic exchange of documents for the ITU-R meetings*

The electronic exchange of documents is of considerable importance to the BR as it offers a potential solution to the rising cost of document production and distribution. It enables contributions to be sent quickly and easily to the BR, reducing effort on the part of the contributor and giving the BR more time for processing the document (see Resolution ITU-R 1 at http://www.itu.int/pub/R-RES-R.1/en, as well as guidelines for the preparation of proposals to the Conferences at http://www.itu.int/en/ITU-R/conferences/wrc/2015/Pages/default.aspx. For administrations, the electronic document exchange reduces the cost of the paper copies in addition to space saving in terms of storage of paper documents.

Case Study 2: Notification of frequency assignments/allotments to the Bureau

At World Radiocommunication Conferences, the Member States develop and adopt the modifications to the Radio Regulations (RR), a set of rules and procedures that serve as a binding international treaty, governing the use of the radio-frequency spectrum (some 40 different services) in the three Regions of the world defined in the RR.

The BR is the secretariat of the Radiocommunication Sector and is responsible for the application of the RR and various regional Agreements. It maintains frequency assignment/allotment Plans and the Master International Frequency Register (MIFR). In addition to the MIFR and Plan database, specialized software is developed by the BR for the purpose of facilitating the tasks involved in the application of the RR. Two specific Departments within the BR are in charge of the application of RR provisions: Terrestrial Services Department (TSD) and Space Services Department (SSD).

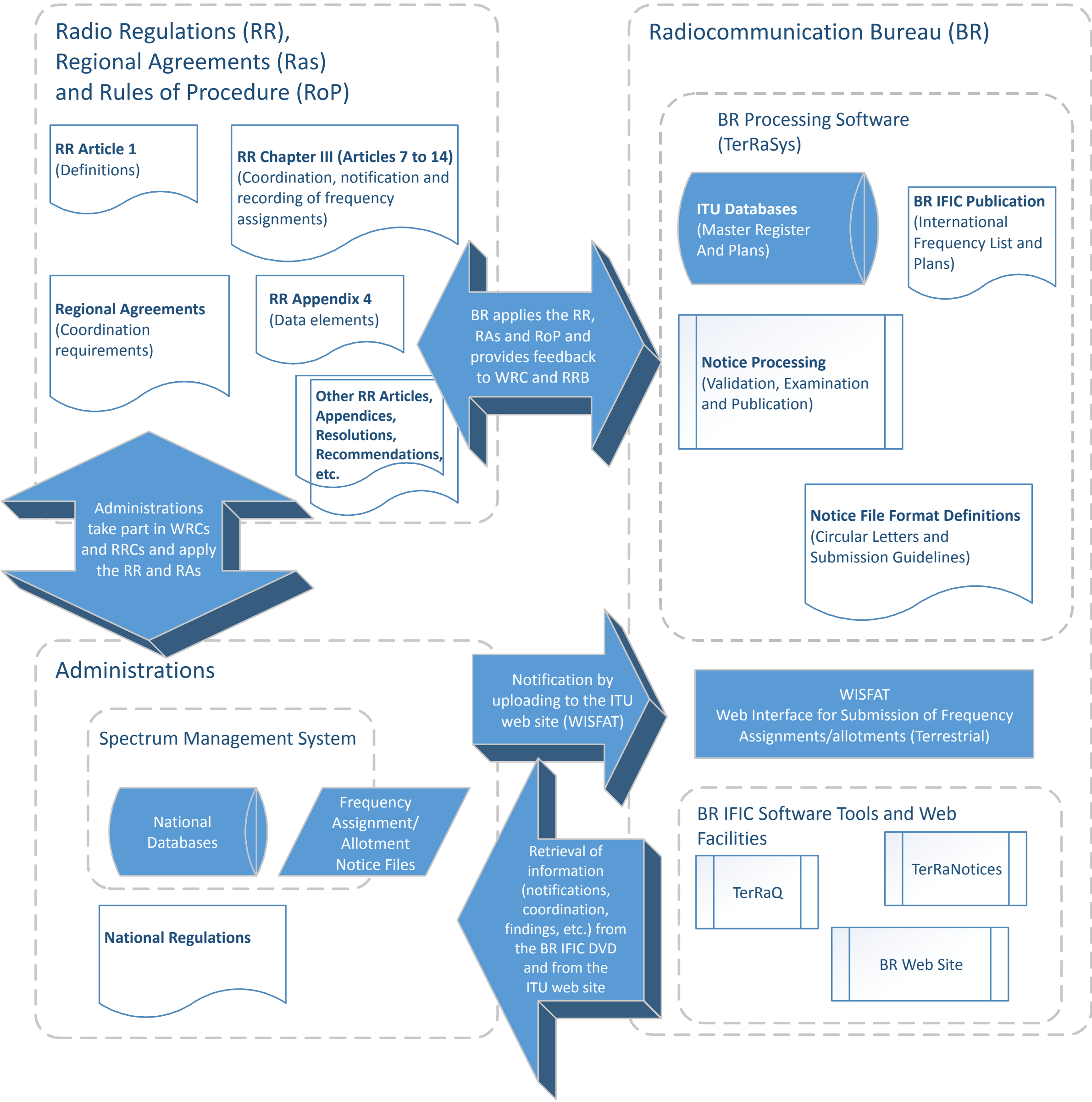
Notification of assignments/allotments to terrestrial services

Circular Letters and Guidelines for submission of terrestrial frequency assignments/allotments are available on the ITU website at: http://www.itu.int/ITU-R/go/terrestrial-notice-forms. These contain instructions to the Member State concerning assignment/allotment notification in electronic format.

When an administration must or may notify after identifying and selecting assignments within its national frequency management system, it should create an electronic notice as explained in the corresponding circular letter or guidelines provided in the above mentioned website. The Bureau provides in its bi-weekly BR IFIC (Terrestrial) DVD a software application called TerRaNotices which facilitates the creation and the validation of electronic notice files (see Figure 4.2).

FIGURE 4.2

ITU-R terrestrial notification scheme



Notification of assignments to space services

For the purpose of submission of all notices for satellite networks, earth stations and radio astronomy stations to the BR, pursuant to RR Articles **9** and **11**, RR Appendices **30**, **30A** and **30B**, Resolution **49 (Rev.WRC-12)** and Resolution **552 (WRC-12)**, as well as for submission of comments/objections to a Special Section published in a BRIFIC for the space services, the BR distributes a BR space software package that is made freely available to all administrations in the BRIFIC DVD and BR web page (see Case Study 3) below).

Guidelines for electronic submission of assignments/allotments to space services are available on the ITU website at http://www.itu.int/ITU-R/go/space-support/.

Case Study 3: BR Software/Tools for notification and consultation of BR databases

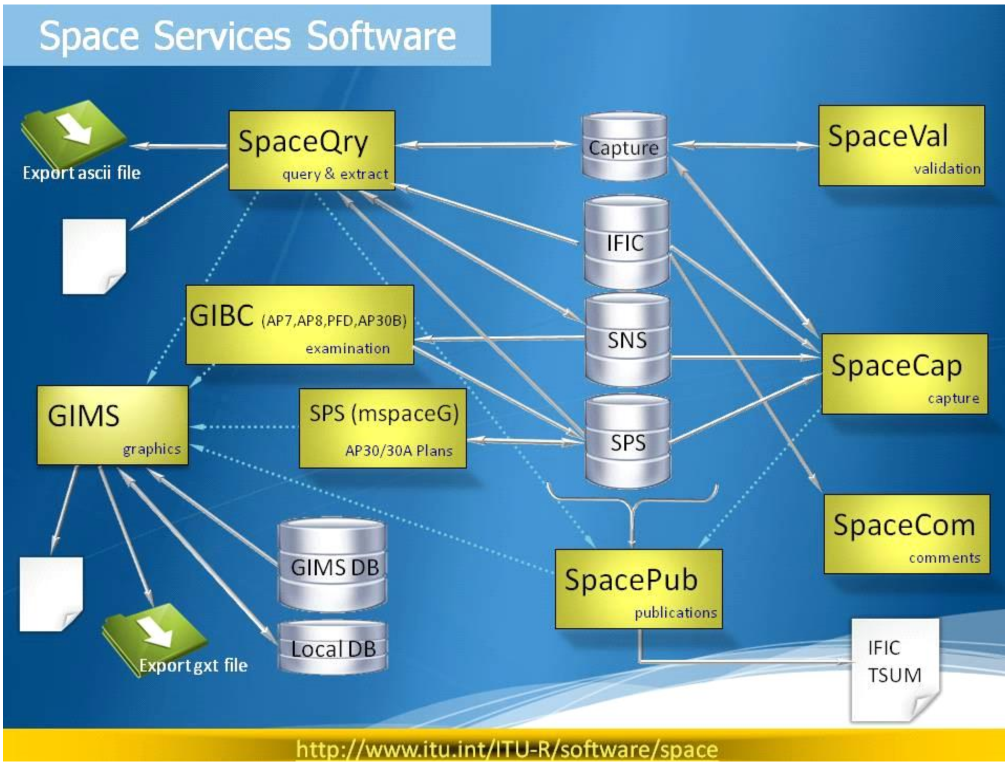
Space Services Software Package

The most current version of the BR soft package for the space services is available to administrations and other users on the space software website (http://www.itu.int/ITU-R/software/space/index.html) and distributed on the BR IFIC (Space Services) DVD-ROM.

The BR has developed software to help users prepare their electronic filings, as listed below and as shown in Figure 4.3:

- **SpaceCap** – capture and modify alphanumeric data related to electronic notification of satellite networks,
- **GIMS** – capture and modify graphical data related to electronic notification of satellite networks,
- **SpaceVal** – validate electronic filings for satellite networks,
- **SpaceCom** – capture comments/objections in response to the publication of Special Sections related to satellite networks,
- **GIBC** – run technical examination,
- **SPS** – Space Plans software to determine coordination requirements for the Plans for space networks in Appendices **30**, **30A** of the Radio Regulations,
- **Space Pub** – print data related to Space Network filings,
- **SpaceQry** – query data related to Space Network filings.
- **SNS Online** – is a web application which you can use to query the BR Master Space Network Systems database. With SNS Online, you can also view the graphical data for both Space networks and Earth stations (http://www.itu.int/sns/).
- **SNL (Space Network List)** – is a web application which will give you a list of basic information concerning Space Network filings (http://www.itu.int/ITU-R/go/space/snl).

FIGURE 4.3



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Most software are provided with some help and tutorials. The BR Space Support web page (http://www.itu.int/ITU-R/go/space-support) contains more information on how to prepare electronic filings.

Terrestrial Services Software Package

The BR International Frequency Information Circular (Terrestrial Services) is a service document in DVD format, published once every two weeks by the Radiocommunication Bureau in accordance with provision Nos. **20.1** to **20.6** and **20.15** of RR Article **20**.

The BR IFIC (Terrestrial Services) consists of the following:

– the International Frequency List (IFL) (including all the frequencies prescribed for common use);
– the Terrestrial Plans annexed to the Regional Agreements;
– the Special Sections associated with the Plans;
– notices under processing in accordance with RR Article **11**;
– notices under processing for modification of a frequency assignment or frequency allotment Plans;
– the TerRaQ program, used for query, display, exporting of the data, etc.;
– the TerRaNotices program which assists administrations in creating and validating electronic notice files before submitting them to the Bureau;
– the Preface.

Case Study 4: ITU-D Spectrum Fees Database (SFDB)

Resolution 9, first adopted by the World Telecommunication Development Conference (WTDC-98) and revised by WTDC-02, requires the Directors of ITU-D and ITU-R to develop a report, in several stages, on current and foreseen national uses of the radio-frequency spectrum. A Joint Group between the Telecommunications Development Sector and the Radiocommunication Sector was established in 1999 to develop the reports required by Resolution 9. The reports on the first and second stages are available on the ITU-D website. In addition to the work programme to develop the second stage of the report, WTDC-02 requested that the Joint Group should include in its scope the preparation of a report in answer to Question 21/2 – Calculation of frequency fees.

The elaboration of a national frequency fee calculation model is a very complex matter and is the source of major difficulties for numerous developing countries and particularly LDCs for which the need is extremely urgent. Question 21/2 requested the establishment, in electronic format, of a document structure bringing together the calculation formulas and frequency fee amounts applied by different countries for different radiocommunication uses in the various frequency bands. The Question also requests a report on the various frequency fee calculation formulas currently applied in different countries.

Comprehensive information from administrations for this part of the report was obtained through Part III of a Questionnaire (Questions 1 to 9) circulated by Administrative Circular CR/12 (ITU-D) and CR/10 (ITU-R), dated 11 September 2002. In order to store the results in electronic format, as requested by Question 21/2, the BDT Secretariat has developed a suitable database, the “Spectrum Fees Database” (SFDB).

The SFDB may be accessed in read-only mode through the ITU-D website using the website address below. No passwords are required for reading the database:

http://www.itu.int/net4/ITU-D/CDS/SF-Database/index.asp

To remain a useful tool, the SFDB depends on administrations to keep it up to date with any changes to their national spectrum fees information. It is the responsibility of administrations to use the procedures below to update the SF with this information:

– Only one person shall be entitled to enter or modify the data in the database. The relevant authority should notify the BDT Secretariat if the administration should decide to change the person already nominated.

– Once a person is designated, the BDT Secretariat will communicate to her/him, the password for entering or modifying the data of the country concerned.

The SFDB structure is based on the structure of the questionnaire as follows:

– Questions 1 to 9 called **Q1-Q9**
– CHARTS A – E (to be filled by yes or no) called **CHARTS**
– CHARTS A – E (Parts to be filled with free text) called **SCALES**.

A version of the questionnaire is given on the ITU TIES website:

English version: http://www.itu.int/ITU-D/study_groups/SGP_2002-2006/circular/12-E.doc

French version: http://www.itu.int/ITU-D/study_groups/SGP_2002-2006/circular/12-F.doc

Spanish version: http://www.itu.int/ITU-D/study_groups/SGP_2002-2006/circular/12-S.doc

ITU-D Document JGRES09/043 (Rev.1) gives the user guide of SFDB (see http://www.itu.int/ITU-D/pdf/2002-JGRES09_043REV1-en.doc).

Case study 5: G-REX, The Virtual Tool for Regulators ITU website

The Global Regulators' Exchange (G-REX) is a password protected website just for communications regulators and policy makers. This initiative, launched by the Telecommunication Development Bureau (BDT) of the International Telecommunication Union (ITU), in May 2001, provides a vehicle for sharing information, views and experiences on pressing regulatory issues. BDT believes that well-informed regulators are more effective regulators and that effective regulators are key to helping to bridge the digital divide.

The most popular feature of G-REX is the Regulators' Hotline through which regulators and policy makers can pose any question they wish and seek feedback from their colleagues around the world. Since launching G-REX, there have been over 120 queries posted on the Hotline. Twenty were posted in 2001, 23 in 2002 and 51 in 2003. For 2004, 27 queries had been posted by June 2004. In other words, G-REX currently receives more than one new question every week. But G-REX is about more than questions. It also provides answers. In 2003, for example, there were approximately 220 replies posted to the Hotline queries.

BDT is helping to encourage more information exchange through its G-REX advisors, bilingual experts who translate all postings into French, Spanish and English, and also research regulators' websites to find additional information responsive to the Hotline queries. G-REX advisors post links and relevant documents, providing an essential addition to the online regulatory discussion.

In addition to the Regulators' Hotline, G-REX offers both text-based and virtual conferences. G-REX has hosted text-based conferences on topics such as interconnection dispute resolution. G-REX also hosted the "Interconnection Emergency Room" through which the Rapporteur for ITU-D Study Group 1, Question 6-1/1 was available to answer countries' interconnection queries.

G-REX virtual conferences combine telephone conference calls with a dedicated website through which participants can, in real time, share power point presentations, documents on their hard drives and engage in online chat. G-REX has hosted virtual conferences on Wi-Fi for Rural and Public Access; Interconnection Dispute Resolution and Spam. Virtual conferences are a cost-effective way to organize live conferences on targeted subjects among a small group of participants obviating the need to travel. G-REX Virtual Conferences have united participants from all five regions of the ITU membership, in developing as well as in developed countries.

G-REX is managed by the Regulatory Reform Unit (RRU) of the BDT. Any regulator or policy maker interested in registering for G-REX is invited to do so at http://www.itu.int/ITU-D/grex/register.asp.

Case Study 6: Agreement for common use of HF direction finders within CEPT

Introduction

This agreement (September 2003) provides the possibility for any Administration of the European Conference of Postal and Telecommunications (CEPT) to access and to undertake measurements with HF direction finders in the range below 30 MHz from other administrations.

Due to the physical characteristics of short wave and the costly nature of HF direction finding equipment, it is agreed that it is appropriate to establish a European common approach to share the HF direction finders amongst the CEPT administrations having signed this agreement. The aim of this agreement is to create a common understanding and to provide cooperation among the signatories for using HF direction finders from other administrations for the purpose of spectrum monitoring and clearance of radio interference.

This agreement establishes the procedures for a common use of HF direction finders on a non-profit making basis within the CEPT. The Universal Control Software allows access to the HF direction finders.

HF direction finders are commonly used for:

– Locating unknown HF transmitters
– Regular and systematic monitoring of the radio-frequency spectrum
– Support of ITU and CEPT measurement campaigns
– Investigation of harmful interference
– Monitoring of the parameters of HF transmissions.

An Internet web page is available and contains the necessary general and technical information as well as the capacity to check the status of the different HF direction finders, or updating the version of the application software “UCS”. The access to this page is limited to signatories (member area).

The coordinating administration is responsible for updates to the general information as well as the technical information of the HF direction finders on the Internet page. Signatories and Operators should provide the information and also all changes immediately to the coordinating administration.

The technical information of the HF direction finders, available on the website are:

– Operational contact points of the Signatories
– Technical contact points of the Operators
– Location name
– Station ID
– Country
– Latitude (“WGS 84” geodetic system)
– Longitude (“WGS 84” geodetic system)
– Frequency range
– Access hours on the HF direction finder
– Manufacturer
– Type of the HF direction finder
– Accuracy of the bearing
– Demodulation
– Bandwidth (D/F)
– Bandwidth (audio)
– Bandwidth (spectrum)
– Attenuation,

and are stored in a configuration file called “Config_file_siteID.ini”.

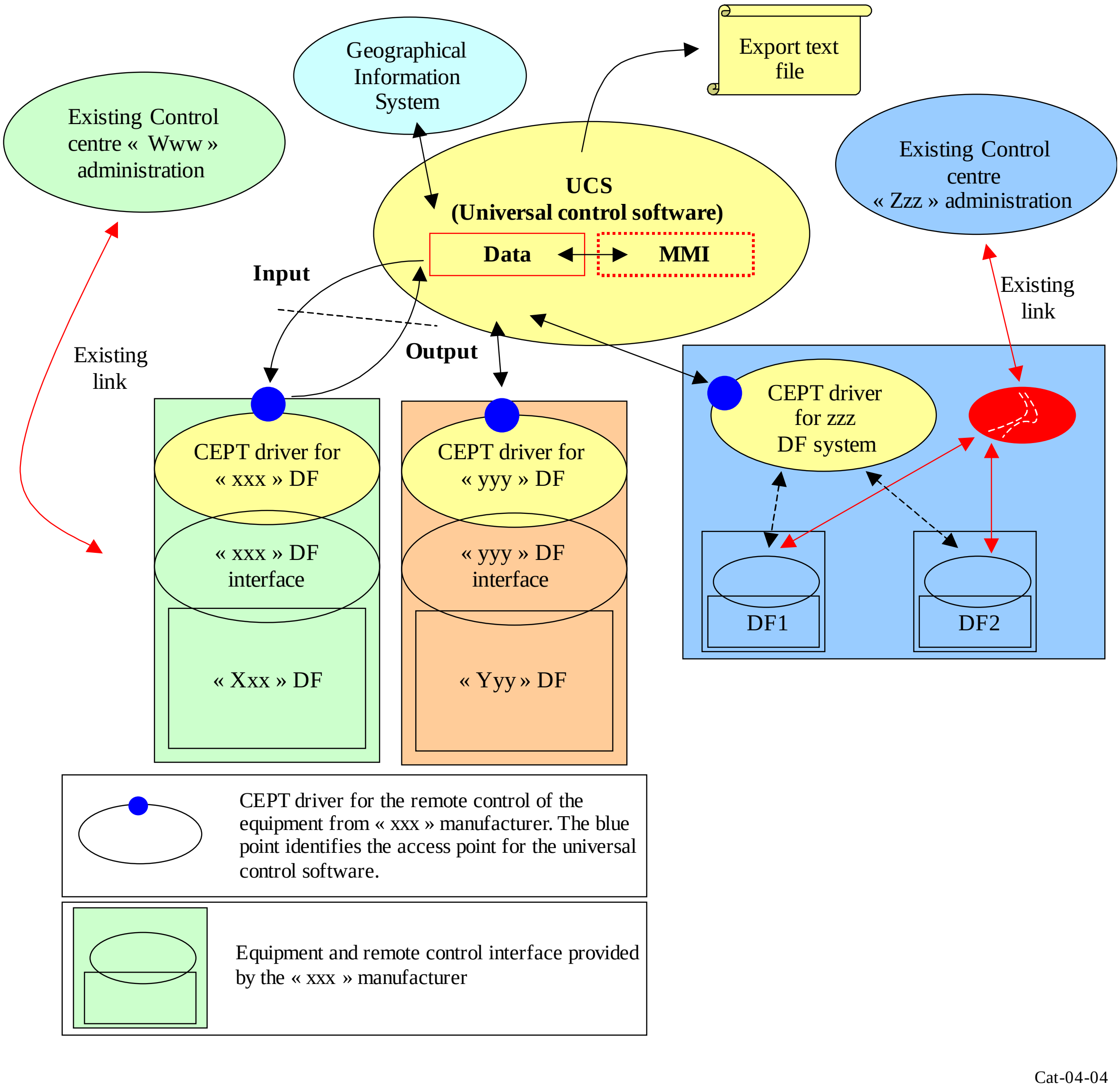
The architecture and description of interfaces

The concept of the HF DFs interconnection is based on a “*common data exchange structure*” (developed by CEPT) for the technical information (measurement commands and results). All equipment, irrespective of the manufacturer, understands these commands and functions in the same manner. It is done by the way of “CEPT device drivers” and “Universal control software (UCS)”.

The architecture is introduced in Figure 4.4:

FIGURE 4.4

Structure of the HF DFs interconnection



– The *existing control centres*, are the equipment and software applications (working in administrations and provided by manufacturers or developed for specification requirements) which are used to control the direction finders in the present situation (not interconnected).

– The existing *Direction Finders*, are provided by the manufacturers with a remote control interface whose commands and results are specific to the equipment.

Case Study 7: Data exchange within the HCM cross-border frequency coordination Agreement

The HCM (Harmonised Calculation Method) Agreement is an agreement concluded by the representatives of the administrations of Austria, Belgium, the Czech Republic, Germany, France, Hungary, the Netherlands, Croatia, Italy, Liechtenstein, Lithuania, Luxembourg, Poland, Romania, Slovakia, Slovenia and Switzerland (17 European countries), under RR Article **6**, on the coordination of frequencies between 29.7 MHz and 43.5 GHz for the purposes of preventing harmful interference to the Fixed and Land Mobile Services and optimizing the use of the frequency spectrum above all on the basis of mutual agreements.

The first version of this Agreement was the Vienna Agreement (VA) signed in 1986. Updated versions have been issued subsequently and are available online (see http://www.hcm-agreement.eu/http/englisch/verwaltung/index_berliner_vereinbarung.htm).

Principles

The general principle of this Agreement is to facilitate the coordination through an equitable distribution of the frequencies at the borders on bi- or multilateral base in "preferential frequencies"; defined as frequencies usable without prior coordination procedure, subject to respecting the pre-defined technical criteria (agreements, annexes).

Frequency bands

For the frequency bands, two types of coordination are applicable:

– *First list*: *Land mobile service*

  For the land mobile service in frequency bands other than those defined in Article 1.2.1 and for all other services in these frequency bands, the coordination procedure set out in the Agreement may be used, and, if necessary, the technical parameters shall be agreed separately.

– *Second list*: *Fixed services*

  The coordination procedure laid down in the Agreement for the fixed service is only valid if in both countries involved in the coordination process the respective frequency band is allocated to the fixed service and the respective frequency falls under the responsibility of the Administrations.

For the land mobile service in frequency bands other than those defined in Article 1.2.1 and for frequencies above 1 GHz used in the countries concerned for the fixed service in frequency bands other than those listed in the frequency table given in paragraph 1.2.3, the Agreement may be used, and, if necessary, the technical parameters shall be agreed separately.

Frequency register

The frequency register is made up of lists set out by every administration indicating its coordinated frequencies, its assigned preferential frequencies, its shared frequencies, its frequencies coordinated for planned radiocommunication networks, and its frequencies used on the basis of geographical network plans and frequencies using preferential codes. All frequency assignments in this register shall be protected according to their status of coordination.

Technical provisions

– In the case of the land mobile service, the effective radiated power and the effective antenna height of stations shall be chosen so that their range is confined to the area to be covered. Excessive antenna heights and transmitter outputs shall be avoided by using several locations and low effective antenna heights. Directional antennas shall be used in order to minimize the potential of interference to the neighbouring country.

  A transmitting frequency shall be coordinated if the transmitter produces a field strength, at the border of the country of the Administration affected, which at a height of 10 m above ground level, exceeds the maximum permissible interference field strength as defined in Annex 1 of the Agreement. A receiving frequency shall be coordinated if the receiver requires protection.

– In the case of the fixed service, the effective radiated power and the antenna height of stations shall be chosen according to the radio links lengths and the required quality of service. Excessive antenna heights, excessive transmitter outputs and too low antenna directivities shall be avoided in order to minimize the potential of interference to the country affected. Annex 9 gives the maximum permissible threshold where the basic transmission loss is calculated in accordance with Annex 10.

Agreement carry out

The carrying out is made according the following principles:

– A common computation method, based on the propagation models defined by ITU-R and standard HCM (harmonized calculation method) used on DTM and borders lines agreed on bi- or multilateral basis.

The HCM Program is a program developed for the harmonized application of the calculation methods as provided in the Annexes of the Agreement.

New versions of the HCM program have to be implemented by all Administrations at the same point in time to avoid keeping different versions for different neighbouring countries. Because the HCM software is only a subroutine, this subroutine has to be implemented in national surrounding programs. A methodology is given in the Agreement to adopt new versions.

– Data exchange

a) *Procedures*

Overall list

According to the Agreement, frequency registers (overall list) have to be exchanged twice a year using disc or CD-ROM or other mutually agreed media.

Coordination and notification

Coordination request as well as, answers to coordination requests or notifications may be exchanged on disc or CD-ROM or other mutually agreed media.

Data to be exchanged during the coordination procedure may be of the following type:

– new entries;

– modifications;

– deletions;

– answers.

Each Administration shall prepare an up-to-date Frequency Register to be supplied to each Administration with which coordination is carried out. These Frequency Registers shall be exchanged bilaterally at least once every six months.

b) *Transmission media*

The following transmission media are preferred but others may be agreed bilaterally:

– E-mail

– Common Disk Media

Paper is limited to the coordination process but generally should be avoided.

Additional specifications for the exchange of data are provided in the relevant Annex of the Agreement and have to be met when disks or email are used.

CHAPTER 5

Examples of automated spectrum management procedures

TABLE OF CONTENTS

5.1 Introduction

This Chapter illustrates the practical use of methods described in the Handbook on National Spectrum Management and in the previous Chapters of this Handbook to aid the spectrum management process. Computer techniques can help in at least two ways: managing and examining large amounts of data; and performing calculations, whether complex, or simple but repetitive.

The examples illustrate both of these features. However, these samples are illustrative only, and do not necessarily represent recommended procedures. Each administration may establish its own procedures, which may also differ from service to service. The real criterion for measuring the success of an automated system is the extent to which it relieves the frequency manager from the tedious manual chores of searching through data files, performing repetitive calculations, and to which it presents results in a clear, concise format.

Each of the following examples uses different computer procedures. These procedures can be of great help in spectrum management and can be used independently. It is not necessary to combine them into a fully automated spectrum management system. However, maximum benefits accrue when such integration is possible.

Some examples show how the data can be applied in more complicated calculations. In many cases, standardised programs for handling data and performing automated co-ordination calculations have been developed by administrations or other organisations.

Short descriptions of automated systems and examples of computer aided techniques for spectrum management and monitoring can be found at the end of this Chapter, as well as in Annexes 2 to 11. Further examples of the use of computers in monitoring can be found in the ITU Handbook on Spectrum Monitoring (edition 2011).

5.2 Processing data in computer systems

Although database management systems attempt to de-couple application programs from the underlying data, the hoped for data independence is never perfect and the applications are invariably tied in some way to the chosen structure of the data. This coupling prevents the easy wholesale reuse of applications in situations where the underlying structures are dissimilar. Administrations are therefore cautioned that adapting the programs developed by others to work with their particular data structures can sometimes be just as difficult as re-developing them from scratch.

Some administrations may wish to access data they have previously notified to the ITU Radiocommunication Bureau (BR) (see Study Case 2 in Chapter 4, section 4.4) in their internal spectrum management or to access data notified by neighbouring administrations. The BR publishes this data and the extraction software (see Study Case 3 in Chapter 4, section 4.4) with the BR IFIC.

The BR's databases, software and on-line services are available at: http://www.itu.int/ITU-R/go/space for the space services and at http://www.itu.int/ITU-R/go/terrestrial for the terrestrial services.

5.2.1 Allocation database

In order to effectively manage the use of the radio-frequency spectrum, it is necessary to know how the spectrum is allocated among the various services. It is also necessary to know how the allocated spectrum is being used by the various services. An automated allocation database can be used to answer these questions. The allocation database should be structured in such a way that the total portion of the spectrum used by a particular service or a particular combination of services can be found. This information can be used to show how the available spectrum is distributed among the various services.

The allocation database should also be structured in such a way that each allocation record can be the "owner" of one or more frequency assignment records. Cross-referencing the allocation database and a frequency assignment database permits actual usage of the spectrum to be estimated for specific services. This information can be used to determine, by service, where the spectrum is congested and where the spectrum is underutilized.

Contents of the allocation database

The allocation database will be more useful if it can be cross-referenced by the frequency assignment data base. The most effective method of providing this cross-referencing is to include authorized station classes as part of the allocation record and should be limited to those that are actually authorized by the Table of Frequency Allocations. The effect of any restrictions placed on the service by footnotes to the Table of Frequency Allocations should be included when selecting the station classes which are permitted.

Some administrations have created database(s) from the Table of Frequency Allocations of RR Article **5** which are sometimes also used to subdivide the bands even further for national purposes. These sub-allocations further restrict the range of frequencies available for assignment for a specific purpose and move part of the workload of frequency assignment to the spectrum planning framework.

5.3 Computer-aided frequency selection

5.3.1 Problem description

To illustrate the application of simple computer techniques, a frequency assignment for a new transmitting station in the mobile service will be made.

Since land mobile services are usually channelized, only one set of discrete frequencies needs to be considered. The data file shown in Table 5-1 will be used as an example. It will be assumed that this file contains data describing all potential emissions, which can possibly affect the choice of frequency. In practice, a much larger file would probably exist.

TABLE 5-1

Example assignment data file

Frequency (MHz)	Channel No.	Station, Location	Power (kW)	Latitude	Longitude	Location	Call sign
160.005	1	Areawide Courier Delivery	0.075	38 58 33 N	077 06 01 W	Bethesda, MD	KED427
160.020	2	W.T. Cowan	0.12	38 56 54 N	076 50 22 W	Hyattsville, MD	DEX523
160.035	3	H.j. Kane Delivery Service	0.12	38 58 57 N	077 05 36 W	Bethesda, MD	KTZ830
165.050	4	Joseph M. Dignanson	0.12	38 55 15 N	076 54 10 W	Ardwick, MD	KDX790
160.065	5	Central Delivery Service	0.12	38 59 49 N	077 06 18 W	Bethesda, MD	KFB424
160.080	6	Hemingway Transportation	0.075	37 30 25 N	077 29 54 W	Richmond, VA	KES899
160.095	7	Halls Motor Transit Company	0.06	39 45 05 N	075 33 39 W	Wilmington, DEL	KQG594
160.095	7	Halls Motor Transit Company	0.12	39 41 47 N	077 30 46 W	Mont Quirauk, MD	KWT696
160.110	8	Jones Express Trash Removal	0.12	38 56 54 N	076 59 49 W	Washington, DC	KJB937
160.125	9	Central delivery Service	0.075	38 57 49 N	077 06 18 W	Bethesda, MD	KFB424
160.140	10	Purolator Services	0.12	38 57 49 N	077 06 18 W	Bethesda, MD	KFB424

Frequency (MHz)	Channel No.	Station, Location	Power (kW)	Latitude	Longitude	Location	Call sign
160.155	11	Preston Trucking Company	0.075	38 56 15 N	076 51 42 W	Ardmore, MD	KEQ762
160.170	12	Hemingway Transport	0.075	39 19 53 N	076 39 28 W	Baltimore, MD	KGG997
160.185	13	Metro Messenger and Delivery	0.12	38 56 50 N	077 04 46 W	Washington, DC	KGX548
160.185	13	A.J. Trucking	0.12	39 19 35 N	076 30 04 W	Baltimore, MD	KVN353
160.200	14	Clarence Wyatt transfer	0.12	37 30 46 N	077 36 06 W	Richmond, VA	KVZ573

The choice of frequency sharing criteria (Recommendation ITU-R SM.337) is the responsibility of the frequency manager. A choice that involves large protection ratios may be simple to analyse, yet ultimately wasteful of spectrum. Given the choice of criteria, the computer system must perform the analysis of the data to determine (in this case) whether a new frequency can be introduced while still satisfying the sharing criteria. The frequency manager should not need to make tedious or repetitive manual calculations. The selection of a frequency will be made in the following examples on two levels of complexity.

5.3.2 Basic selection procedure

A very simple frequency-sharing criterion can be defined as follows: "A given frequency may not be used simultaneously by two transmitters which are separated by a distance less than "*R*" km." To this can be added, if appropriate, "Adjacent frequencies (i.e. channels, in this example) may not be used simultaneously by two transmitters separated by a distance less than "*D*" km." For frequency sharing situations, the co-channel criteria should not be used.

Criteria of this type are very simple to apply, and are typical of the criteria used in certain designs of "cellular" mobile radio systems. The simplicity of the criteria is a big help in designing mobile networks involving hundreds of fixed transmitters.

A computer-aided selection procedure could be implemented in many different ways. One example method is outlined in Figure 5.1. Each frequency (channel) in the allocated band of available frequencies is examined in turn, beginning at the lowest frequency. The program extracts records from the file in sequence. If the frequency found in the record is equal to that under examination, or is adjacent to it, the program will calculate the distance from the proposed transmitter to the existing assigned transmitters. If this distance is greater than *R* (for co-channel) and *D* km (adjacent channel), then a frequency will be assigned. Otherwise, the program proceeds to read further records until the "end of file" is reached. The program then returns to the beginning of the data file, and examines the next frequency if necessary. The program as shown stops as soon as an acceptable frequency (channel) is found, but it could also be arranged to find all acceptable frequencies, and a further criterion could be later applied manually to choose among them.

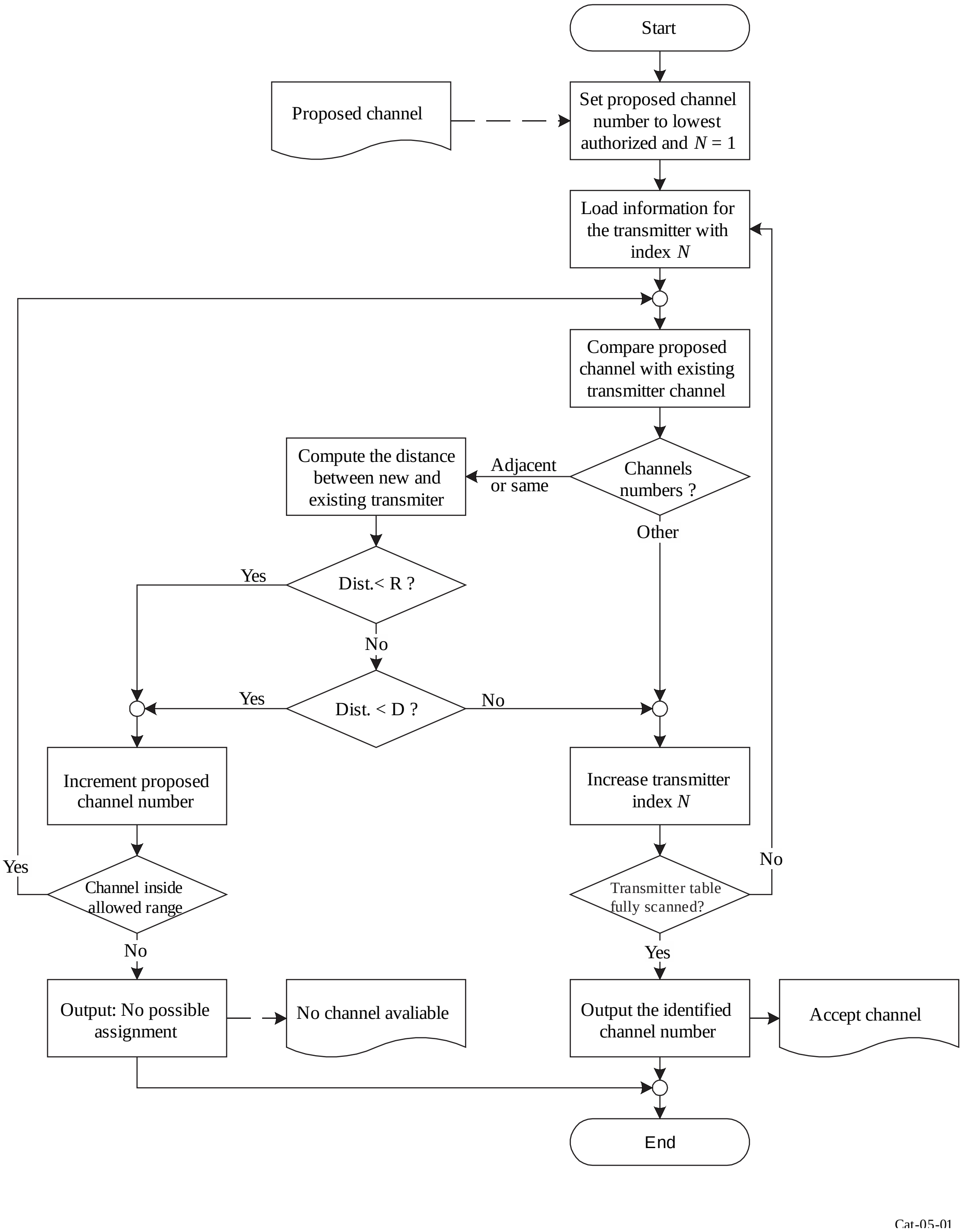
This example is a simple one; the only calculation performed finds the distance between two transmitters. Nevertheless, the use of a computer technique permits the whole procedure to be performed very rapidly. The frequency planner is relieved of the tedious task of performing hundreds of distance calculations (in a realistic case) and of the need to extract information from printed documents, which is prone to error.

5.3.3 An example of implementation of basic selection procedure

Using the existing assignments listed in Table 5-1, the State of Maryland, United States of America, desires a channel assignment for a transmitter location at latitude 39°10'45" N, longitude 76°40'07" W. Frequency-distance rules (assumed for this example) require 100 km separation for co-channel, and 40 km separation for adjacent channels. The solution is an assignment on channel 6, which satisfies all requirements. The new assignment list is shown in Table 5-2. This list could provide the frequency manager with additional useful information by including a listing of the distance of each existing transmitter location from the proposed site. The calculations can be readily made by the computer. The results allow the frequency manager to evaluate alternatives and to bring to bear his expertise and judgement on the selection process.

FIGURE 5.1

Basic frequency assignment routine



Note 1 – Consider R ≤ D, i.e. distance between transmitters that uses adjacent channel is equal or smaller than the distance between transmitters that uses the same channel.

Note 2 – When a channel is selected, then to identify all possible channels, channel number has to be increased as explained in section 5.3.2 above.

TABLE 5.2

Example assignment data file

Frequency (MHz)	Channel No.	Station, Location	Power (kW)	Latitude	Longitude	Location	Call sign
160.005	1	Areawide Courier Delivery	0.075	38 58 33 N	077 06 01 W	Bethesda, MD	KED427
160.020	2	W.T. Cowan	0.12	38 56 54 N	076 50 22 W	Hyattsville, MD	DEX523
160.035	3	H.j. Kane Delivery Service	0.12	38 58 57 N	077 05 36 W	Bethesda, MD	KTZ830
165.050	4	Joseph M. Dignanson	0.12	38 55 15 N	076 54 10 W	Ardwick, MD	KDX790
160.065	5	Central Delivery Service	0.12	38 59 49 N	077 06 18 W	Bethesda, MD	KFB424
160.080	6	Commonwealth of Maryland	0.12	39 10 45 N	076 40 07 W	Anne Arundel, MD	KAS454
160.080	6	Hemingway Transportation	0.075	37 30 25 N	077 29 54 W	Richmond, VA	KES899
160.095	7	Halls Motor Transit Company	0.06	39 45 05 N	075 33 39 W	Wilmington, DEL	KQG594
160.095	7	Halls Motor Transit Company	0.12	39 41 47 N	077 30 46 W	Mont Quirauk, MD	KWT696
160.110	8	Jones Express Trash Removal	0.12	38 56 54 N	076 59 49 W	Washington, DC	KJB937
160.125	9	Central delivery Service	0.075	38 57 49 N	077 06 18 W	Bethesda, MD	KFB424
160.140	10	Purolator Services	0.12	38 57 49 N	077 06 18 W	Bethesda, MD	KFB424
160.155	11	Preston Trucking Company	0.075	38 56 15 N	076 51 42 W	Ardmore, MD	KEQ762
160.170	12	Hemingway Transport	0.075	39 19 53 N	076 39 28 W	Baltimore, MD	KGG997
160.185	13	Metro Messenger and Delivery	0.12	38 56 50 N	077 04 46 W	Washington, DC	KGX548
160.185	13	A.J. Trucking	0.12	39 19 35 N	076 30 04 W	Baltimore, MD	KVN353
160.200	14	Clarence Wyatt transfer	0.12	37 30 46 N	077 36 06 W	Richmond, VA	KVZ573

5.3.4 Frequency selection using more detailed sharing criteria

The Table of Frequency Assignment data used in the previous example contains the total radiated power of each transmitter, which was not used in the example. Some sharing criteria would need to use this information. For example, consider the following criterion: "No transmitter assignment may be introduced into the existing assignment table at a given frequency if it will produce a power flux-density at any other transmitter using that frequency that exceeds a certain value." (This is a simplified version of a more general procedure in which a frequency manager could define a number of test points, perhaps several hundred, and require that at each test point the power flux-density from a desired transmitter exceeds by a certain ratio the sum of that from all undesired transmitters combined, including the proposed new assignment.)

To select a frequency according to this criterion, the radiated power of each transmitter must be considered; also the attenuation of radiated power flux-density as a function of distance from the transmitter (i.e. propagation information), is needed. For this example, it will be assumed that a single propagation model is used to describe every path considered. The propagation data stored in the computer is, therefore, a simple function listing attenuation as a function of distance increments. For distances not in the list, interpolation is used to find the loss value.

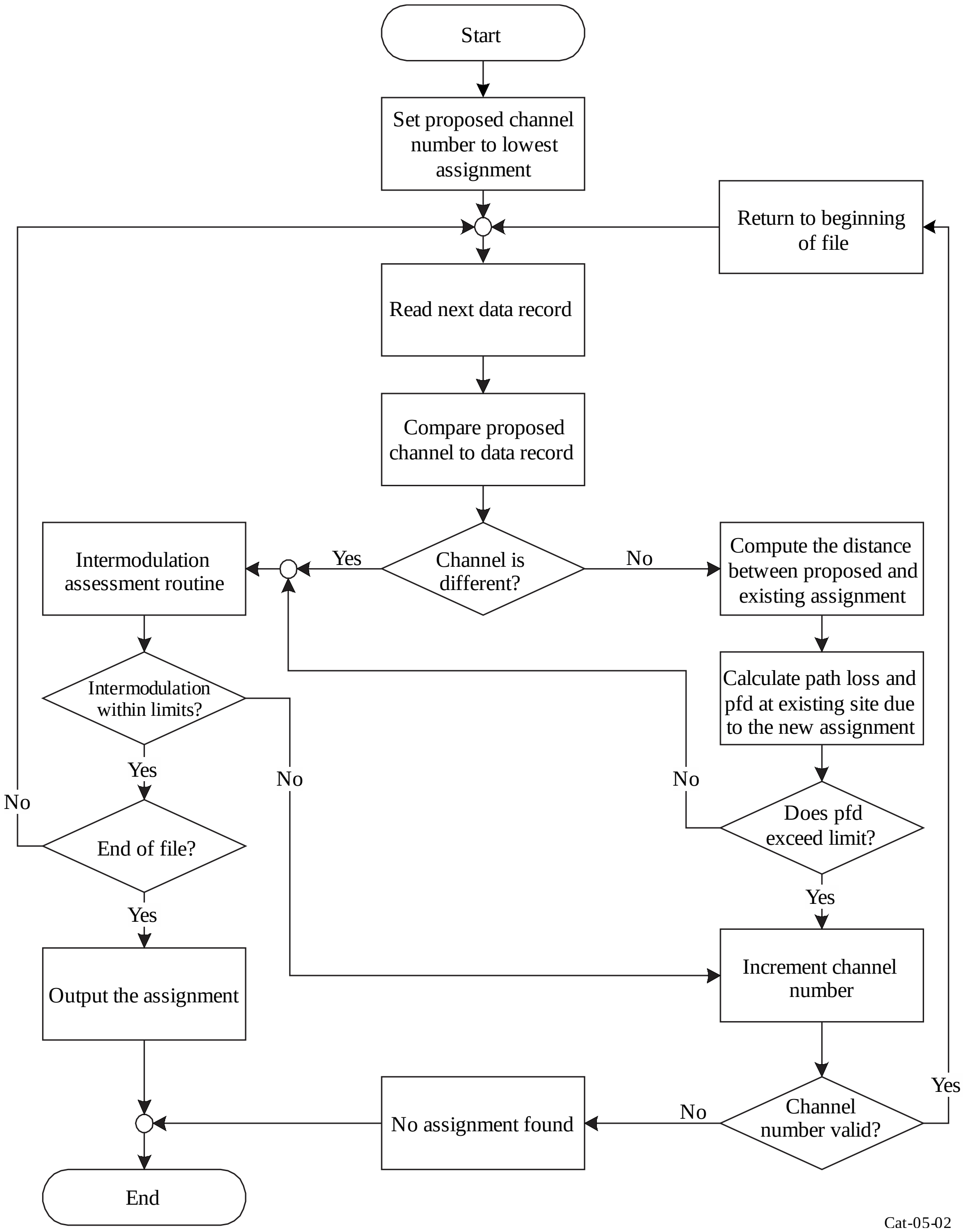
A further degree of complexity is incurred by considering the effects of inter-modulation products. Several "transmitters" may be located at a single site. In fact, they could even use a common antenna and radio-frequency amplifier. The existing frequency plan assigns carrier frequencies to the transmitters at a given site, but there will be radiations at additional new frequencies formed by inter-modulation between the main carrier frequencies. Such products are likely to be insignificant when received at other sites, but can be very damaging in the region of the transmitting site. The treatment of inter-modulation is in general rather complex, so for this example, the problem will be simplified to the following additional selection criterion: "No proposed frequency may be assigned to a new transmitter at a given site if any third order inter-modulation product formed from any frequencies already assigned to that site equal the proposed frequency."

To further simplify the example, only co-channel inter-modulation signals will be examined; adjacent channel power flux-density will not be considered.

Figure 5.2 shows a possible method of automating the selection procedure for this example. In this case, it is clear that the effort needed to perform the task manually is prohibitive; but for even a modest computer system the procedures used are easy to implement, fast, and not prone to errors in data handling.

FIGURE 5.2

Advanced frequency assignment routine



NOTE – PFD or Field Strength are calculated at the border of the service area.

5.3.5 Land mobile radio-frequency assignment

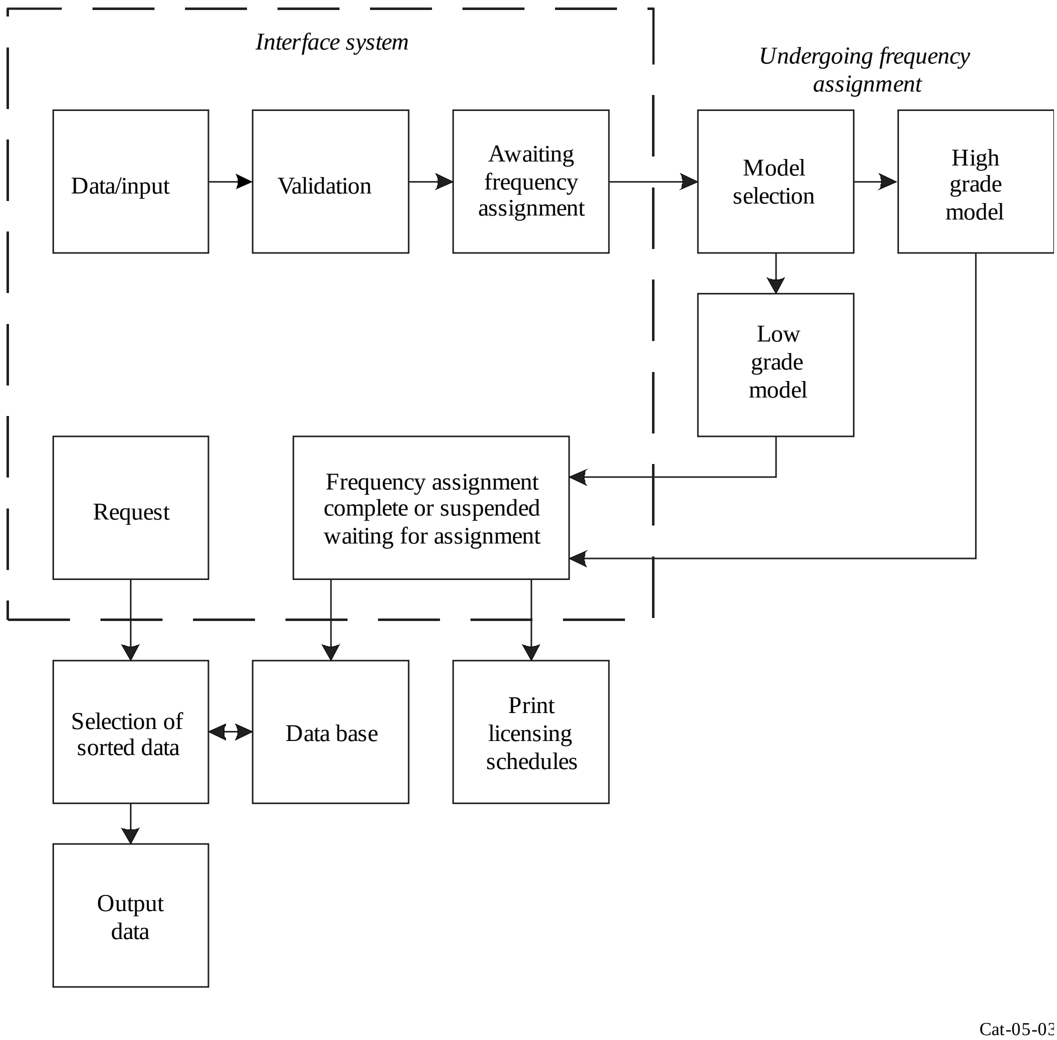
For land mobile radio computerized frequency assignment systems, it is necessary to consider certain operational aspects in addition to a basic frequency assignment routine such as that shown in Figure 5.1. For example, in order to provide the co-channel protection required by high grade mobile radio services, a computer model is required which assigns channels in accordance with permissible coverage area overlap between adjacent co-channel services areas. If low grade mobile radio services, which require no co-channel protection, operate in the same area, then the computer model should calculate the channel time occupancy and check that this occupancy is less than limits stored in "look-up" tables. The two models form segments of the simplified land mobile radio-frequency assignment system shown in Figure 5.3.

The degree of sophistication and accuracy of the mobile radio-frequency assignment model determines the frequency re-use achievable in a zone and hence the efficiency of spectrum utilization. For example, a simple "free space" propagation model can be used to give worst-case prediction with reasonable results in areas where VHF and UHF mobile radio services are sparse and channels are underutilized. In areas containing congested mobile radio services it is necessary to use a more accurate propagation model which needs to take into account terrain characteristics in order to estimate diffraction loss.

An operational system should contain a database that is readily accessible for updating and is capable of providing information for spectrum management and licensing purposes. Spectrum management requirements include listings of records or groups of records for various characteristics. The licensing function consists essentially of printing frequency assignment schedules or records for account purposes.

FIGURE 5.3

Simplified land mobile radio computerized frequency assignment system



An operational computerised frequency assignment system for mobile radio services based on Figure 5.3, incorporates the following features:

– contains a database of service users, technical parameters, and administrative details. The database can be readily amended with new user data or incorporate changes to existing records;

- validation checks are made to ensure that data is acceptable to the frequency assignment system;
- frequency assignment of a new exclusive user (requiring protection) is based on calculating the field strength contours of the base station service area and ensuring the overlap of the contours with existing base stations is limited to an acceptable level. The frequency assignment program accesses a terrain data file;
- time occupancy is assessed for channels which are shared in the same area. Checks are also performed on user business class to ensure the selection of a suitable channel, e.g. users having the same business class are not necessarily allowed to share the same channel;
- if a suitable channel cannot be found, the failed assignment will be queued until it can receive the attention of a frequency assignment officer who will then make the appropriate decisions;
- on the completion of a batch of automatic frequency assignments, technical schedules giving details of the assignment are generated automatically or manually for issue to the service users;
- a management information system is provided to examine frequency assignment files, and to produce plots of terrain profile and of field-strength contours;
- the frequency assignment program refers to an interference source file which lists channels unavailable in certain areas of the country due to a potential interference between existing radio services and mobile radio services.

The frequency assignment program calculates the overlap of a proposed base station (PBS) signal upon other existing base station (EBS) service areas. This overlap routine applies to exclusive (protected) assignments and is repeated for all channels listed in a "pre-scan" routine which selects the possible suitable channels based on a simplified version of the overlap routine. The channel with minimum EBS/PBS overlap is selected automatically.

The frequency assignment program, including the service area overlap and channel time occupancy calculation have been designed to maximize the re-use of channel frequencies leading to the more efficient utilization of frequency spectrum. The automatic frequency assignment system permits rapid assignments to be made of consistent high quality for mobile radio services and will continue to do so as the number of service users continues to increase in the future.

The problem with this simplified system is that it gives rules to eliminate some channels from consideration, but it does not provide the capability to choose between the possible channels, which can be numerous. In other words, it tells which channels are impossible, but it does not say which channels are best.

5.4 Propagation analysis

Automated techniques for determining losses based on real conditions (curved Earth, obstructions, varying soil conditions) allow accurate propagation predictions to be made routinely, thus increasing the accuracy of EMC analyses and finally, improving the efficiency of spectrum usage.

5.5 Equipment characteristics

Many EMC problems require the repeated use of technical characteristics concerning transmitters, receivers and their associated antennas. Certain of these characteristics do not consist of fixed values, but rather vary parametrically as a function of frequency, or the direction of antennas.

Converting the shape of the function into incremental data points and storing them in a data bank provides an input to the calculations of many EMC problems. The data files explained in this Chapter may be used in the analysis shown in section 5.6.

In addition, many administrations require that equipment imported or used within their boundaries meet specific standards that are updated from time to time. They usually publish the requirements that must be met by transmitters (and in some cases receivers) and document test methodologies for use in ensuring that these criteria are met. The administration then tests samples of each equipment type or allows approved test laboratories to test equipment against the standards and maintains a list of equipment makes and models that are approved for use and are therefore licensable. This list often forms part of the spectrum management database.

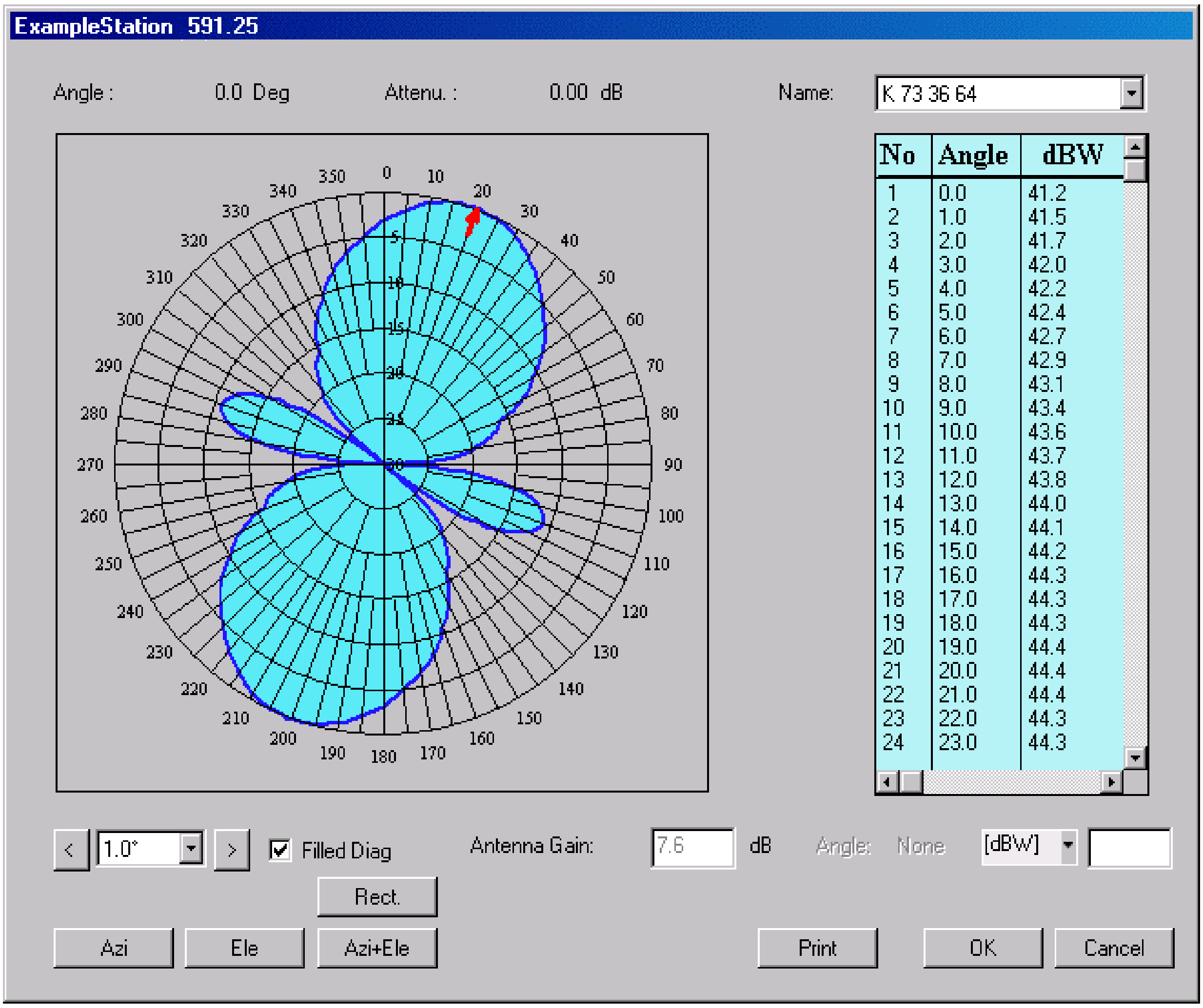
The minimum acceptable equipment characteristics established for the type approval process described in the last paragraph can then be used for interference analysis purposes rather than actual specific equipment parameters, thus facilitating the task somewhat.

5.5.1 Antenna patterns

Except for omnidirectional antennas, the gain of an antenna is a function of relative direction. In EMC calculations, it is desirable to know the antenna gain in the direction of a potential victim or interferer. Frequency assignment files may include antenna type and main beam direction. If the antenna type is known, the antenna data file may be automatically accessed to enter the appropriate antenna gain figure for computational purposes. The data is entered as gain as a function of direction relative to the main beam (highest gain) direction (see Figure 5.4).

FIGURE 5.4

Gain as a function of direction relative to the main beam (highest gain) direction (in horizontal plane)



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This is an example of a look-up table approach to modelling. When a value for gain is required, a value for direction is specified, which is then used by the computer to interpolate for the correct value between two of the tabulated values. The antenna pattern may also have been represented by an analytical function which approximates the data (e.g. $G = 32 - 25 \log \varphi$).

The BR software packages accessible from the hyperlinks mentioned in section 5.2 include antenna patterns implemented in accordance with relevant parts of the RR and/or ITU-R Recommendations (e.g. Recommendation ITU-R F.699).

5.5.2 Emission spectra of transmitters

The emission spectrum of a transmitter in mathematical terms is often complex, and difficult to apply to EMC problems. To describe the amplitude of the spectrum as a function of frequency is relatively simple, however, and can be graphically illustrated. By converting points on the spectrum curve to data points, a data table may be constructed. This data may then be used by computer programs that require spectral information.

5.5.3 Receiver selectivity

In a manner similar to sub-section 5.5.2, the envelope of a receiver pass-band may be converted into data points and stored for use in EMC calculations.

5.6 Frequency dependent rejection

For EMC calculations, it is desirable to know the effect on receivers by transmitters which are not co-tuned, but are in the same frequency band. As the transmitter and receiver are separated in frequency, less of the transmitted energy is coupled into the receiver. The exact amount of coupling is a function of the transmitter emission spectrum, the receiver selectivity, and the frequency separation (see Recommendation ITU-R SM.377).

If the undesired signal power at which the receiver performance is degraded is known, calculations can be performed to determine the distance the interfering transmitter must be removed from the receiver to preclude interference, as a function of frequency separation. This results in a set of distance and frequency separation points, which, when connected, form a frequency-distance curve. Pre-calculated propagation data may be stored as distance/loss values or propagation calculation routines may be used. Automated calculations allow practical application of this technique. Inputs to the program are:

– frequency;
– emission spectrum;
– receiver sensitivity and selectivity;
– transmitter e.i.r.p. (transmitter power multiplied by antenna gain in direction of receiver) or e.r.p..

5.7 Earth station coordination area calculations

Automated methods are applicable to the procedure outlined in RR Appendix **7** for determining the coordination area around an earth station in frequency bands between 100 MHz and 105 GHz shared by space and terrestrial services. Computer programs developed by the BR and other administrations are available in the BR software packages accessible from the hyperlinks mentioned in section 5.2 and are used to calculate coordination distances during technical examination of frequency assignment notices as outlined below. A coordination diagram has been automatically drawn on a computer-generated map (see Figure 5.5).

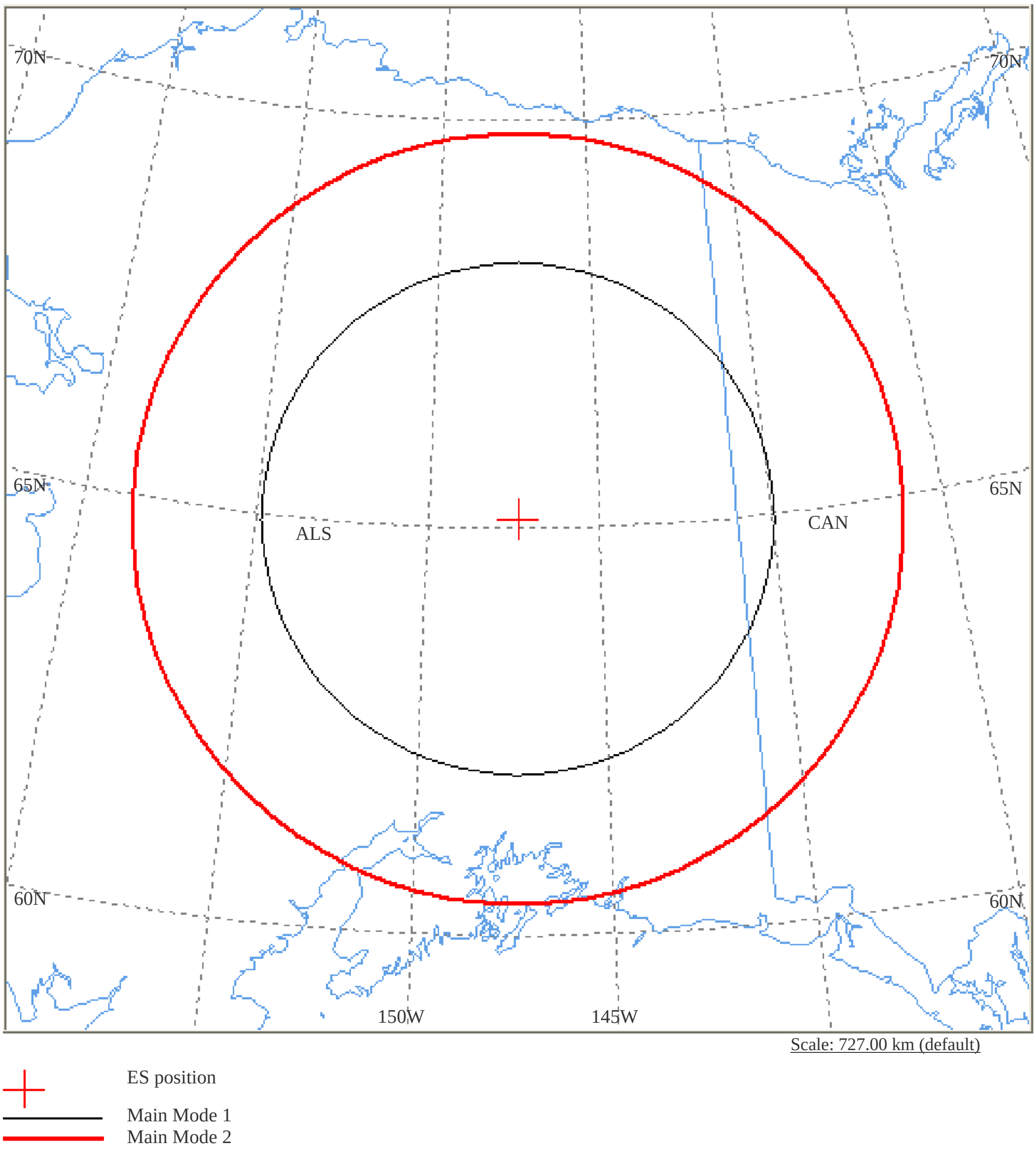
FIGURE 5.5

Coordination diagram for a transmitting earth station

- Transmitting NGSO ES W.R.T. receiving terrestrial stations.

Notice ID: 100500002
Administration/Geographical area: USA/USA
Satellite orbital position:
Frequency band: 2040.00-2040.00 MHz

Earth station name: Foker Flat Alaska
Earth station position: 147W230065N0 700
Satellitre name: ICESAT



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The black contour is the main mode (1) contour. The red contour is the mode (2) contour.

5.7.1 Program capabilities and procedures

This program computes the coordination distance as a function of azimuth angle from true North in 5° increments and draws the coordination contour using computations as follows:

– with the help of the Ap7Capture tool, the user enters the earth-station parameters that are required for the computations and stores them in a database file;

– in GIBC, the user specifies the database file location and the notice id of the earth station;

– the program calculates for each diagram, the permissible interference power (dBW) in the reference bandwidth to be exceeded no more than *p*% of the time at the receiver input of a station subject to interference, from each source of interference;

– the program then calculates the earth station off-axis antenna gain as a function of azimuth, antenna elevation angle and horizon elevation angle;

– the program calculates a minimum permissible transmission loss in a particular azimuth from the earth station;

– to determine the final coordination distance for propagation mode 1, the program performs an analysis of mixed paths as required, automatically checking radio-climatic zone boundaries using data from the ITU-R Digitized World Map (IDWM);

– the program calculates the coordination distances for rain scatter propagation (mode 2);

– along each azimuth the values of coordination distances for propagation mode 1 and mode 2 are compared and the greatest are taken to form the final coordination contour around the earth station;

– the program calculates (if necessary) auxiliary contours for great circle propagation mechanisms;

– the program generates a database file containing each resulting coordination diagram for the earth station;

– the program generates (if required) a report document in rtf format showing for each diagram the coordination distances in tabular form and a map including political boundaries of a part of the surface of the Earth which is of interest. The map is drawn in azimuthal-equidistant projection. Calculated values of final coordination distance are used to draw the nominal and auxiliary coordination contours on the map;

– the report document includes also the list of potentially affected countries;

– the program can be used for determination of the coordination contours for earth stations which operate with geostationary and non-geostationary satellites.

5.7.2 Other coordination and notification assistance

In many cases, administrations have used electronic data interchange to facilitate the coordination and notification processes. The RDD specifies the data elements for the items required for coordination with neighbouring countries. The RR Appendix **7** software package determines the list of the countries with whom to coordinate using the IDWM routines of the ITU-R.

5.8 Online BR calculation services for testing purposes and assisting in coordination

The BR has implemented a fully automated system which allows TIES users to perform calculations on-demand for testing purposes and assisting in broadcasting coordination. The system is composed by a web front-end portal (for input data submission and display/download of calculation results) and a back-end system composed of services (for managing the calculation workload) and a database (for queuing requests and storing input data and calculation results). The front-end and the back-end are decoupled components: the user is notified by an e-mail when its calculation has completed and results are available for consultation. Most calculation results are displayed at the front-end via a GIS Internet server.

The system is easily scalable to cope with increasing workload: the 2012 ITU pilot-project in Cloud Computing has proven that cloud resources can be added to local ones in an integrated infrastructure.

The system is accessible from the URL: http://www.itu.int/ITU-R/eBCD/MemberPages/eCalculations.aspx

Detailed description of calculation types available from the above mentioned URL, at the time of the development of this handbook, are briefly described in the following paragraphs.

5.8.1 Test coordination examination in the scope of the GE06 Agreement

The user submits test electronic input files (which should have been previously validated by TerRaNotices) via the web portal referred to above. The calculation services perform the coordination examination taking into considerations the latest Plan snapshot.

Coordination contours are displayed using a GIS Internet Server along with the list of potentially affected administrations. The user can then start coordination activities in order to obtain all the necessary agreements before officially notifying the notices to the BR via WISFAT, streamlining the overall process and reducing the time needed for recording into the Plan.

5.8.2 Test compatibility examination in the scope of the GE06 Agreement

The user submits test electronic input files (which should have been previously validated by TerRaNotices) via the web portal referred to above. The calculation services perform the compatibility analyses taking into considerations the latest Plan snapshot.

For each input notice a compatibility assessment is established by determining the interference with respect to existing plan notices and recorded assignments/allotments. The calculation results are made available for download at the web portal as a database file.

5.8.3 View detailed compatibility examination results in the scope of the GE06 Agreement

The BR offers the GE06Calc application for viewing compatibility examination results. GE06Calc is installed from the ITU website and runs on the user's computer but still has the advantage of receiving automatic updates when connected to the Internet, as if it were a browser-based application. The user downloads the database file with the results of compatibility examinations and views these results using GE06Calc on the local PC. The GE06Calc tool enables the user to perform detailed calculations for more thorough compatibility analyses. However, if Internet connectivity is not available or is blocked for security reasons, GE06Calc remains fully functional.

5.8.4 Test conformity examination in the scope of the GE06 Agreement

The same benefits of automatic Internet updates and standalone operation extend to the other functionality in GE06Calc: testing conformity examinations in the scope of the GE06 Agreement. The user prepares test electronic input files (which should have been previously validated by TerRaNotices) and tests them for conformity to the GE06 Plan using GE06Calc on a local PC in conjunction with the BR IFIC DVD. The tool provides full-featured GIS displays of the detailed conformity examination calculation results.

5.8.5 Propagation prediction calculations using Recommendations ITU-R P.1812

The user submits a calculation request by filling a form in the web portal specifying the technical parameters needed for the propagation assessment. This calculation uses terrain profile information and can be a useful tool during coordination activities.

Both point to point (profile) and point to area (coverage) calculations can be performed (see Figure 5.6). The calculation currently uses the SRTM3 terrain databases (3arc-sec resolution); the possibility of using higher resolution DEM is under investigation.

FIGURE 5.6-a

Field strength and terrain profile

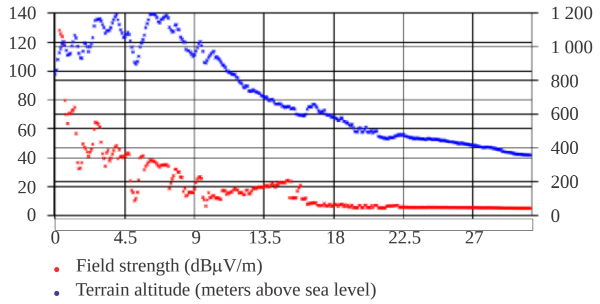
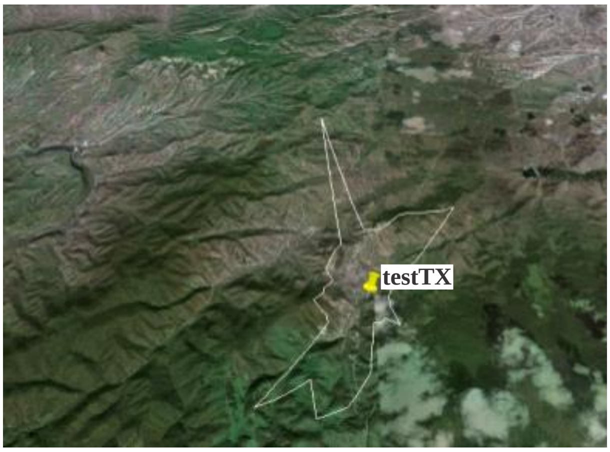


FIGURE 5.6-b

Coverage contour



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5.9 Integrated spectrum management and monitoring systems

As many spectrum management processes as possible should be supported by computers and software in order to reduce processing and staff time.

The ITU recommends in Recommendation ITU-R SM.1537 that administrations consider using spectrum management and monitoring systems which are automated and integrated so that the management and monitoring portions of a system share database information and operate seamlessly together to perform the functions required by the spectrum manager. Integration of spectrum management and spectrum monitoring is also discussed in ITU Handbooks, including the ITU Handbook on Spectrum Monitoring, which provides information on equipment and illustrates typical system block diagrams, and the ITU Handbook on National Spectrum Management, which gives an example of an integrated system.

5.9.1 Definition of an integrated management and monitoring system

An automated, integrated spectrum management and monitoring system typically consists of a national spectrum management centre and multiple fixed and mobile monitoring stations. The stations are interconnected via a network to allow voice and data communications. All of the stations in the network, including both spectrum management and spectrum monitoring stations, exchange information electronically and/or share common databases. Monitoring stations can be remotely controlled.

A typical integrated system diagram is illustrated in Figure 5.7. The configuration (number of stations, number of workstations at each station, etc.), methods of communication (transmission control protocol/Internet protocol (TCP/IP) or other protocol; use of a wide area network (WAN); use of the public switched telephone network (PSTN); radio or satellite), and other details will vary according to the application and available infrastructure. In some configurations, a monitoring centre may be present which is connected directly to the monitoring stations and in turn to the management centre.

The spectrum management system consists of a database server with one or more workstations and software which:

1) manages the database of frequency assignments;

2) provides a variety of engineering analysis tools to analyse propagation and determine if a given path with given communications equipment will support the desired communications;

3) displays geographic maps superimposed with results of analyses, and

4) interfaces to a spectrum monitoring system to perform a variety of functions including automatic detection of licensing violations.

The spectrum management system includes a large relational database, accepts a variety of inputs including applications for licences, issues a variety of notices and reports, and connects to monitoring stations.

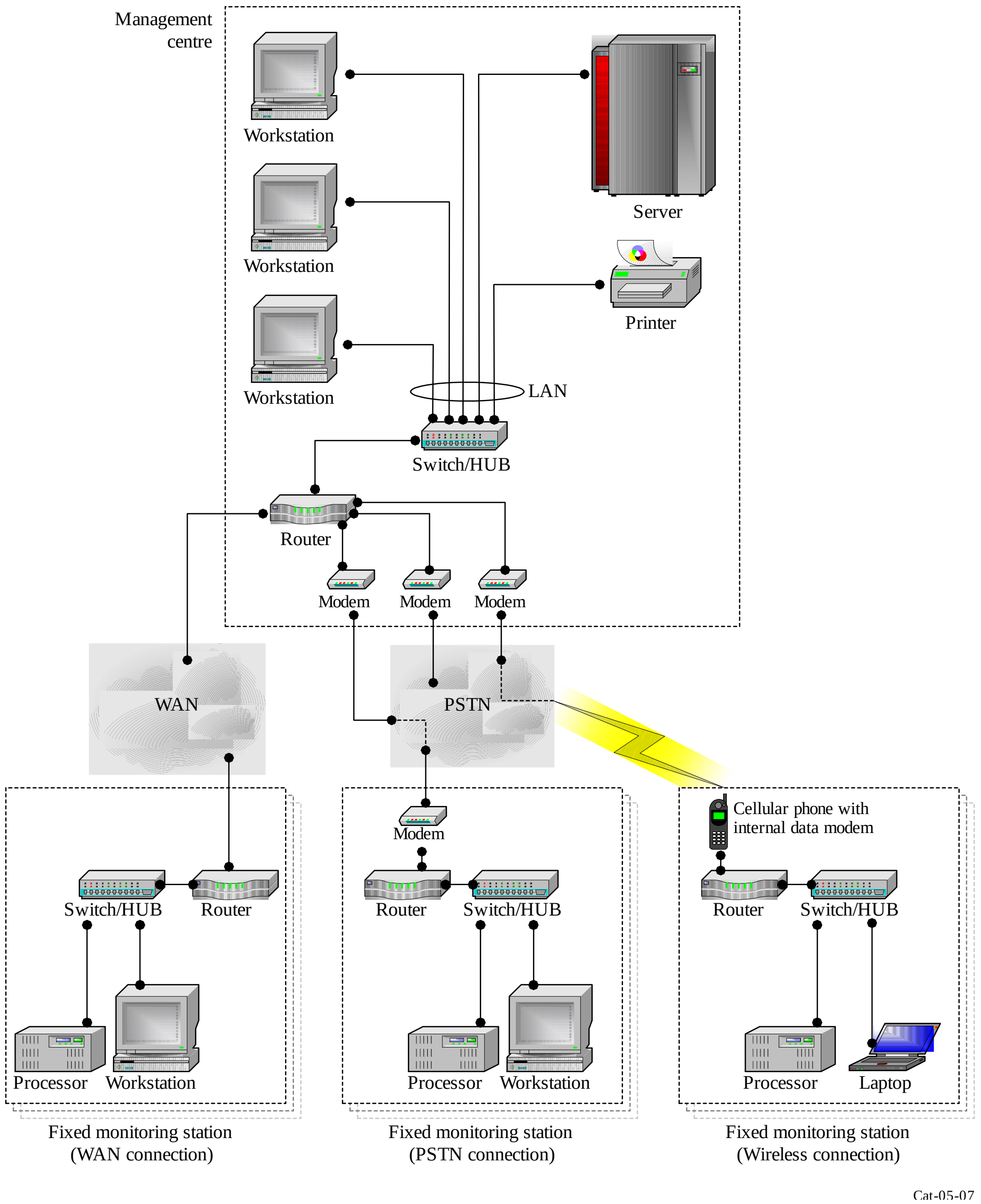
Monitoring systems automate the process of performing spectrum occupancy, parameter measurement and direction finding (DF) to verify clear channels and identify and locate sources of interference. In the past, monitoring systems have included a large collection of test and measurement equipment to perform spectrum occupancy and specific signal parameter measurements. With the recent revolution in digital signal processing (DSP), a monitoring system now consists of only two elements:

1) a small group of sophisticated measurement equipment modules, including antennas and receivers, operated by a computer which is often referred to as a measurement server; and

2) computer workstations or clients which are used for operator interface and which contain computer software which make the system easy to use and maintain.

FIGURE 5.7

Typical integrated spectrum management and monitoring system



5.9.2 Importance of an integrated system

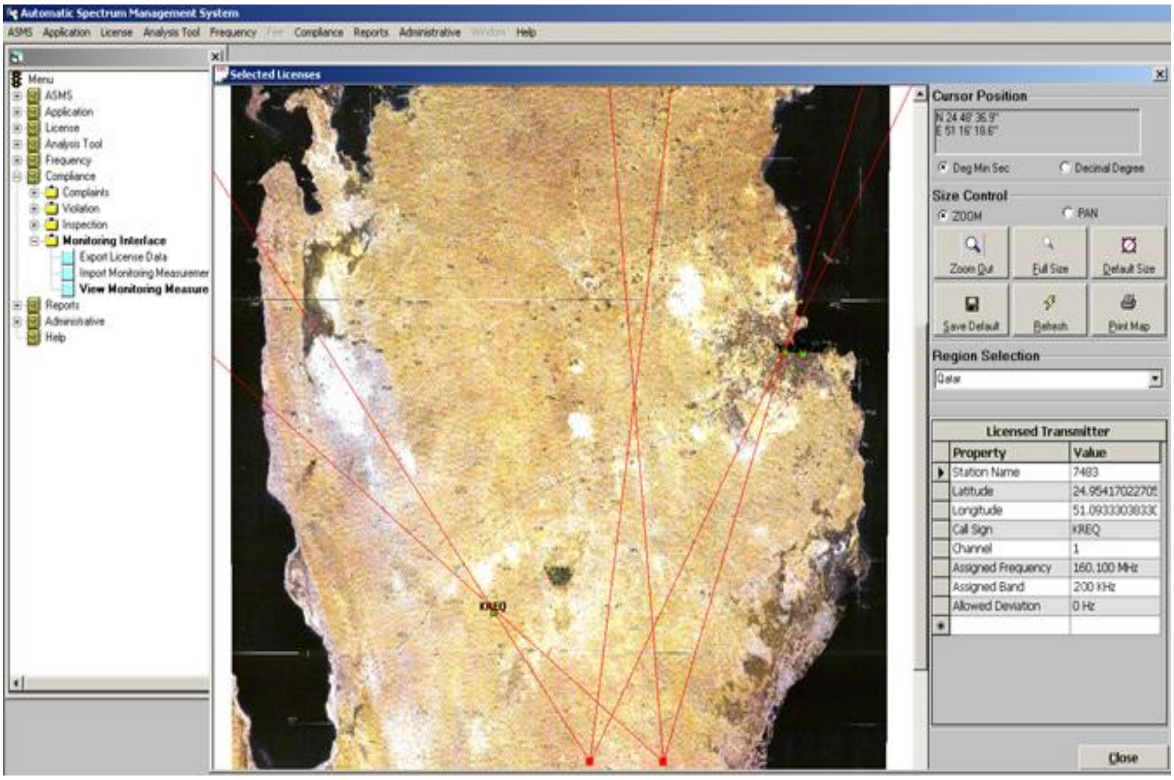
One feature of an integrated, automated spectrum management and monitoring system can be its ability to access and compare information from the management and monitoring databases to automatically determine stations which are likely to be unlicensed or operating outside their licensed parameters.

The operator specifies a frequency band of interest, and the system performs spectrum occupancy, and parameter and DF measurements and compares these measurements against information in the licence database. The system flags frequencies where signals are found where there is no corresponding licence, and frequencies where the parameter measurements do not correspond with those licensed. This function is known as automatic violation detection (AVD) and is a very important function of a modern, automated, integrated system.

The results of the AVD function may be displayed in tabular or graphical form. A tabular display shows for each channel whether a signal has been found, and if so whether there is a licensed station at this frequency and whether the measured signal is compliant or not compliant with its licensed parameters. The measured locations of signals and the locations of corresponding licensed stations may be displayed on a geographic map, such as the map illustrated in Figure 5.8, to allow the operator to visualize the results. This Figure illustrates the locations of two monitoring stations (red squares at the bottom of the figure) and three licensed stations (green squares), and shows the measured locations (lines of bearing intersection) of the two currently transmitting stations. The Figure shows one licensed station is currently not transmitting (a green square with no lines of bearing), and shows the location of an unlicensed transmitter (lines of bearing intersection with no green square).

FIGURE 5.8

Typical map display illustrating AVD data



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Another important feature of a fully integrated system is the ability of an operator, with proper authority, at any management or monitoring workstation, to access and utilize the resources of the entire system, including:

– use of the licence database;

– remote tasking and control of monitoring stations;

– production and review of reports which combine information from the management and monitoring databases;

– performance of other functions an operator needs to do to effectively manage the radio spectrum.

A fully integrated spectrum management and monitoring system provides common human and computer interfaces throughout the system, which greatly facilitates training and use of the system.

ANNEX 1

Spectrum management data tables

1 Tables A1-1 to A1-6 were prepared as inventories of data elements which should be considered during a data-analysis phase to design and implement an automated inter and intra-administration spectrum management system. These inventories were first compiled during studies carried out by CCIR Interim Working Party (IWP) 1/2 in conjunction with the IFRB. They have been updated by Radiocommunication Study Group 1. The definite source for data requirements for coordination and notification remains RR Appendix **4** with additional descriptions and formatting outlined in the Radiocommunications Data Dictionary (see the most recent version of Recommendation ITU-R SM.1413) and therefore these requirements are not repeated in this Annex.

2 It is essential that spectrum management data for intra-administrations use comply with the following requirements:

2.1 the data should contain, as a minimum, the data required for National Spectrum Management and notification to the ITU-BR. Recommendation ITU-R SM.667 recommended that the data fields specified in previous versions of this Annex should be used.

2.2 the sub-set of data used for ITU-BR notification purposes should be compatible with ITU-BR data record and data element specifications. In order to ensure that this is so, Administrations are invited to review all the relevant Circular Letters on the ITU website on a regular basis.

3 The following abbreviations are used in the Tables:

BC: broadcasting

RR: Radio Regulations

TX: transmitting

BR IFIC: (ITU International Frequency Information Circular that includes the PIFL (Preface to the International Frequency List))

GE75: the LF/MF Broadcasting Agreement (Region 1 and Region 3), Geneva, 1975

GE84: the Regional Agreement for FM Broadcasting (Region 1 and part of Region 3), Geneva 1984

RJ81: the Regional Agreement for MF Broadcasting (Region 2), Rio de Janeiro, 1981.

TABLE A1-1

Basic national frequency allocation data

No.	Data element	Number of characters (A or B.C)[(1)]		Definitions
		A	B.C	
1	Lower frequency band limit		12.6	The lower frequency limit of the band being allocated
2	Frequency unit	1		H = Hz; k = kHz; M = MHz; G = GHz
3	Nature of the frequency limit	1		I = international (ITU); N = national
4	Upper frequency band limit		12.6	The upper frequency limit of the band being allocated
5	Service	30		The name of the service being allocated. (Code still to be established) (RR **20-57**)
6	RR category of service	1		The RR category of the service being allocated (P = Primary, S = Secondary)
7	National category of service	1		If different from the RR category
8	Function	40		The name of a function within the service to which the band is allocated (ex.: radio-beacon, distress and calling)
9	Band allocation footnote	7		The footnote number that allocates the service to the band (where appropriate)
10	Service footnote	7		Footnote number that restricts the use of the service
11	Band footnote	7		Footnote number that restricts the use of the band
12	Class of station	30		Indicates the class of station permitted by the allocation, using the symbols shown in Table 6A1 of the PIFL or RR Appendix **10**. More than one class of station can be entered separating each class of station by a space
13	National spectrum management agency or ministry	10		National spectrum management agency or ministry managing the assignments in a given band and for a given service
14	ITU Region	1		Indicates the ITU Region in which the service is allocated

[(1)] A: number of alphanumeric characters.
B: total number of numeric characters.
C: number of decimal characters.

TABLE A1-2

Licence holder: indicative list of data

No.	**Data element**	**Number of characters (indicative)**	**Definitions**
1	Reference number to assignment/proposal data	7	Code to be specified by the national administration
2	Regional authority for assignment	2	
3	Type of registration	1	N: new entry; M: modification; D: deletion
4	Name of licence holder	30	If required the same data elements can be used additionally for the point of contact
5	Postal code	(6)	
6	Town	30	
7	Street	24	
8	Abbreviated name	12	
9	Billing name	30	
10	Billing address	60	
11	Licence fee		To be defined
12	Date licence fee is due		
13	Date licence fee is paid		
14	Telephone number	12	If required, 3 more characters for country codes
15	Telefax number	12	
16	email address	20	
17	X-400 address	40	
18	Telex code	12	

NOTE – ( ) Indicates that number depends upon code size being used.

TABLE A1-3

Equipment characteristics data: indicative list

No.	**Data element**	**Status**		**Number of characters (A or B.C)**		**Definitions**
		Basic	**Optional**	**A**	**B.C**	
1.	*General data*					
1.1	Transaction and date of action					
1.1.1	Kind of transaction	x		1		Code, e.g.: N: new registration M: modification D: deletion
1.1.2	Date of transaction	x			4.0	Indicates month and year of action
1.2	Source of data			1		Code, e.g.: T: technical description of equipment R: measuring test report; etc.
1.3	Security classification		X	1		Code, e.g.: U: unclassified R: restricted C: confidential S: secret T: top secret
1.4	Type of equipment	x		1		Code, e.g.: S: complex system C: combined TX/RX facility T: independent transmitter R: independent receiver A: antenna, etc.
1.5	System or equipment nomenclature	x		16		Indicates code designation of system or equipment
1.6	Manufacturer and country of origin					
1.6.1	Manufacturer	x		12		
1.6.2	Country of origin		X	3		Code, e.g.: abbreviations according to the PIFL

TABLE A1-3 (*continued*)

No.	Data element	Status		Number of characters (A or B.C)		Definitions
		Basic	Optional	A	B.C	
1.7	Equipment deployment and function					
1.7.1	Deployment				1.0	Code, e.g.: 1: civil 2: military 3: civil/military
1.7.2	Function			1		Code, e.g.: A: radiotelephone B: sound broadcasting C: television-broadcasting D: radio-relay; etc. The second character indicates supplementary characteristics
1.8	Equipment platform and mobility					
1.8.1	Equipment platform		X	1		Code, e.g.: A: airborne L: ground R: on rivers, canals, lakes S: space; etc.
1.8.2	Mobility					Code e.g.: F: fixed, permanently installed T: fixed during operation, but transportable M: mobile, but not portable, operation possible during movement P: portable
1.9	Type approval					
1.9.1	Executing office		X	1		Code is to be established depending on requirements
1.9.2	Type approval number		X		8.0	
1.9.3	Year of certification		X		2.0	
1.10	Number of equipment		X		5.0	Indicates the number of equipment in use on the territory of a state

TABLE A1-3 (*continued*)

No.	**Data element**	**Status**		**Number of characters (A or B.C)**		**Definitions**
		Basic	**Optional**	**A**	**B.C**	
1.11	Number of transmitters, receivers and antennas incorporated by the system					
1.11.1	Number of transmitters		X		1.0	
1.11.2	Number of receivers				1.0	
1.11.3	Number of antennas				1.0	
2.	*Transmitter data*					
2.1	Transmitter nomenclature	x		15		Indicates manufacturer's designation of transmitter type
2.2	Tunable frequency range					
2.2.1	Tunability	x		1		Code, e.g.: F: fixed TX-frequency S: TX-frequency switchable in steps T: TX-frequency continuously tunable
2.2.2	Lower limit of frequency range	x			9.4	
2.2.3	Upper limit of frequency range	x			9.4	
2.2.4	Unit	x		1		Code: H: Hz k: kHz M: MHz G: GHz
2.3	Switchable modulation types					
2.3.1	Necessary bandwidth	x		4		Code according to RR Appendix **1**
2.3.2	Class of emission	x		5		Code according to RR Appendix **1**. These records are furnished several times to accommodate different classes of emission if switchable

TABLE A1-3 (*continued*)

No.	Data element	Status		Number of characters (A or B.C)		Definitions
		Basic	Optional	A	B.C	
2.4	Number of pre-set channels	x			4.0	
2.5	Channel separation					
2.5.1	Unit	x		1		Code: H: Hz k: kHz M: MHz
2.5.2	Value of channel separation				9.4	Channel separation
2.6	Transmitter power					
2.6.1	Tunability	x		1		Code, e.g.: T: TX-power tunable F: TX-power fixed
2.6.2	Type of power					Code, e.g.: C: carrier power D: effective radiated carrier power M: mean power N: effective radiated mean power P: peak envelope power Q: effective radiated peak envelope power R: equivalent isotropically radiated power S: maximum power averaged over any 4 kHz delivered to the antenna T: maximum power averaged over any 1 MHz delivered to the antenna
2.6.3	Lower limit of tunable power range	x			4.1	Value
2.6.4	Upper limit of tunable power range	x			4.1	Value
2.6.5	Unit	x		1		Code: U: microwatt L: milliwatt W: watt K: kilowatt M: megawatt G: gigawatt

TABLE A1-3 (*continued*)

No.	**Data element**	**Status**		**Number of characters (A or B.C)**		**Definitions**
		Basic	**Optional**	**A**	**B.C**	
2.7	Transmitter output type		X		2.0	Code, e.g.: 01: transistor 02: magnetron 03: klystron; etc.
2.8	Special pulse modulation description		X		2.0	Code, e.g.: 01: pulse CW 02: pulse FM/CW 03: pulse compression; etc.
2.9	Pulse width					
2.9.1	Tunability		X	1		Code, e.g.: F: fixed pulse width T: tunable pulse width
2.9.2	Lower limit of pulse width range		X		3.0	
2.9.3	Upper limit of pulse width range		X		3.0	
2.9.4	Unit		X	1		Code, e.g.: N: nanoseconds U: microseconds L: milliseconds
2.10	Pulse repetition frequency (PRF)					
2.10.1	Tunability		X	1		Code, e.g.: F: fixed PRF T: tunable PRF
2.10.2	Lower limit of PRF		X		4.0	PRF (kHz)
2.10.3	Upper limit of PRF		X		4.0	PRF (kHz)
2.11	Pulse rise time and decay time					
2.11.1	Rise time		X		3.1	
2.11.2	Unit		X	1		Code, see section 2.9.4
2.11.3	Decay time		X		3.1	
2.11.4	Unit		X	1		Code, see section 2.9.4

TABLE A1-3 (*continued*)

No.	Data element	Status		Number of characters (A or B.C)		Definitions
		Basic	Optional	A	B.C	
2.12	FM-CW deviation ratio					
2.12.1	Tunability		X	1		Code, e.g.: F: fixed T: tunable
2.12.2	Lower limit of FM-CW deviation ratio				4.0	
2.12.3	Upper limit of FM-CW deviation ratio		X		4.0	
2.12.4	Unit		X	1		Code: H: Hz k: kHz
2.13	Attenuation of harmonics					
2.13.1	Attenuation of the 2nd harmonic	x			3.0	Attenuation (dB)
2.13.2	Attenuation of the 3rd harmonic	x			3.0	Attenuation (dB)
3.	*Receiver data*					
3.1	Receiver nomenclature	x		15		Indicate manufacturer's designations of receiver type
3.2	Tunable frequency range					
3.2.1	Tunability	x		1		Code, e.g.: F: fixed RX-frequency S: tunable in steps T: continuously tunable
3.2.2	Lower limit of frequency range	x			9.4	
3.2.3	Upper limit of frequency range				9.4	
3.2.4	Unit	x		1		Code: H: Hz k: kHz M: MHz G: GHz
3.3	Switchable modulation types					
3.3.1	Bandwidth	x		4		Code according to RR Appendix **1**

TABLE A1-3 (*continued*)

No.	**Data element**	**Status**		**Number of characters (A or B.C)**		**Definitions**
		Basic	**Optional**	**A**	**B.C**	
3.3.2	Class of emission	x		5		Code according to RR Appendix **1**. These records are furnished several times to accommodate different classes of emission, if switchable
3.4	Type of receiver		X	1		Code, e.g.: A: detector B: single superheterodyne C: multiple superheterodyne, etc.
3.5	Receiver sensitivity				3.0	Sensitivity (dBm)
3.6	Number of pre-set channels				4.0	
3.7	Channel separation					
3.7.1	Value of channel separation				9.4	
3.7.2	Unit					Code: H: Hz; k: kHz; M: MHz
3.8	Receiver selectivity Bandwidth of the passband					
3.8.1	At the 3 dB point	x			9.4	
3.8.2	At the 20 dB point	x			9.4	
3.8.3	At the 40 dB point	x			9.4	
3.8.4	At the 60 dB point	x			9.4	
3.8.5	Unit	x		1		Code, see section 3.7.2
3.9	Mixer and IF stages					
3.9.1	Mixer type		X	1		Code, e.g.: A: additive mixing B: broadband ring mixing with pulse shaper M: multiplicative mixing S: self-heterodyning mixing
3.9.2	Value of intermediate frequency	x			9.4	
3.9.3	Unit	x		1		Code, see section 3.2.4
3.9.4	IF bandwidth	x			9.4	
3.9.5	Unit	x		1		Code, see section 3.2.4

TABLE A1-3 (*continued*)

No.	Data element	Status		Number of characters (A or B.C)		Definitions
		Basic	Optional	A	B.C	
3.9.6	Local oscillator position		X	1		Code, e.g.: A: up-conversion in normal position B: up-conversion in inverted position C: down-conversion in normal position D: down-conversion in inverted position These records are furnished three times to accommodate the data for the 2nd and 3rd IF-stage, if necessary
3.10	Image frequency rejection	x			3.0	Indicates image frequency rejection (dB)
3.11	Special circuitry		X		3.0	Code is to be established depending on requirements
4.	*Antenna data*					
4.1	Antenna nomenclature	x			15	Indicates manufacturer's designation of antenna type
4.2	Frequency range					
4.2.1	Adjustability	x		1		Code, e.g.: F: antenna frequency range not adjustable T: antenna frequency range is adjustable
4.2.2	Lower limit of frequency range	x			9.4	
4.2.3	Upper limit of frequency range	x			9.4	
4.2.4	Unit	x		1		Code: k: kHz; M: MHz; G: GHz
4.3	Class of antenna	x		1		Code: T: transmitting antenna R: receiving antenna C: transmitting and receiving antenna

TABLE A1-3 (*continued*)

No.	Data element	Status		Number of characters (A or B.C)		Definitions
		Basic	Optional	A	B.C	
4.4	Type of antenna	x			2.0	Code, e.g.: 01: dipole 02: half-wave dipole 03: full-wave dipole etc.
4.5	Antenna characteristic	x		1		Code, e.g.: N: non-directed D: directional (unidirectional) X: directional (revolving)
4.6	Antenna polarization		X	1		Code, e.g.: H: horizontal V: vertical C: circular, etc.
4.7	Isotropic gain of antenna					
4.7.1	For horizontal polarization	x			3.1	Gain (dB)
4.7.2	For vertical polarization	x			3.1	Gain (dB)
4.8	Type of antenna feed and line attenuation					
4.8.1	Antenna feed		X	1		Code, e.g.: A: parallel-wire line B: coaxial line C: rectangular wave guide; etc.
4.8.2	Line attenuation		X		3.1	Line attenuation (dB)
4.9	Antenna scanning cycles					
4.9.1	Adjustability					Code, e.g.: F: fixed scanning rate T: variable or adjustable scanning rate
4.9.2	Lower limit of scanning cycles		X		4.0	Scanning cycles per minute
4.9.3	Upper limit of scanning cycles				4.0	Scanning cycles per minute
4.10	Antenna rotations					
4.10.1	Adjustability		X	1		Code, e.g.: F: fixed rotation rate T: variable or adjustable rotation rate

TABLE A1-3 (*end*)

No.	Data element	Status		Number of characters (A or B.C)		Definitions
		Basic	Optional	A	B.C	
4.10.2	Lower limit of rotation cycles		X		4.0	Rotation cycles per minute
4.10.3	Upper limit of rotation cycles		X		4.0	Rotation cycles per minute
4.11	Antenna dimension					
4.11.1	Dimension		X	1		Code, e.g.: L: effective length of antenna D: effective area of antenna, etc.
4.11.2	Value				3.0	Value (m)
4.12	Antenna scan method		X	1		Code, e.g.: E: rotary scan within a limited sector R: 360° rotary scan V: vertical sector scan N: horizontal and vertical sector scans, etc.
4.13	Half-power beam width					
4.13.1	Horizontal		X		4.1	Beam width (degrees)
4.13.2	Vertical		X		4.1	Beam width (degrees)
4.14	Horizontal antenna diagram		X		36.0	Indicates the isotropic gain of the antenna at 20° intervals beginning at 0° (peak of the directional diagram) sense clockwise (each value: two characters)
4.15	Vertical antenna diagram					
4.15.1	Multiplication factor		X		2.0	Indicates the value of the factor (degrees) which is to be multiplied with 9 values: +2.0, +1.5, +1.0, +0.5, 0, –0.5, –1.0, –1.5, –2.0, to obtain 9 desired angular values
4.15.2	Values of isotropic gain at 9 desired angles		x		18.0	(Each value: 2 characters)

TABLE A1-4

Frequency monitoring data: indicative list

No.	Data elements	Number of characters	Volume of information		
			BR IFIC		Adminis-tration
			Reduced	Compre-hensive	
1	Monitoring station	4	x	x	x
2	Date of observation	6	x	x	x
3	Time of observation	8	x	x	x
4	Frequency measured	8	x	x	x
5	Lower and upper limit of measured frequency range	16			
6	Designation of emission (RR Appendix **1**)	5	x	x	x
7	Type of system	6	x	x	x
8	Type of user and operational equipment function	4			x
9	Class of station	2	x	x	x
10	Nature of service	2			x
11	Country in which transmitter is located	3			x
12	Name or call sign	20	x	x	x
13	Location information	15		x	x
14	Corresponding station	20		x	x
15	Remarks	18		x	x
16	Assigned frequency	11		x	x
17	Notice of ITU-BR registration	1			
	Total	149	8	12	15

TABLE A1-5

Data elements for monitoring: indicative list

No.	Data element	(1)	No. of characters	
			(A or B.C)(2)	
			A	B.C
1	Monitoring station: name or call sign Location (3)	1 1	20 15	
2	Data of measurement	10		6.0
3	Time of measurement (UTC)	10		6.0
4	Frequency (4)	1	1	10.5

TABLE A1-5 (*end*)

No.	**Data element**		**(1)**	**No. of characters (A or B.C)(2)**	
				A	**B.C**
5	Frequency offset	(4)	10	1	6.1
6	Field strength	(5)	10		4.1
7	Harmonic	(5)	10		4.1
8	Harmonic	(5)	10		4.1
9	Sub-harmonic	(5)	10		4.1
10	Sub-harmonic	(5)	10		4.1
11	Azimuth of the emission	(6)	10		5.0
12	Name of other monitoring stations and their evaluation of the azimuth	(3), (6), (7)			
	1. Station: name or call sign		1	20	
	Location		1	15	
	Azimuth		10		5.0
	2. Station: name or call sign		1	20	
	Location		1	15	
	Azimuth		10		5.0
	3. Station: name or call sign		1	20	
	Location		1	15	
	Azimuth		10		5.0
	4. Station: name or call sign		1	20	
	Location		1	15	
	Azimuth		10		5.0
13	Location of the emission	(3), (8)	10	15+1	
14	Class of emission		1	5	
15	Maximum modulation deviation	(4)	10	1	4.1
16	Maximum modulation depth	(9)	10		4.1
17	Maximum modulation frequency	(4)	10	1	4.1
18	Code (teletype)		10	16	4.1
19	Baud rate (teletype)	(10)	10		5.0
20	Shift (teletype)	(11)	10		4.0
21	Bandwidth	(4), (12)	1/10	1	4.1
22	AF information (comment)	(13)	1	80	
23	Readability	(14)	1	2	
24	Receiver and analyser settings. Test system description	(15)	1	x	
25	Activity list (concluded events)	(16)	x	26	
26	Class of station		1	2	
27	Name or call sign		1	20	
28	Country of transmitter location		1	3	
29	Corresponding station		1	20	
30	Operators comments			80	

Notes to Table A1-5:

(1) Number of data fields (some parameters are measured and stored more often to achieve higher reliability of data).

(2) A or B and C

A: number of alphanumeric characters;

B: total number of numeric characters;

C: number of decimal characters.

(3) Coordinates of locations are defined by longitude and latitude as follows:

3 characters: degrees longitude;

1 character E (East) or W (West);

2 characters: minutes longitude;

2 characters: seconds longitude;

2 characters: degrees latitude;

1 character: N (North) or S (South);

2 characters: minutes latitude;

2 characters: seconds latitude.

Location coordinates of mobile monitoring stations have to be stored for evaluation of the collected data.

(4) The first character indicates the unit: H (Hz), k (kHz), M (MHz), G (GHz).

(5) Values (dB(μV/m)).

(6) The azimuths are stored by a value from 0 (=North) clockwise to 359 with standard deviation (2 digits).

(7) The azimuths obtained from other monitoring stations could be displayed on a map (preferably on a colour video screen).

(8) Besides the location, a quality factor is stored.

(9) Values (%).

(10) Values (Bd).

(11) Values (Hz).

(12) If bandwidth is measured manually, one data field should be efficient.

(13) A tape number can be stored here, if the AF was recorded.

(14) Readability is stored in numbers from 0 to 5. The storage of two numbers is possible, if the signal quality fluctuates significantly.

(15) The quantity of data depends on the equipment used.

(16) A concluded event could contain the following information:

– Time of appearance and disappearance (12 characters)

– Minimum and maximum measured level (4 characters)

– Minimum and maximum frequency offset (10 characters).

Some additional information is needed for a list of concluded events.

The number of concluded events depends on the observation period, on the resolution of data (pause time) and the stability of the activity status.

TABLE A1-6

Automated monitoring of licensed frequencies data: indicative list

No.	**Data element**		**(1)**	**No. of characters (A or B.C)[2]**	
				A	**B.C**
1	Monitoring station: name or call sign		1	20	
4	Frequency	(3)	1	1	10.5
5	Frequency offset	(3)	2	1	6.1
6	Field strength	(4)	2		4.1
7	Harmonic	(4)	2		4.1
8	Harmonic	(4)	2		4.1
11	Azimuth of the emission	(5)	2		3.0
12	Name of other monitoring stations and their evaluation of the azimuth	(5)			
	1. Station: name or call sign		1	20	
	Azimuth		2		3.0
	2. Station: name or call sign		1	20	
	Azimuth		2		3.0
	3. Station: name or call sign		1	20	
	Azimuth		2		3.0
	4. Station: name or call sign		1	20	
	Azimuth		2		3.0
15	Modulation deviation	(3)	2	1	4.1
16	Modulation depth	(6)	2		4.1
17	Modulation frequency	(3)	2	1	4.1
18	Code (teletype)		1	16	4.1
19	Baud rate (teletype)	(7)	2		5.0
20	Shift (teletype)	(8)	2		4.0
21	Bandwidth	(9)	2	1	4.1
24	Receiver and analyser settings; Test system description	(10)	1	x	
25	Time schedule of transmission	(11)	x		8.0

A reference number should be stored for access to the corresponding data of the frequency assignment file.

Notes to Table A1-6:

(1) Number of data fields:

1: The measured parameter must be exactly equal to the stored parameter in the data field.

2: The measured parameter must be within the boundaries stored in the data fields.

(2) A or B or C

A: number of alphanumeric characters;

B: total number of numeric characters;

C: number of decimal characters.

(3) The first character indicates the unit: H (Hz), k (kHz), M (MHz), G (GHz).

(4) Values (dB(μV/m)).

(5) The limits of an acceptance section are defined by two numerical values from 0 (=North) to 359 (clockwise). Rotation to the first value followed by a clockwise rotation to the second value defines the angular range of acceptance. An azimuth outside the acceptance section could imply a deterioration in signal quality.

(6) Values (%).

(7) Values (Bd).

(8) Values (Hz).

(9) This data field is only necessary if emission bandwidth is measured automatically.

(10) The quantity of data depends on the equipment used.

(11) A time schedule of the allowed transmission can consist of single blocks which contain the time of appearance and disappearance (8 characters).

ANNEX 2

Spectrum management system for developing countries (SMS4DC)

Introduction

The International Telecommunication Union Telecommunication Development Bureau (ITU-BDT) can supply a computer program to assist the administrations of developing countries to perform their spectrum management responsibilities more effectively. This program is known as the Spectrum Management System for Developing Countries (SMS4DC). SMS4DC is intended to be a low-cost, entry-level spectrum management system; however, it is a very complex software tool with many technical features and functions.

In 2002, Radiocommunication Study Group 1 approved new Recommendation ITU-R SM.1604 calling for improvements/upgrades to Windows Basic Automated Spectrum Management System (WinBASMS). In addition WTDC-02 decided on the further development of the computerized spectrum management system. The SMS4DC is the successor of the WinBASMS which has been developed according to specifications prepared by the ITU Telecommunication Development Bureau (BDT) and the Radiocommunication Bureau (BR) on the basis of Recommendation ITU-R SM.1048.

A voluntary group of experts met on several occasions informally in an attempt to draft specifications for this upgrade and SMS4DC has been developed based on this specification to manage frequency assignments to the Land Mobile, Fixed and Broadcasting services and for frequency coordination of Earth stations (RR Appendix **7** procedures). The SMS4DC can be used to support most functional requirements defined in the ITU Handbook on National Spectrum Management.

It is emphasized that, for successful installation and operation of SMS4DC, the administration should have in place existing legal, regulatory and technical mechanisms for national spectrum management. Also, while the system automates many of the technical processes, the final choice and decision for the frequency assignment remains with the engineer. Therefore, operating staff must have sufficient knowledge to understand the regulatory and technical processes that are the operational core of SMS4DC and to interpret correctly the results of the algorithms so that they can make good decisions.

The main features of SMS4DC include:

1 User-friendly GUI

2 Incorporating the ITU IDWM

3 Installable in networked environments

4 Availability of different user access levels

5 Employment of digital terrain model (DTM) on server or workstations

6 Management of a shared hierarchical administrative database

7 Integration of several propagation models

8 Demonstration of calculation results on DTM

9 Generation of BR electronic notice forms

10 Interference calculation

11 Frequency assignment

12 Consideration of regional/national frequency allocation tables

13 Consideration of regional agreements in technical calculations

14 Frequency-planning capabilities

15 Interface with BR-IFIC databases

16 Generation of informative reports
17 Employment of ITU modules for coordination contour calculation around Earth stations
18 Frequency spectrum billing management
19 Link to budget calculation
20 User log for audit control
21 English and French software interface (soon also Spanish)
22 Links to Argus (R&S) and Esmeralda (Thales) monitoring software
23 Interface to Google™ Earth mapping

1 Main functions of the SMS4DC

I Utilities and Administrative
II Technical
III Graphical user interface
I Utilities and Administrative functions

a) geographical map based utilization of Administrative functions,
b) use of a relational database management system,
c) generation of the electronic notices,
d) BR IFIC database import interface,
e) security features to access the database
f) recording frequency applications, frequency plans, frequency assignments etc.
g) identifying the priority and necessity of data items,
h) consideration of regional and international frequency allocations tables in frequency assignment,
i) consideration of (national) frequency plans designed for each frequency band,
j) multi-user capability of software utilization in a local area network,
k) data entry masks with on-line data validation mechanisms, where applicable,
l) local and global administrative-technical data base,
m) inclusion of an electronic library of antenna patterns and equipment specifications necessary to perform technical calculations, electronic library of frequency plans,
n) electronic data base for microwave links,
o) spectrum fee data base and capability to provide customized fee calculation model,
p) capability to integrate customized formats for reports and licences,
q) capability to switch the user language interface into the English, French and Spanish languages,
r) ability to track coordination requests or responses received to coordination requests,
s) ability to export the calculation results of SMS4DC to GoogleEarth™
t) ability to communicate bi-directionally with ARGUS (R&S) and ESMERALDA (Thales) monitoring software
u) ability to export data as Comma Separated Values files

II Technical features:

a) implementation of ITU-R propagation models as well as other relevant ITU-R Recommendations for various types of implemented radio services,
b) implementation of GE84, GE89, GE06 and ST61 regional plans,

c) utilization of a three dimensional digital terrain map (GLOBE-DEM with 30 seconds resolution) in propagation model implementation,

d) utilization of clutter maps available in IDWM

e) capability to integrate three dimensional digital terrain maps with other, better, resolutions,

f) capability to integrate raster maps and vector maps,

g) frequency coordination calculations,

h) on-line display of mouse pointer geographical coordinates and active area-variable such as height, field strength value etc.

i) field-strength calculations using different propagation models within a selected area (coverage area), along a profile, along a polygon, at given points and generation of contours.

j) calculation of network coverage and the best server,

k) interference calculation around the selected terrestrial transmitters and victim receivers,

l) interference calculation between Earth stations operating with Geostationary satellites and microwave stations,

m) interference analysis for assigning frequencies to stations in given locations,

n) possibility to track and customize the issue of licences for frequency utilization,

o) determination of affected countries for conducting international coordination,

III Graphical user interface

p) User friendly interface, displaying of DTM, capability of importing standard mapping formats including Globe map and displaying of geographical maps,

q) Online latitude, longitude and altitude presentation, overlaying, Scrolling and Zooming functionality capability of handling vectors

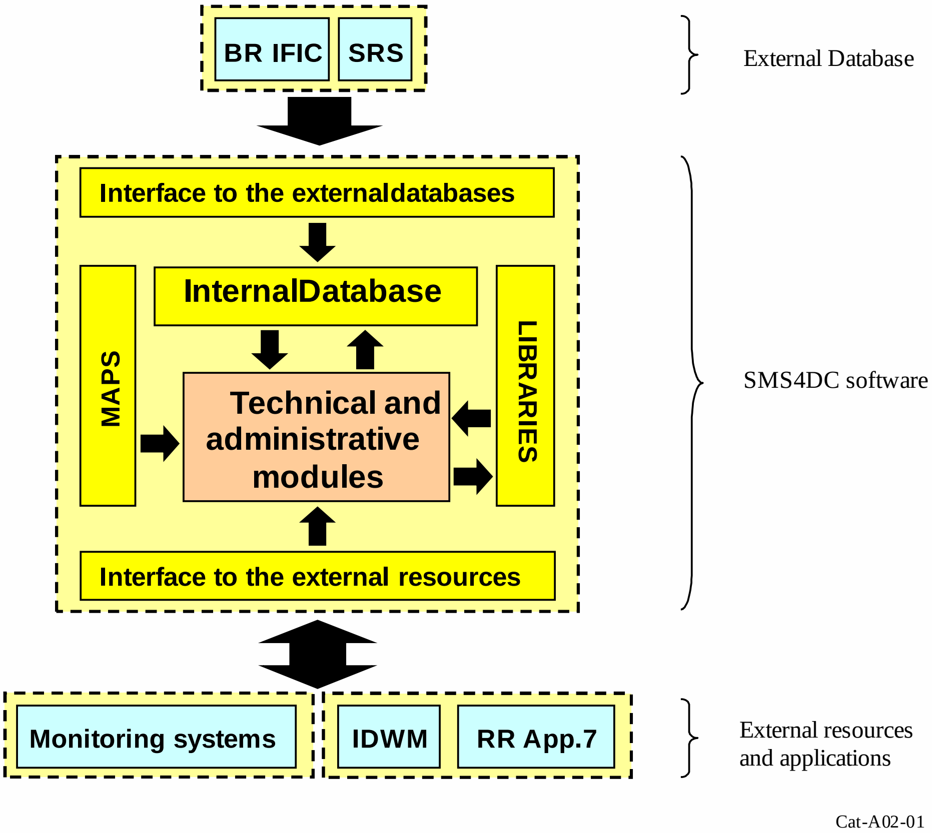
r) Providing multiple entry functions, menu items, assigning new stations on map and searching and displaying a station or group of stations on map

2 Structure of SMS4DC software

The SMS4DC software, working under the Microsoft Windows operating system, has been developed as a single package using visual C++6.0 language and, consists of a core, shell and external parts (see Figure A2-1).

FIGURE A2-1

Structure of SMS4DC software



2.1 Core of SMS4DC software

The SMS4DC core provides a user-friendly machine interface and supplies all the tools necessary to perform or administrate the required technical and administrative tasks of SMS4DC software. The core part of the software has been enabled to employ the ITU-developed and authorized modules, IDWM and RR Appendix **7**, to generate internationally reliable technical results. Moreover, importing of records from Terrestrial BR IFIC, Space BR IFIC and SRS databases is also possible.

2.2 Shell and external elements of SMS4DC software

The Shell of the SMS4C software consists of: geographical raster and vector maps, an administrative/technical database of stations, various libraries and different interfaces to use external resources and databases. Several vector maps have been extracted from the latest ITU Digitized World Map (IDWM) module together with GLOBE DEM, and integrated into the software as a raster map, as required by the BDT specification for SMS4DC.

3 Geographical information systems of SMS4DC software

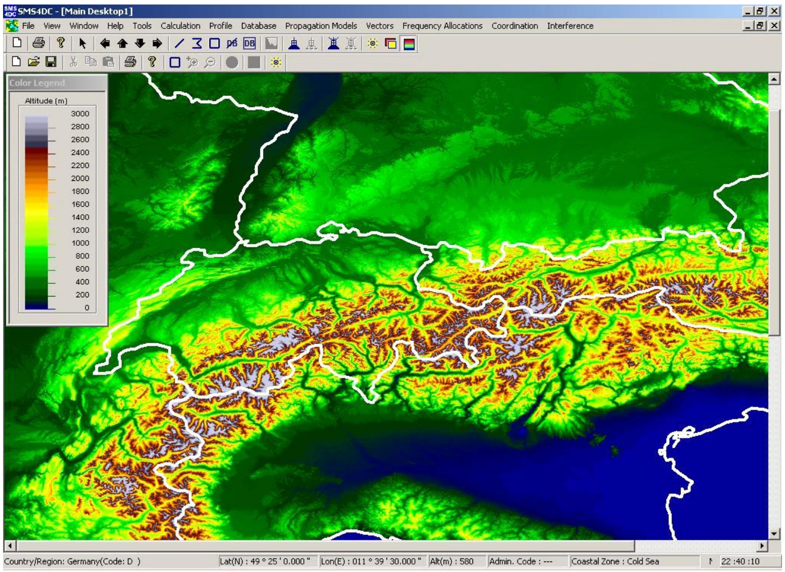
SMS4DC software enables both vector and raster map facilities within the different technical and administrative modules to be available to any user, regardless of the user’s access level

SMS4DC has two map displays: International Digital World Map (IDWM) and the Digital Elevation Map (DEM). These also provide an interface, through Windows-style tool bars, to other functions including Google™ Earth.

- ○ **Vector maps**
  - The SMS4DC software employs the latest ITU Digitized World Map (IDWM) for provision of following vector maps: political border lines, coastal lines, ITU radiocommunication regions, geographical areas for ST61, GE84, GE89 and GE06 plans.
- ○ **Raster maps**
  - The SMS4DC software uses a digital elevation model (DEM), named GLOBE (Global Land One-kilometre Base Elevation). The GLOBE DEM is a global data set covering from 180 degrees west to 180 degrees east in longitude and from 90 degrees north to 90 degrees south in latitude. The resolution is 30 arc-seconds (0.008333... degrees) in latitude and longitude. The supported projection systems are Lambert and UTM and the datum should be World Geodetic System 84 (WGS84) (see Figure A2-2).

FIGURE A2-2

The Digital Elevation Map (DEM)



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This screenshot has a topographical colour-scale and shows the Swiss border and surrounding countries. The colour-scale altitude is shown in the legend.

The DEM menus and toolbars access the main engineering, assignment and coordination tools.

- **The SMS4DC is also able to read other DEM maps with a resolution better than 1 km**

Of course the map should have the same geographic projection system and datum.

4 Technical information database

SMS4DC uses several internal technical reference tables during the assignment process, like Channel Arrangements, Equipment and Antenna Libraries, etc.

5 Engineering tools (Calculation, Profile and Vector Menus)

In addition to the frequency assignment and service-specific analysis tools, the engineer may use a number of engineering tools. These tools may be accessed through Calculation, Profile and Vector menus on the DEM. Lines and polylines (two or more joined lines) can be drawn on the DEM.

Once a Line or Polyline has been drawn, the following calculations can be done: Distance, Area, Azimuth, Elevation, Profile, Fresnel zone (for line only). In vectors menu users can Draw Circle, Draw from file, Remove from display, Vector handling.

The following additional calculations can be done by the SMS4DC: Radio Horizon, Intermodulation, Unit conversion, Antenna editor, Effective antenna height.

SMS4DC provides an interface for conversion many of its calculation results (field-strength contours, point-to-point links and other types of vectors and raster results) into KML format files so that they may be seen as overlays on the Google™ Earth mapping system.

6 Propagation tools

Two main types of model for predicting propagation are implemented: those for point-to-point systems (e.g. fixed services) and those for point to area systems (e.g. land mobile or broadcasting services). Some models can be used for both types. All propagation models are designed to enable different values of parameters to be used to take account of differences in the particular path or area under examination.

Table A2-1 shows the propagation models implemented in SMS4DC and the valid combinations of model and type of analysis and Figure A2-3 is an example for link budget analysis.

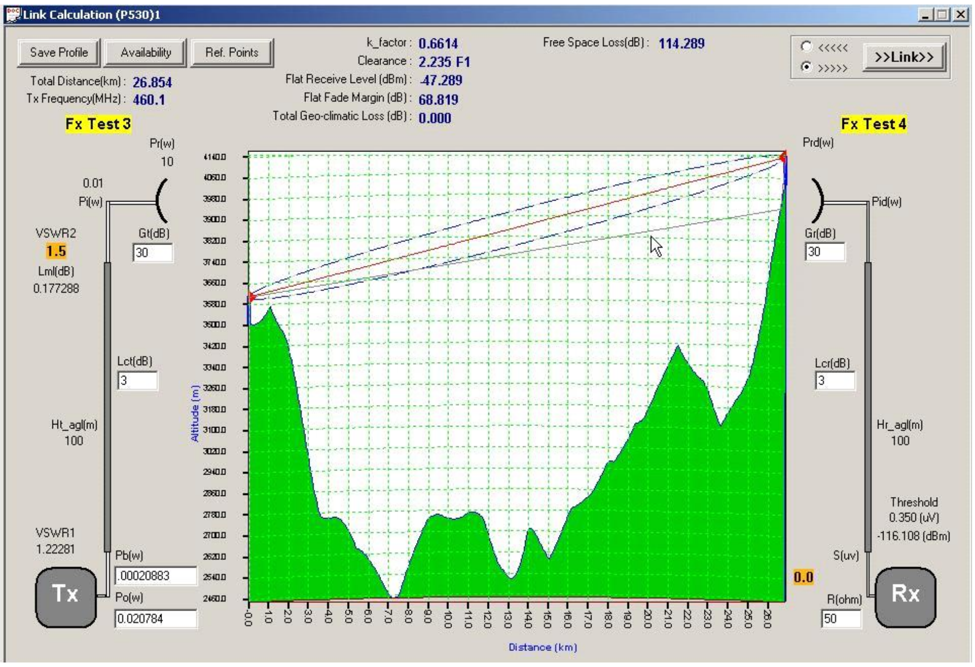
TABLE A2-1

Implemented propagation models

Propagation Models	Analysis type					Network Processor	
	Line	**Polyline**	**Area**	**Link**	**Contour**	**Max Field Strength**	**Best Server**
Free Space	Y	Y	Y	N	N	Y	Y
Line of Sight	Y	Y	Y	N	N	N	N
ITU-R P.370	Y	Y	Y	Y	Y	Y	Y
ITU-R P.1546	Y	Y	Y	Y	Y	Y	Y
Okumura-Hata	N	N	Y	N	N	Y	Y
ITU-R P.526 (by diffraction)	N	N	N	Y	N	N	N
ITU-R P.526 (Smooth Earth)	N	N	N	Y	N	N	N
ITU-R P.452	N	N	N	Y	N	N	N
ITU-R P.530	N	N	N	Y	N	N	N

FIGURE A2-3

Link budget analysis using Recommendation ITU-R P.452



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7 Administrative database and Licensing System

The database structure, the user access control and the networking capabilities permit SMS4DC to be operated in several configurations depending on the needs (size and resources) of the Administration (or spectrum management authority). In addition, SMS4DC provides a simple accounting system for recording fee payments and invoicing.

Licensing information is presented in a "tree" or hierarchical format. There are three main sections: Anonymous stations: These stations are not (yet) licensed. However, such stations could also be added for test purposes only and deleted once the analysis is complete; Active licences and Archived licences. Licences and bills can customized and then prepared from the database.

8 Frequency Assignment and Interference

SMS4DC offers a range of functions that can be used to provide detailed technical and administrative assistance in the assignment of frequencies to the Land Mobile, Fixed and Broadcasting Services.

These include:

- Providing a database structure that contains all the necessary technical and administrative information;
- Ability to specify which channels are available;
- Automatic assessment of all available channels in a given frequency range;
- Propagation tools to estimate service/coverage/interference areas;
- International frequency coordination tools

SMS4DC automates the technical analysis used in the assignment process but does not decide which frequency should be assigned. The engineer must have a thorough understanding of the principles of frequency assignment in order to interpret the results and, if necessary, carry out more detailed analysis.

The following calculations can be done by the SMS4DC:

- Determine available channels from the Channel Arrangement Tables
- Initial analysis of the available channels for existing stations
- Land Mobile Service
- Fixed service
- Broadcasting service
- Earth stations in space services

9 Frequency Co-ordination Menu

SMS4DC contains the co-ordination tools required for:

- Broadcasting service (Regional Agreements): ST61, GE89, GE84, GE06 (see Figure A2-4)
- Fixed and Land Mobile services: enables the technical details of Coordination Agreements to be stored in the database, while (*Border*) provides functions to assess whether a station meets the technical conditions of the Agreement
- Earth station coordination (**RR** Appendix 7 procedure): calculation of the coordination contour and the effected countries. Also calculate interference caused or received by a selected Earth station on or from other Earth stations or Fixed stations located inside the coordination contour.

FIGURE A2-4

GE06 Agreement FXLM2BCBT (Affected Admin)

Identification of Administrations whose broadcasting service is likely (potentially) to be affected by a wanted station in fixed or land mobile service inside another country. Right-and screenshot shows the coordination contour for the wanted FX station crossing the border of an administration whose broadcasting service is likely to be affected. Left-hand screenshot shows this result exported to Google Earth.

Cat-A02-04

10 Generation of notices of frequency assignments for electronic submission to the ITU Radiocommunications Bureau (ITU-BR)

- SMS4DC can generate, store and display electronic notices to notify ITU BR the assigned frequency(s) or administrative modification(s) for assignments to Land Mobile, Fixed and Broadcast stations.
- Also for Earth stations, electronic notice files will be created in the form of Microsoft Access database files.

11 Importing data from BR IFIC (Terrestrial Services) and BR IFIC (Space Services) on DVD-ROMs

SMS4DC provides an import facility so that relevant data, in particular about frequency assignments in selected countries, can be imported from the BR IFICs into the SMS4DC database.

12 System and Database Security

- **Database back-up and restore**

SMS4DC provides the facility to back-up the database so that it may be stored in a secure location separate from the SMS4DC server.

- **Log file**

SMS4DC creates a log file of activities performed by the users on modification of the data. Therefore the system administrator would be able to track destructive actions based on their dates and restore the appropriate version of the backup.

- **User access security levels**

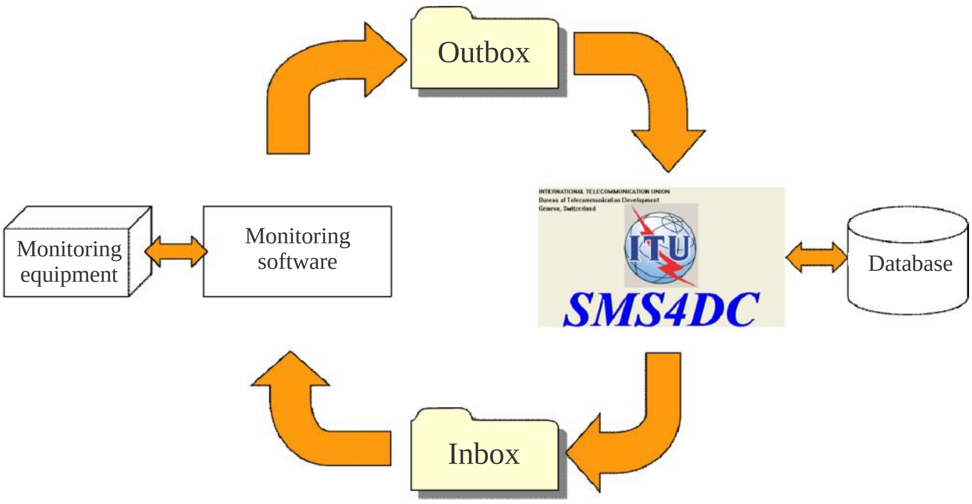
SMS4DC has six (6) levels of security for user access to prevent unauthorized persons using the system, modifying licensee records or reference tables.

13 Monitoring Menu

One of the important parts of a spectrum management system is the monitoring sub-system which acts as the eyes of the total system. With the cooperation of Rohde and Schwarz (R&S) and THALES Companies, it is now possible for SMS4DC to interact with ARGUS (R&S monitoring software) and ESMERALDA (THALES monitoring software) and communicate bi-directionally. In addition, the requirements for a general interface were developed by ITU-R Working Party 1C (see Annex 6 to Document 1C/122 of 18 October 2010), in order to specify the connection between two software systems through two shared folders called “Inbox” and “Outbox”. The information is to be provided in XML format (see Figure A2-5).

FIGURE A2-5

General interface between SMS4DC and monitoring software



Cat-A02-05

For more information see http://www.itu.int/pub/D-STG-SPEC-2012-V4.0 or contact: SMS4DC@itu.int

ANNEX 3

SMIs – Spectrum management intelligent system

1 General information

The SMIs (Spectrum Management Intelligent system), developed by National Radio Research Agency (herein after RRA) of the Republic of Korea, covers the range of technical functionalities for analysis of compatibility and sharing of all radio services. The system has been continuously updated and would be further developed in terms of functionalities and modern IT technologies.

1.1 The task of the SMIs

To carry out all required activities of compatibility and interference analysis related frequency management in a country on strategic and operational level, the SMIs covers the spectrum management process by identifying and analysing the compatibility and sharing analysis among the broadcasting service, terrestrial service and satellite network service.

1.2 The procedures

All procedures and all calculations of SMIs are strictly in line with the latest ITU recommendation and regulation of Republic of Korea. Potential modifications in the procedures are usually introduced to the SMIs system by module upgrades for systems, which are already in operation.

In addition, the formats of all output documents can be customized within the system in order to meet specific client or administration requirements.

1.3 Subcomponent system

The SMIs is based on a highly modular client server architecture allowing functional and geographical splitting between the database server and the various application modules. This scalable architecture allows system modification projects to start with basic system configurations, which may be extended to more complex and comprehensive configurations in later project phases when required. The SMIs consists of broadcast network analysis system, terrestrial network analysis system, satellite network analysis system and Frequency sharing analysis system that conducts analysis on compatibility, interference, and sharing between different wireless services.

1.4 Digitized maps

Digitized Terrain Maps (DTM) are used in the SMIs as a basis of spectrum analysis in administrative and technical procedures in order to provide the real geographical information. The commercial GIS (Geographic Information System) data formats commonly used in the market can be migrated to internal formats for efficient data access in SMIs. The system can handle different types of layers in simulation, among other topographical maps, land usage and population data.

2 Description of the SMIs

RRA's SMIs provides a comprehensive integrated solution for the licensing procedures of all radio services.

The main features of the SMIs can be summarized as follows:

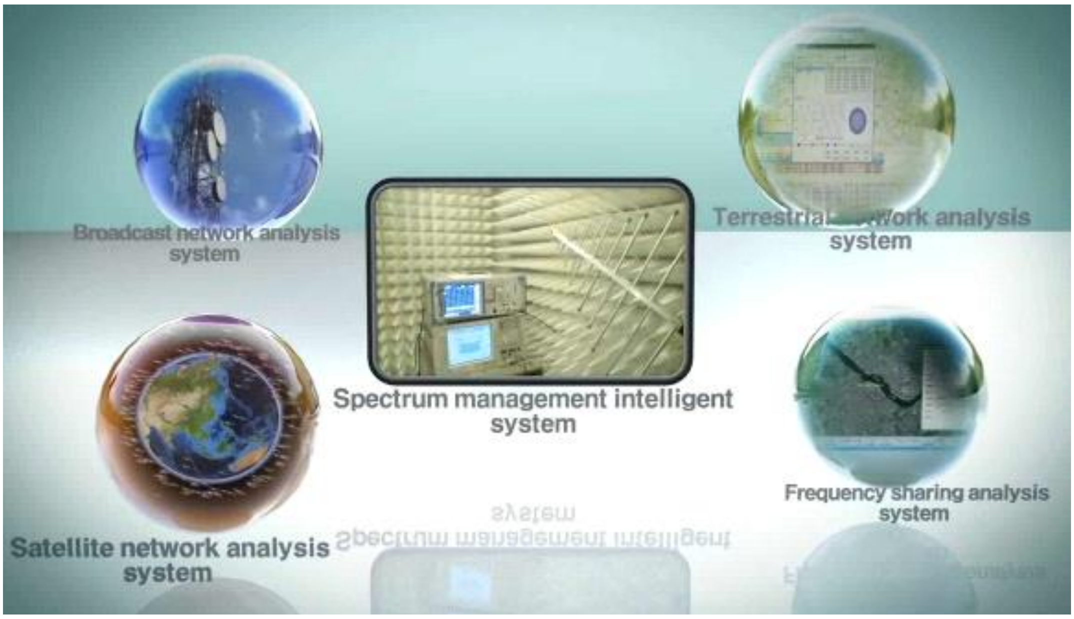
– SMIs portal for user access
– Subsystem of Spectrum Management Intelligent system

  - Analysis of broadcasting service
  - Analysis of terrestrial (Fixed and Land mobile) service
  - Analysis of satellite service
  - Analysis of frequency sharing and compatibility
- Frequency assignment procedures based on calculations (propagation models) and technical data specified for the particular radio service

Figure A3-1 illustrates the general overview including modules for licence administration, which are technical analysis and coordination for all radio services, domestic frequency assignment plans and interface to radio monitoring with analysis of measurement data. The modules are described in the following section.

FIGURE A3-1

RRA's Spectrum Management System – SMIs



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2.1 Brief module description

2.1.1 Portal Web

SMIs' Portal web has the search function of the subsystem and contains a lot of relevant information of radio waves law, regulation, and table of frequency allocation, etc. Figure A3-2 illustrates supporting a function of user management and allows application data of radio operational information by any web browser on.

FIGURE A3-2

Portal Web of SMIs

Cat-A03-02

2.1.2 Broadcast Network Analysis System

The Broadcast Network Analysis System is the Analysis (Planning) and Coordination of analogue and digital Broadcasting Services.

The system has several functions as follows:

– function of broadcasting domain analysis for broadcasting stations;

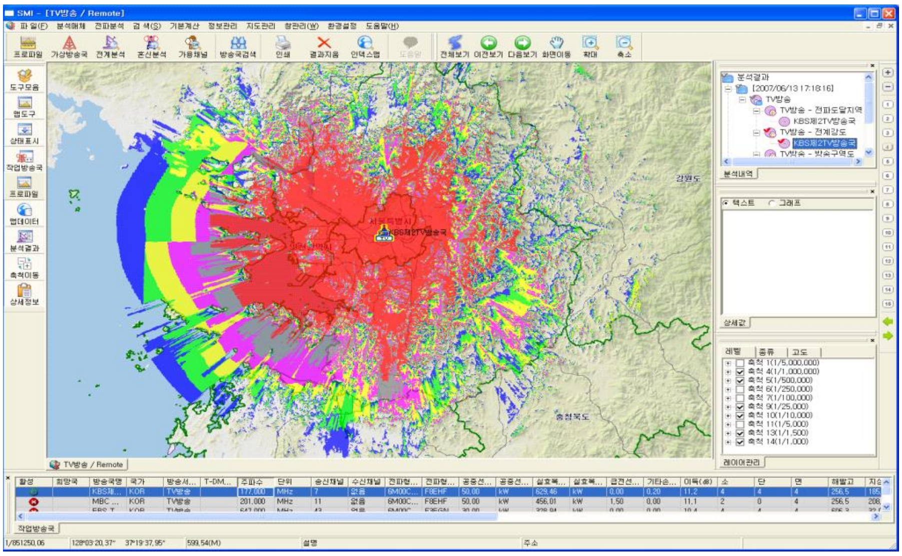
– function of broadcasting signal /interference analysis;

– function of analysis of available channels;

– International registration of broadcasting frequency.

FIGURE A3-3

Analysis of Broadcasting Service



Cat-A03-03

To analyse potential broadcast areas, information of frequencies, which has a characteristics of broadcast facilities, antenna height and output power, is used to verify regions where broadcast services are available. The ground height and type of terrain as well as the height of buildings are taken into consideration when conducting the analysis

2.1.3 Terrestrial Network Analysis System

The Terrestrial Network Analysis System is used in the analysis (Planning) and coordination of terrestrial services with fixed services (Microwave Links) and land mobile services**.**

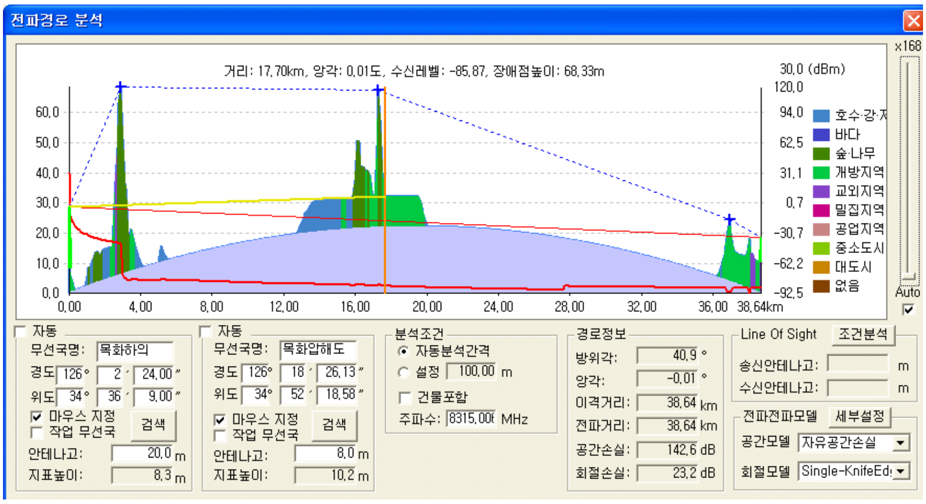
The system supports the analysis for mobile telecommunication services such as CDMA, LTE, and TRS (Trunked Radio System) and fixed services. The wireless broadband communications network integrated information to support building the facility that is connected wirelessly.

The system consists of functions as follows:

- function of terrestrial domain analysis for fixed and land mobile stations;
- function of terrestrial intermodulation /interference analysis;
- function of analysis of available channels for terrestrial service;
- International registration of terrestrial frequency.

FIGURE A3-4

Analysis of Fixed Service Link Design



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2.1.4 Satellite Network Analysis System

The Satellite Network Analysis System is utilized in the analysis and coordination of satellite services. Satellite networks refer to satellites floating in the sky and earth stations to wirelessly connect inter-satellite and satellite-earth stations.

The system consists of functions as follows:

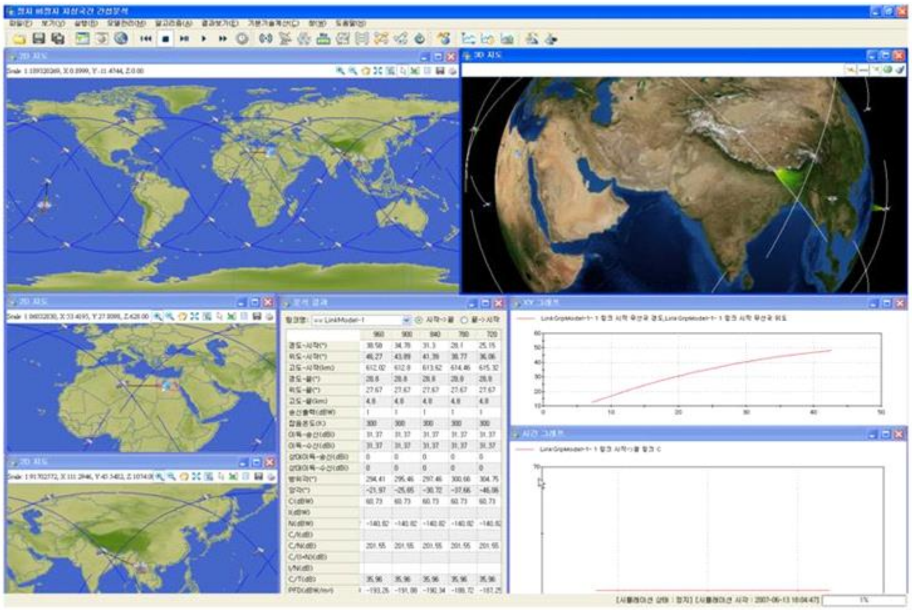
– function of analysis for GSO/NSGSO satellite stations and earth/ground station;

– function of intermodulation/interference analysis between satellite network (Non-geostationary orbit station, geostationary orbit station) and ground station;

– International registration and coordination of satellite network.

FIGURE A3-5

Analysis of Satellite Service



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2.1.5 Frequency Sharing Analysis System

Frequency Sharing Analysis Systems use the methods of analysis which are used similarly in broadcast networks and terrestrial networks, etc. to analyse operation parameters for frequency sharing when different wireless equipment and services are used in the same frequency band.

The system has functions as follows:

– function of compatibility analysis of terrestrial and broadcasting service;

– function of terrestrial intermodulation /interference analysis;

– function of analysis of available channels for terrestrial service.

ANNEX 4

SIRIUS – National system for spectrum management

1 Introduction

An automated national system for spectrum management, known as SIRIUS was developed in Kyrgyz Republic and has been in operation since 2003. The system was designed to be simple and intuitive in its design and operation, and to be used effectively under conditions typical for developing countries, i.e. limited staff resources without any specialized training beyond basic radio technology. The system fully complies with Recommendation ITU-R SM.1604 – Guidelines for an upgraded spectrum management system for developing countries. It was further designed to perform all of the core functions that are typically performed by more powerful and complex systems, including multi-user access and simulations using digital terrain data. SIRIUS has shown itself to be very user-friendly in an environment where the number of frequency assignments is not too large (up to 50 000-100 000), which is also typical of developing countries.

2 The SIRIUS system

The automated spectrum management system SIRIUS was developed using modern technological platforms, topology and IT architecture, ensuring a high level of security, reliability, integrity, safety of information and rapidity of response. Multi-user data processing on the basis of client-server technology provides many advantages for the organization of a central database, unique user interface, security and audit systems, and strategies for backing up, restoring, logging, and importing and exporting data.

SIRIUS was developed in compliance with the following:

– Recommendations ITU-R SM.1370, ITU-R SM.1604, ITU-R SM.1048, ITU-R SM.1413, ITU-R SM.667.
– Evaluation methods and analysis models for EMC and calculation procedures given in relevant ITU-R Recommendations and regional and inter-regional agreements.

SIRIUS is capable of performing the following core functions:

– Administrative module:
  • licensing of frequency assignments;
  • domestic and international coordination and notification;
  • invoicing and fines.
– Engineering analysis module:
  • spectrum use planning;
  • different analytical methods of assessing station SNR and EMC;
  • general-purpose engineering analysis tools for calculating interference and coverage areas for stations, path analysis etc. using digital terrain data.
– Monitoring module:
  • recording interference complaints, investigating and eliminating interference;
  • preparation of spectrum monitoring jobs for monitoring stations;
  • collection and analysis of spectrum monitoring data;
  • analysis of emission measurements for comparison with database.

SIRIUS operates with the following inputs:

– administrative and technical data of frequency assignments;
– data from domestic and international tables of frequency allocations;
– hardware and antenna catalogues;

– data from coordination distance tables;
– service data required for operation of SIRIUS;
– terrain data.

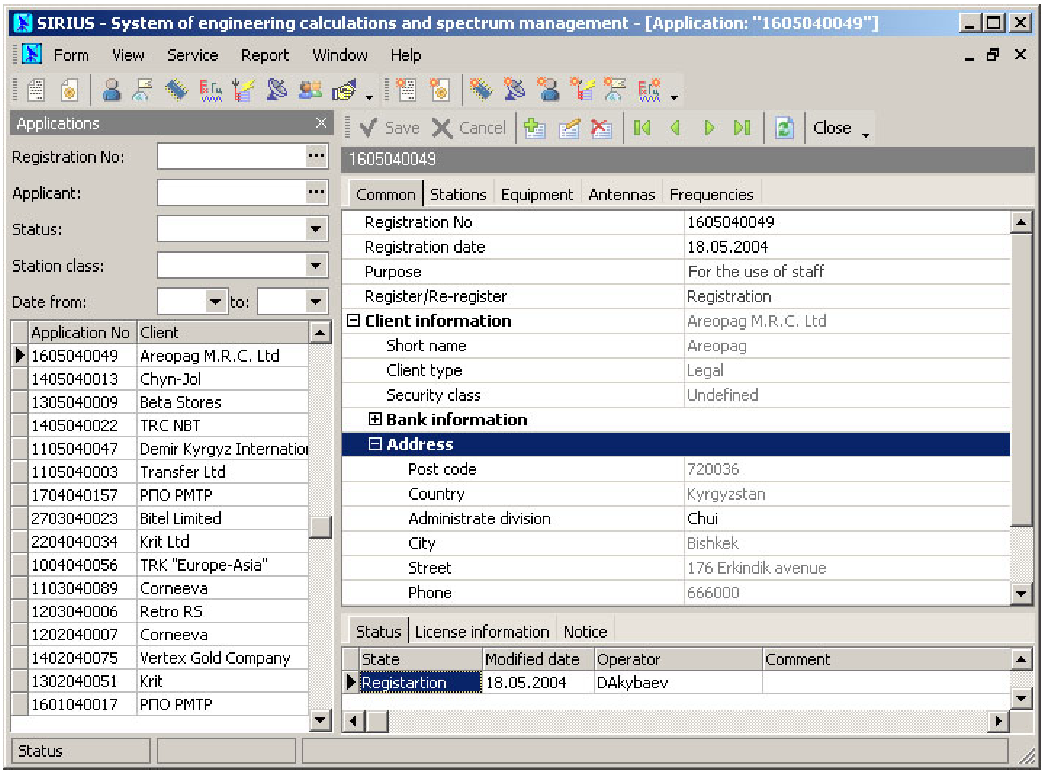
3 Administrative module

The following functions are included in the administrative module:

– Recording of frequency assignment notices in the system. Verifying that information provided is complete and correct.
– Verification of notified frequency assignment for compliance with international and domestic tables of frequency allocations.
– Registration of licences for frequency assignments in the system.
– Entry of data from certification and approval of antennas in the system.
– Generation of notices for coordination of frequency assignments (domestic and international coordination).
– An adaptable system for calculation of fees and fines for spectrum utilization.
– Administrative and technical reports.
– Data storage for domestic and international tables of frequency allocations.
– Importing and exporting data.
– Backing up and restoring data.
– Registration of system users, audits.

FIGURE A4-1

Administrative module



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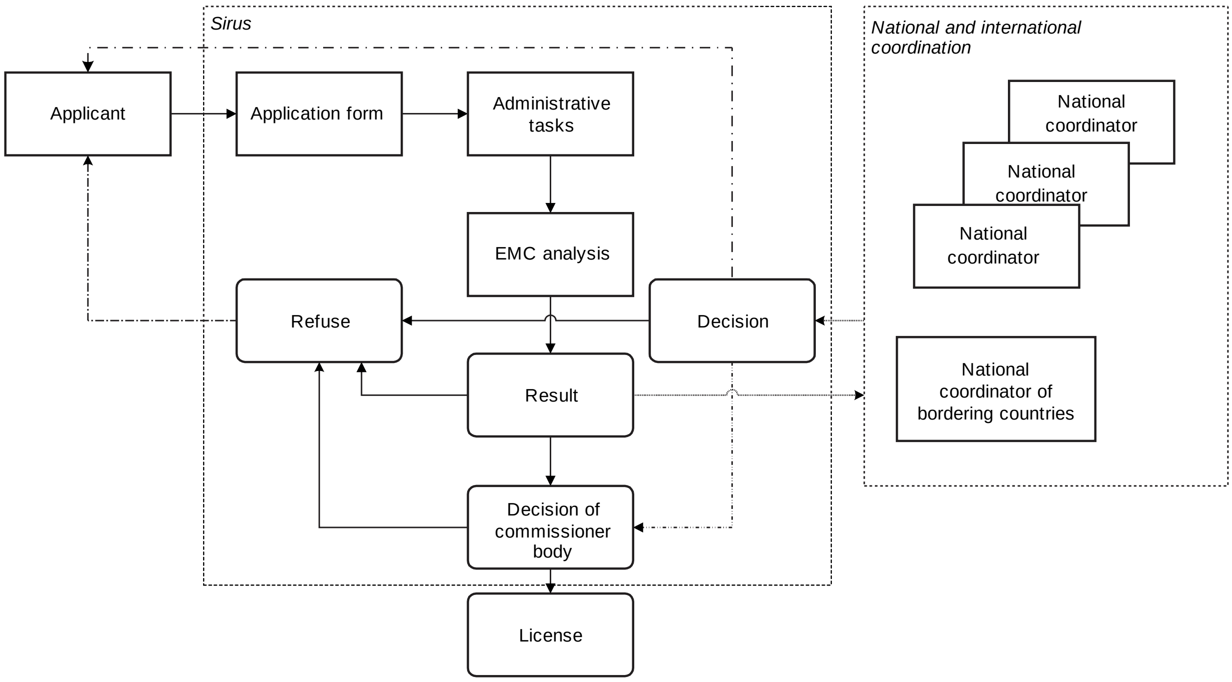
3.1 Licensing frequency assignments

The client completes a form for notification of a frequency assignment and submits it to the national administration, in paper or electronic form. The flow diagram in Figure A4-2 illustrates the sequence of actions taken in SIRIUS for the licensing process.

FIGURE A4-2

Flow diagram



Cat-A04-02

The operator enters the application for a frequency assignment in the system. After verifying that the information provided is correct and complete, the system assigns the application the status "under consideration". If the applicant failed to supply all of the information required, the status "registration" is assigned. If the results of the EMC analysis are positive, the application is forwarded for coordination at the domestic and international level. The frequency assignment is only carried out if the results at every stage are positive. If there is an unsatisfactory result at any stage, the operator changes the notice parameters in consultation with the client. The system is capable of automatically extracting data from notices submitted electronically.

4 Domestic and international coordination, notification to ITU-R

SIRIUS can prepare requests for inter-agency and international coordination using the correct ITU-R notification forms required for the category of station to be coordinated. The coordination process is based on existing regulations and agreements, concluded between the coordinating parties or in the form of regional agreements. To this end SIRIUS incorporates the coordination methods and procedures contained in regional agreements such as Geneva 1984, Geneva 1989, Stockholm 1961, Berlin 2003 and others.

Coordination requests are handled in SIRIUS like any other request for a frequency assignment, except that specific statuses are assigned.

Once the forms have been prepared, they can be forwarded to ITU-R for notification purposes in either electronic or paper form, indicating the coordinating countries.

5 Reports

The system offers the following reports:

– *Standard reports*: statistical, administrative, technical and financial reports. Examples: number of applications received, applications with positive results, rejected applications, results of examination of applications, coordination results, etc.

– *Report generator*: a flexible system that can be used to formulate different reports, based on templates and scripts.

The report generator creates reports by means of a report wizard. The report wizard selects the necessary data (entries) and selection criteria, and formulates the query. It is also possible to create reports using macro scripts.

6 Technical and administrative database

The structure of database complies with Recommendation ITU-R SM.667, providing for performance of the core system functions.

SIRIUS has an adaptable interface which allows the user to customize the forms used to enter and edit data, depending on technical characteristics and administrative requirements.

For the main objects, the system tracks all changes in status, giving the date, the operator and an explanation of the change. Logging status changes makes it possible to determine the delays for administrative processing of applications received, and to formulate administrative queries to determine spectrum utilization effectiveness and efficiency.

7 Engineering analysis module

The following functions are included in the engineering module:

– Spectrum planning tools.

– Analytical tools for the broadcasting, mobile and fixed services.

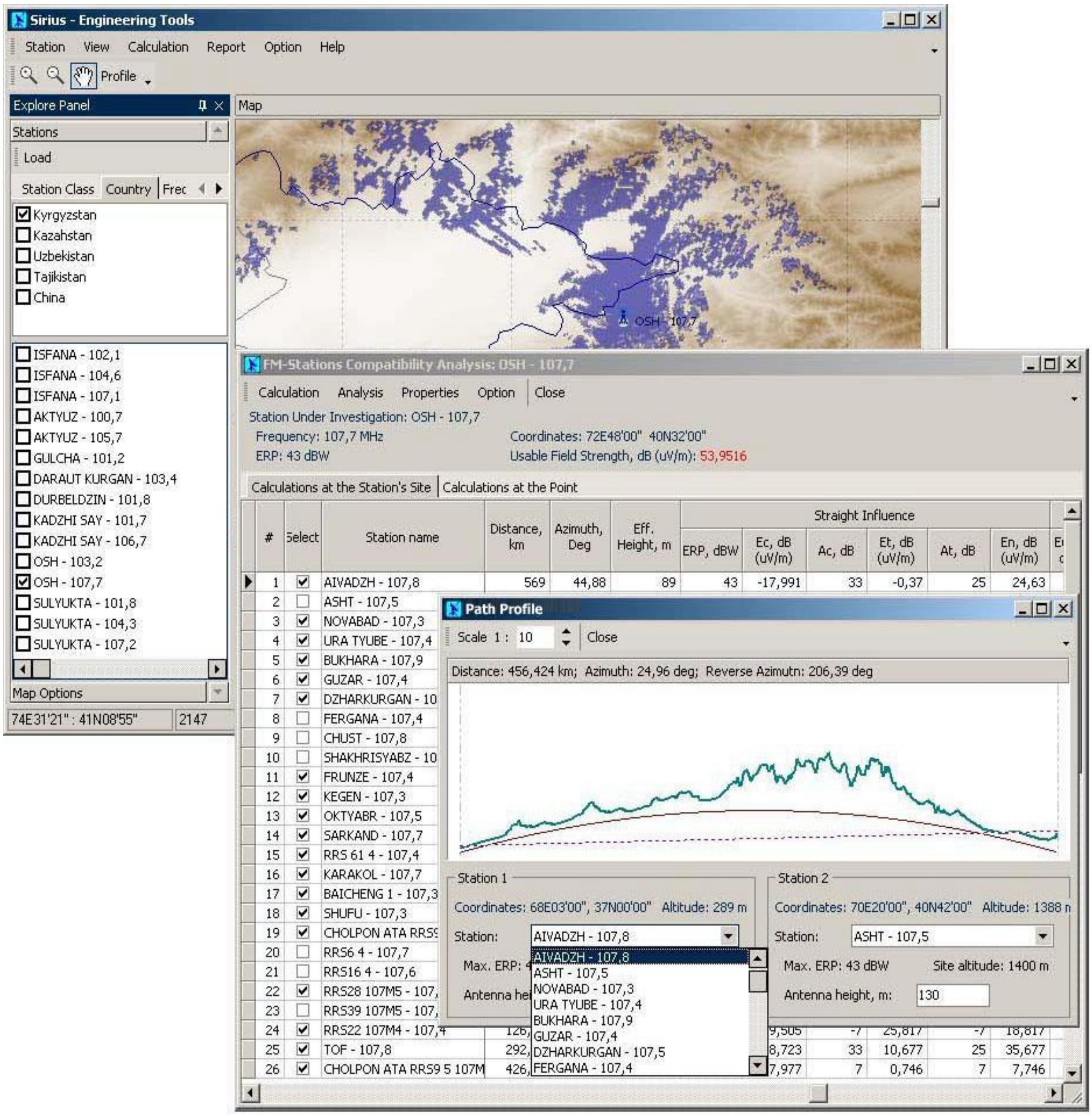
– Analytical tools for assessing EMC between stations in different services.

– General-purpose engineering tools for spectrum analysis.

– Forecasting models for radio wave propagation in SIRIUS.

FIGURE A4-3

Engineering analysis module operating windows



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7.1 Spectrum planning tools

SIRIUS offers the following capabilities for spectrum planning:

– Support of domestic and international tables of frequency allocations, including services and footnotes.

– Entry and editing of new and existing tables of frequency allocations.

– Editing of allocation plans and channels.

– Flexible reporting system for tables of frequency allocations (display in graphic and table form).

– Functions for verifying that frequency assignments are in accordance with tables of frequency allocations.

7.2 Analytical tools for the broadcasting, mobile and fixed services

These tools allow SIRIUS users to do the following:

- Analyse and assess the effects of existing and planned stations on a given station (individual and overall effect) at any geographical location within the service area of the station (by service), using calculations based on digital terrain data.
- Perform a quick calculation or a detailed analysis of the effect that a given station will have on existing and planned stations (by service).
- Channel-by-channel analysis of interference at a given location (for purposes of frequency assignments).
- Analysis of intermodulation products.

7.3 Analytical tools for assessing EMC between stations in different services

These tools allow engineers to perform an EMC analysis for stations operating in different services.

- The calculation methods described in Recommendation ITU-R IS.851-1 have been implemented. The following features are provided:
  - protection of the broadcasting service from systems in the fixed and land mobile service;
  - protection of the land mobile service from the broadcasting service;
  - protection of the fixed service from the broadcasting service.
- Analysis of compatibility between systems in the sound broadcasting service (87-108 MHz band) and the aeronautical services (108-137 MHz band) using the methods of Recommendation ITU-R SM.1009-1.

7.4 General-purpose engineering tools for spectrum analysis

- Indexed station search in database. Results are displayed geographically, with user-selected layers (national boundaries, urban areas, relief, morphological data, etc.).
- Calculation and graphic depiction of coverage areas and areas of interference for a given station, using different models of radio wave propagation.
- Display of path profiles and attenuation values for propagation (depending on propagation model selected) between any two stations, and path parameters (azimuth, geographical coordinates, altitude) between any two locations.
- Distribution of channels between stations in accordance with frequency-space separation.

7.5 Forecasting models for radio wave propagation in SIRIUS

SIRIUS contains a large collection of radio wave forecasting models, covering a broad range of frequencies and different types of applications, from elementary ones such as a free-space wave propagation model, to complex models that take into account terrain, climate, ground and morphology over the path profile. Some of the models included are:

- free-space wave propagation model;
- smooth Earth model;
- Okumura-Hata model;
- NSM model;
- Recommendation ITU-R P.370 model;
- Recommendation ITU-R P.1546 model;
- Recommendation ITU-R P.530 model.

8 Monitoring module

Interference complaints, investigation and elimination

SIRIUS records complaints and classifies them by type of interference. The investigation and elimination of interference sources, and measures taken for those sources are systematically logged, for use with future cases of interference of a similar nature. If the source is determined to be a licensed station, then an internal procedure is launched to re-evaluate the parameters of the frequency assignments to the stations involved. If the source is not a licensed station, then measures are taken to terminate the interfering emissions.

Preparation of spectrum monitoring jobs for monitoring stations

SIRIUS offers a list of standard jobs for different monitoring stations, with the necessary sets of job data. Stations then prepare and return results for each job, which can be stored in the system.

Collection and analysis of spectrum monitoring data

The system makes it possible to collect and store monitoring data, so that changes in the characteristics of emissions can be tracked. The spectrum monitoring database is set up in accordance with [Touré *et al*., 2002].

9 Multi-user operation

SIRIUS can support the simultaneous operation of up to 20 workplaces. It is possible to increase the number of parallel user sessions still further by upgrading certain portions of the system.

10 Final remarks

In spite of the fact that recently the system is mainly used for solving separate EMC problems and training purposes, the experience of the Kyrgyz Republic in the mater still can be interesting for other entities and spectrum management specialists.

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ANNEX 5

Application software for Angle of Arrival spectrum monitoring network planning and optimization

The software is aimed for planning and optimization of spectrum monitoring networks or groups of monitoring stations based on the traditional Angle Of Arrival (AOA) technology in accordance with sections 6.8 and 4.7.3.1.4 of the ITU Handbook on Spectrum Monitoring (2011 edition). As an investment in a monitoring sub-system is a major part of the total spectrum management system investments, the optimization and efficient planning of the monitoring networks have great technical and economic significance as it is specifically stressed by Recommendation ITU-R SM.1392-2. The software can also be used for visualization of coverage areas of VHF/UHF spectrum monitoring stations – especially mobile ones – in the course of their field operations, as well as for determination of interaction conditions of fixed and mobile monitoring stations in performing various monitoring functions, in accordance with section 3.6.2.2.7 of the ITU Handbook on Spectrum Monitoring (2011 edition).

The software permits administrations and operators:

– to obtain exact and quantitative information on the real situation with capabilities of their actual national monitoring networks or groups of fixed monitoring stations in fulfilment of all monitoring functions: emission parameter measurements (including listening), DF and location by triangulation; detailed atlases of monitoring coverage at different frequencies (in the range 30-3 000 MHz) and with various test transmitter parameters (power and antenna height) can be developed;

– to assess, by considering various options, a gain which can be achieved by upgrading monitoring equipment parameters (mainly – monitoring receiver sensitivities for different monitoring functions and DF instrument or system accuracies) as well as monitoring antenna heights and gains of fixed monitoring stations;

– to identify areas where one or another monitoring function is not fulfilled or fulfilled with limited quality by existing fixed monitoring stations; these areas can be candidates for optimized installation of new monitoring stations;

– to identify those fixed monitoring stations that do not provide significant contribution to the overall monitoring coverage and can be eliminated or transferred to other places to achieve better coverage;

– to develop technically and economically sound plans for upgrading and extension of the existing monitoring networks or groups of fixed monitoring stations;

– to develop plans for the creation of new monitoring networks or groups of fixed monitoring stations in the most efficient manner;

– to optimize the operation of mobile monitoring/DF stations during their missions by a prior calculation of relevant service areas at different points along their route.

As an additional function, the software permits the calculation of coverage areas of radio transmitters working in the "point-to-area" mode (mainly broadcasting and land mobile ones) based on minimum usable field strength threshold values (Recommendation ITU-R BS.638).

The software implements a methodology initially developed in [Kogan and Pavliouk, 2004a and b] and further detailed in [Krutova and Pavlyuk, 2011]. It calculates actual monitoring coverage areas for all monitoring functions (listening, measurements, DF and location) based on field strength determination taking into account terrain features of the region under consideration, using provisions of Recommendations ITU-R P.1546-4 and P.2012-2. The calculation routine is outlined in Figure A5-1.

Due to the fact that location by triangulation requires availability of DF coverage by at least two DF stations in a test point under consideration, in this case it is not possible to use a field strength calculation methodology along propagation paths given by various azimuths from each station as it is usually used for broadcasting and mobile communications coverage calculations. It is necessary to implement more sophisticated (and more time consuming) methodology – to calculate field strength values at each fixed monitoring station created by a test transmitter placed in each test point (upper part and sequence of operations A, Figure A5-1).

By a field strength data matrix calculated for each pixel of the screen, borders of coverage areas for listening, measurements and DF are calculated and can be displayed. Using the data for terrain elevation profile along any selected path, together with related field strength, the distribution data can be calculated and displayed (display 4, Figure A5-1). Example of coverage area calculation for one of monitoring stations in the group of three stations is presented in Figure A5-2.

The field strength data matrix is the basis for calculation of overall location coverage area and sub-zones of different location accuracies with known probability (location coverage templates), as it is shown at lower part and sequence of operations A, Figure A5-2. At each pixel of the display screen, it is determined at which DF in the group field strength exceed a threshold level necessary for reliable DF operation, and then instrumental (system) errors of these DFs are re-calculated into location uncertainty achieved with known probability under triangulation operation. It is clear that for location by triangulation there should be a minimum two DFs at which the field strength exceeds the threshold level. Therefore location is the most sensitive and limiting monitoring operation and location coverage calculations should be taken as a basis for monitoring network planning and optimization, if sufficient coverage within a certain region is required.

Example of location coverage area calculation for the same group of three monitoring/DF stations (as in Figure A5-2) is presented in Figure A5-3a). Red (thick in black and white display) line gives overall DF coverage area of these three monitoring/DF stations). As it follows from the right-hand palette at this Figure, the program permits to display up to 16 colour gradations of location accuracy, covering the range from 10 m to 10 km (for V/UHF option). Some of these gradations can be combined resulting in decreasing number of gradations (Figure A5-3) for more distinctive their visibility in black and white display.

For comparison purposes, the program permits calculation of location coverage templates without taking into account exact terrain features in the region under consideration, with fixed radiuses of circular DF coverage areas (sequence of operations B, Figure A5-1). The same procedure is used for location coverage calculation in HF frequency band. It estimates maximum possible location coverage areas and templates under smooth Earth condition in VHF/UHF frequency band and under perfect HF propagation conditions – uniform propagation in all directions from the HF DF stations within their DF coverage areas.

Example of such location coverage calculations in VHF/UHFN frequency band for the same group of three monitoring/DF stations (as in Figure A5-2) is presented in Figure A5-3b). Comparison of Figures A5-3a) and A5-3b) permits a better evaluation of particular terrain features that influence location coverage templates.

FIGURE A5-1

System for optimal planning and design of AOA spectrum monitoring networks

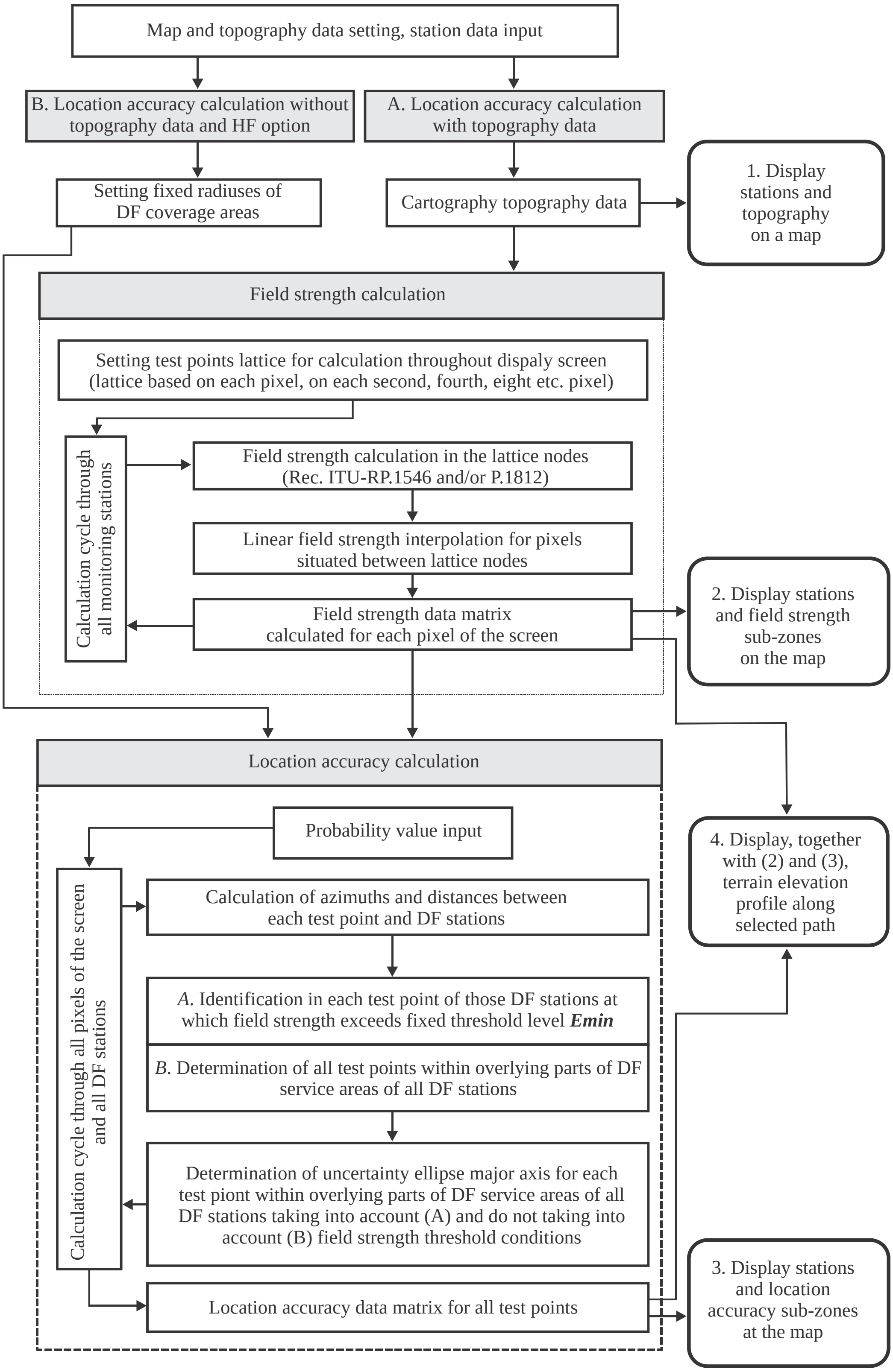

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FIGURE A5-2

Monitoring coverage areas

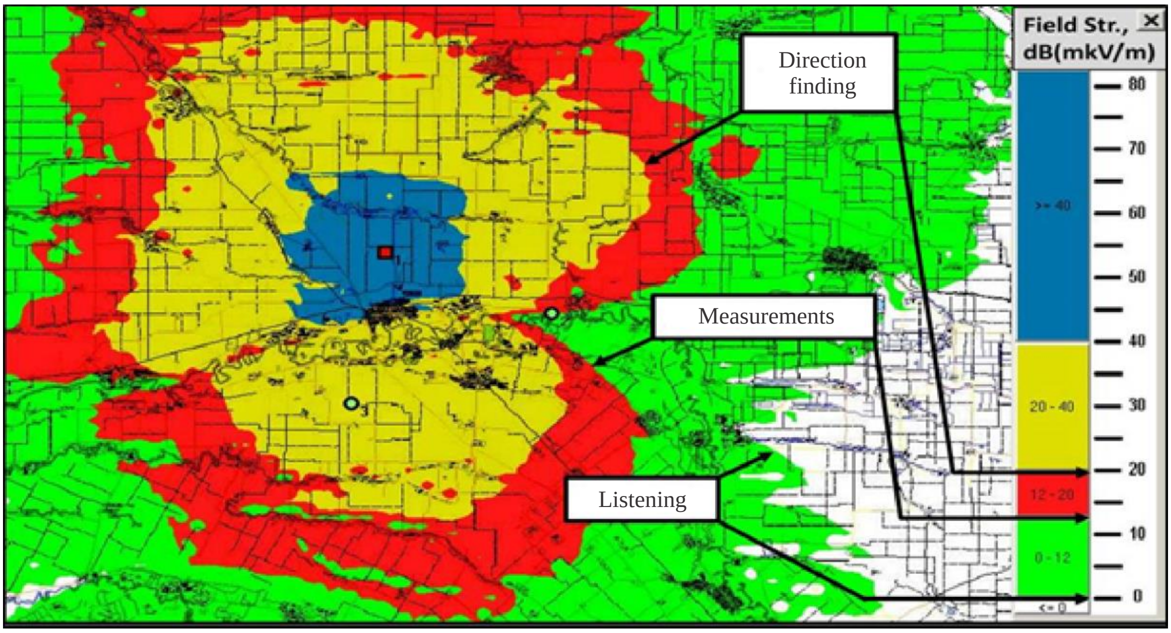

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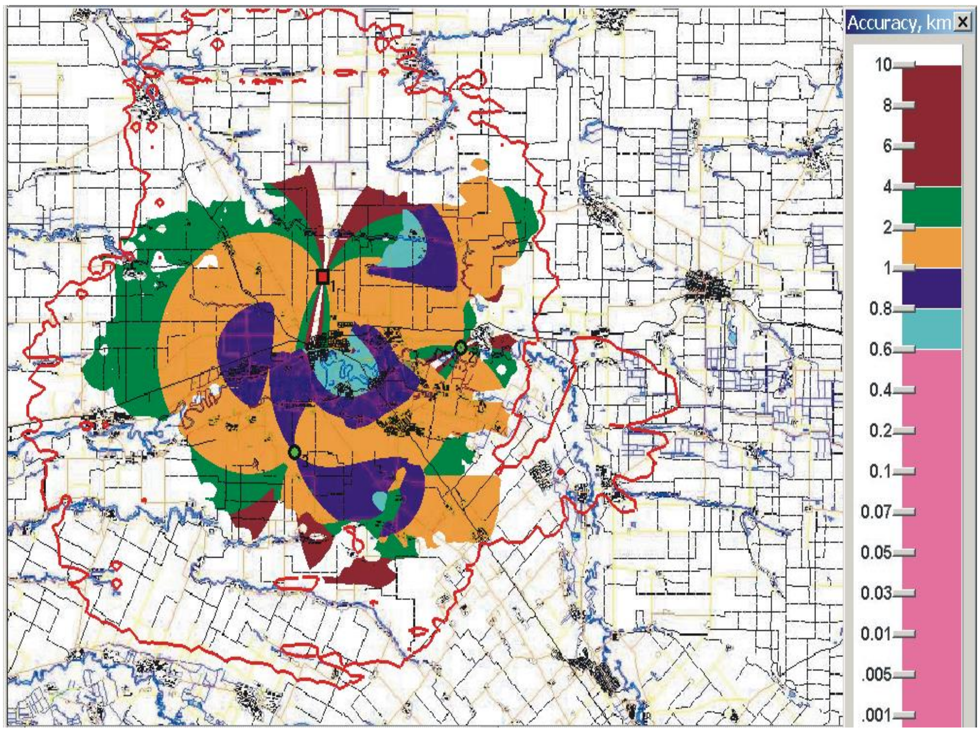
FIGURE A5-3

Location coverage templates



a)

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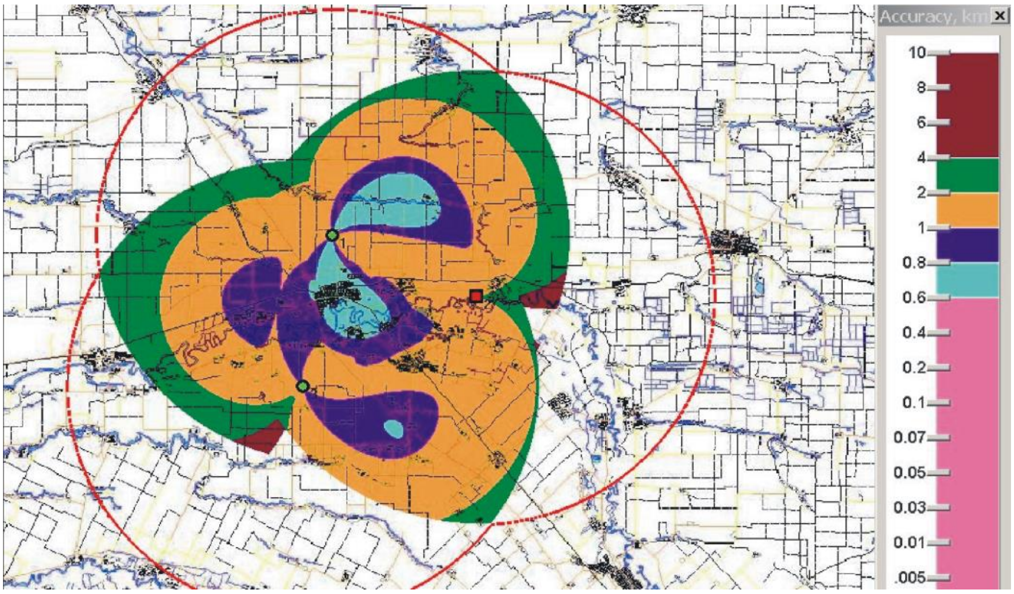

b)

Cat-A05-03b

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ANNEX 6

RAKURS – Software tool for spectrum management in the broadcasting service

1 Introduction

Software tool RAKURS (Calculation and Analysis Applications for Spectrum Management) was designed in the EMC Analysis Centre of the Federal State Unitary Enterprise Radio Research and Development Institute, Russia (CAEMC FSUE NIIR) [1].

Current RAKURS version is the fifth generation of the Russian national automated spectrum management system for examining, designation and registering of frequency assignments to TV and VHF FM broadcasting stations and relevant frequency allotments. The first version was developed in late 70-s by FSUE NIIR specialist team and since that time it is continuously upgraded and expanded following latest ITU developments and IT achievements.

RAKURS is designated to automate spectrum management functions in the interests of the national radio broadcasting service (analogue and digital TV and sound broadcasting in VHF and UHF frequency bands) and, during latest years, broadband wireless access systems. The tool is applied to carry out expert examination of frequency assignments (both analogue and digital) and frequency allotments, developing recommendations for frequency channel and sites selection for new or modified frequency assignments and allotments, and filing of such assignments and allotments. It is also widely used for the purposes of bilateral and multilateral coordination of frequency assignments and allotments in border regions and their recording by the ITU. The RACURS architecture is presented in Scheme A6-1.

With the help of the RAKURS Software tool, frequency plans for the RCC members and a number of neighbouring countries were developed and coordinated, in particular frequency allotment contours were shaped, and channels were also allocated for a numerous sites taking into account their equitable access. During preparation to the RRC-06 five draft frequency plans were elaborated for the RCC region and neighbouring countries. At this Conference, six draft frequency plans for the RCC region and neighbouring countries were calculated with the help of the RAKURS tool. However, it does not mean that the development of plans was entirely entrusted to the tool. During negotiations with the RCC countries and other neighbouring countries a huge scope of works was carried out to check and correct data on mutual incompatibility of assignments and allotments to terrestrial digital broadcasting, which are to be included into the plan.

The Software tool allows easily coordinate activities of many engineers and database administrators; it also automates all aspects of frequency planning operations by a user-friendly interface. This tool solves a wide range of tasks emerging in the process of the frequency-site planning process.

The RAKURS is being dynamically upgraded and operated over thirty five years, and it is a basic NIIR’s tool to plan Russian digital TV and calculate data for international protection of frequency assignments. Due to the fact that the system together with the relevant database in the process of its continuous updating was continuously checked and verified the system and the database exhibit extremely high correctness and reliability. It is also used by Russian Radio Frequency Service to conduct electromagnetic compatibility expertise of applications to install radio broadcasting equipment and for the international coordination. Its implementation expanded functionality of the spectrum management and international protection, responsiveness, adequacy and accuracy of decision-making process.

The RAKURS is continuously used by a number of other telecom administrations such as Belarus, Armenia, Moldova and Uzbekistan.

2 System design philosophy

During Software development the task was to do it a maximum flexible, not requiring changes in the Software when modifying the initial frequency planning data such as, for example, tabulated propagation curves, services distribution across frequency bands, standards and frequency bands allocated to analogue and digital broadcasting, minimum used field strength values, protection ratios, and coordination distances. Therefore, in addition to records on transmitting stations and frequency analogue and digital assignments and frequency allotments, data base contains a large quantity of electronic tables with frequency planning parameters. If necessary, data in these tables can be easily modified.

Automated calculation of radio wave propagation conditions based on digital topographic map is implemented within the Software package. Scope of system application is extended to the digital TV and sound broadcasting and, therefore, the system includes all new criteria and procedures of frequency-site planning in relation to these applications.

The RAKURS Software tool is based on many ITU-R Recommendations and international agreements regulating technical criteria and methods of frequency planning and multilateral coordination (see Table A6-1).

TABLE A6-1

Recommendations ITU-R used for the Software development

Category	ITU-R Recommendations
Terms and definitions	SM.1413-2, BS.638, V.431-7, V.573-5
General approach	SM.337-6, SM.668-1, SM.1049-1, SM.1370-1
Transmission standards and technical requirements for broadcasting	BS.450-3, BS.707-5, BS.774-3, BT.470-7, BT.1700, BT.1701, BT.804, BT.1206
Radio wave propagation	P.1546-4, P.1812-2, P.525-2, P.1147-4, P.368-9, P.2001-1
Minimum field-strengths, protection ratios and territory separations	BS.412-9, BS.599, BS.773, BT.417-5, BT.419-3, BT.565, BT.655-7, SM.851-1

3 RAKURS basic capabilities

– Expert evaluation of frequency assignments features; development of Recommendations on frequency channel selection for new or modified frequency assignments;

– Border (bilateral, multilateral) international coordination of frequency assignments both under GE06 and frequency agreements between separate countries (see Figures A6-1 to A6-3);

– Calculation of service areas for single stations and single-frequency networks in the bands allocated for the analogue and digital sound and TV broadcasting of standards DVB-T, DVB-T2, DVB-H and T-DAB;

– Calculation of harmful interference from LTE networks (Figure A6-3);

– Calculation of frequency assignment service areas in the DW/MW bands;

– Determination of mutual interferences between various stations;

– Estimated cost calculation of components for the designed network in assignable prices;

– Project optimization to decrease the network cost and extend the coverage;

– Automated network generation for optimal coverage of the given region.

4 Reports and data exchange

The following formats are supported:

– MS Excel and MS Word to generate reports on an analytical project information;

– KML to import data concerning coverage areas, stations and geographical objects into the Google Earth;

– SHP to import objects;

– BRIFIC to import international frequency applications;

– Support of station import/export in the ITU-R formats (T01, T02, G02, GT1, etc.).

5 Structure of RAKURS Software package

The Software elements can be grouped into 5 main blocks:

1) Database;

2) Core;

3) Project;

4) Products;

5) Visualization.

5.1 Database

One of the most important parts of the RAKURS Software is a subsystem for the collection, storage, search and processing of large volume of information concerning frequency assignments. Within the RAKURS Software there is a database and utility to maintain data integrity, administer, input and correct information in the database, as well to search and systemize information. The database contains information on accounting and technical characteristics of frequency assignments (in two types: international/internal status of frequency requirements or stations), types and technical features of equipment, synchronous networks of digital broadcasting and so on. The database volume is not software-limited, being limited by the server capabilities only.

RAKURS is capable to operate with two DBMS types: Informix MySQL.

The network computing resources are administered by the database. The entire computation power available is possible to be instantaneously focused on solving a single complex task. Scheme A6-1 provides the main structure of the RAKURS Software.

5.2 The core

RAKURS Software allows frequency- site planning of the broadcasting networks. All initial data for frequency planning, i.e. transmission standards and frequency bands for broadcasting, minimum used field-strength values, protection ratios and spatial separations has been taken from ITU-R Recommendations and approved calculation techniques for compatibility determination between terrestrial broadcasting services are used.

All calculations are based on field-strength calculations of a transmitting station in the given geographical point. Several techniques of such calculations have been implemented in the RAKURS Software as it is indicated in Table A6-1, as well as Bullingtons and Okumura-Hata models.

RAKURS contains a number of modules for the calculation and analysis of the electromagnetic compatibility (EMC). All calculations are based on the sorting of interference of the given station under consideration. Interference is considered from stations in co-channels, overlapping, adjacent, image, heterodyne channels, as well as stations, the second or triple-frequency harmonics of which coincide with the frequency of the station under consideration. In the process of calculations the user always operates with a certain set of interferences; for this reason the Software complex provides a variety of useful functions for operating this device, including versatile sorting, capability of excluding interference from calculations both manually and by means of filters.

In the calculation of the EMC many computing options are available:

- Ability of sorting interferences for the station according to different databases;
- Consideration of sea paths;
- Clearance angle consideration;
- Ability of choosing the type of calculations: direct effect (to-station)/inverse effect (from-station);
- Ability of turning on and off the consideration of image channels;
- Selection of interference combining methods.

The control of the computing core module is carried out by means of a single interface in all calculation modes – calculation parameters windows.

Here it can be chosen a propagation model, altitude and water surface parameters, defying the requirements to digital, sound and analogue TV and radio broadcasting and also can be assigned the clutter data.

5.3 Project

User operational module. Similar to term "document" in well-known software products, such as MS Office.

The project consists of:

- The number of stations determined by the user that in some way logically interconnected with each other. As a rule, these stations are located in some geographical region, i.e. within a local broadcasting network;
- Computing core parameter setting;
- Calculation results.

5.4 Products

The results of user operations are:

- Broadcasting coverage area;
- A number of various reports;
- Calculation results in given points;
- Analysis results of international coordination;
- Channel selection results;
- Frequency plan, etc.

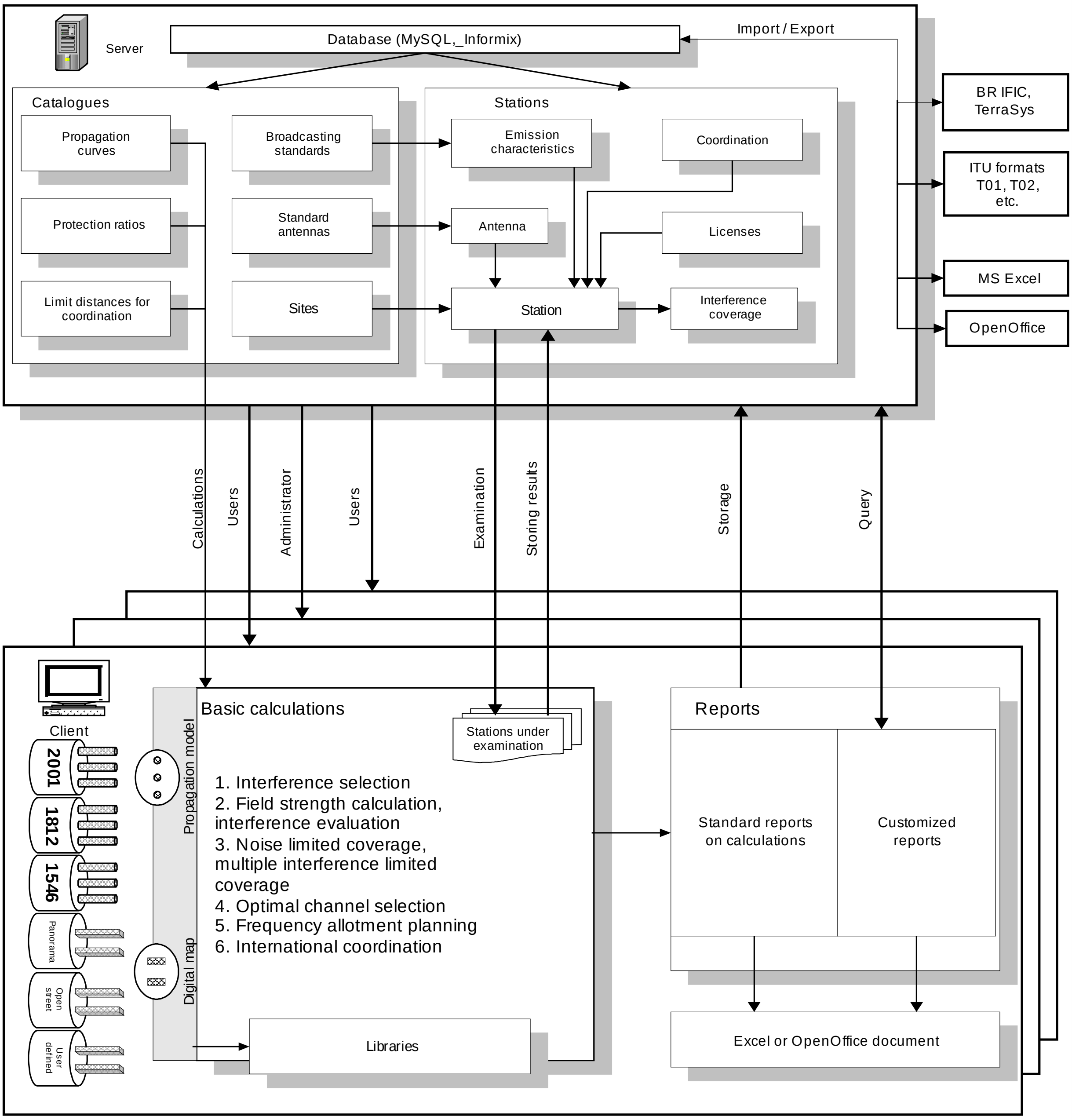
5.5 Visualization

Any textual and numeral information is easier understood when displayed graphically. For this purpose there is a visualization module at the disposal of the user consisting of the displaying module on the two-dimensional map and export of data into the three-dimensional media of Google Earth.

By supplying of GIS data, the Panorama module can be used; also any raster or vector image can be downloaded. Scheme A6-1 is the synthesis of the five described modules.

SCHEME A6-1

The generalized block-scheme of the package RAKURS



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6 Performance

The EMC calculations with a fine accuracy for a large quantity of stations require high computing power. RAKURS was designed in such a way that it can activate all computers and supercomputers available in the local network when necessary.

Due to such capabilities, the EMC Analysis Centre of the NIIR is able to perform calculations hundreds of times faster than if the calculations have been performed at a separate computer. Besides, the goals of optimizing large broadcasting and broadband wireless access networks are becoming more realistic.

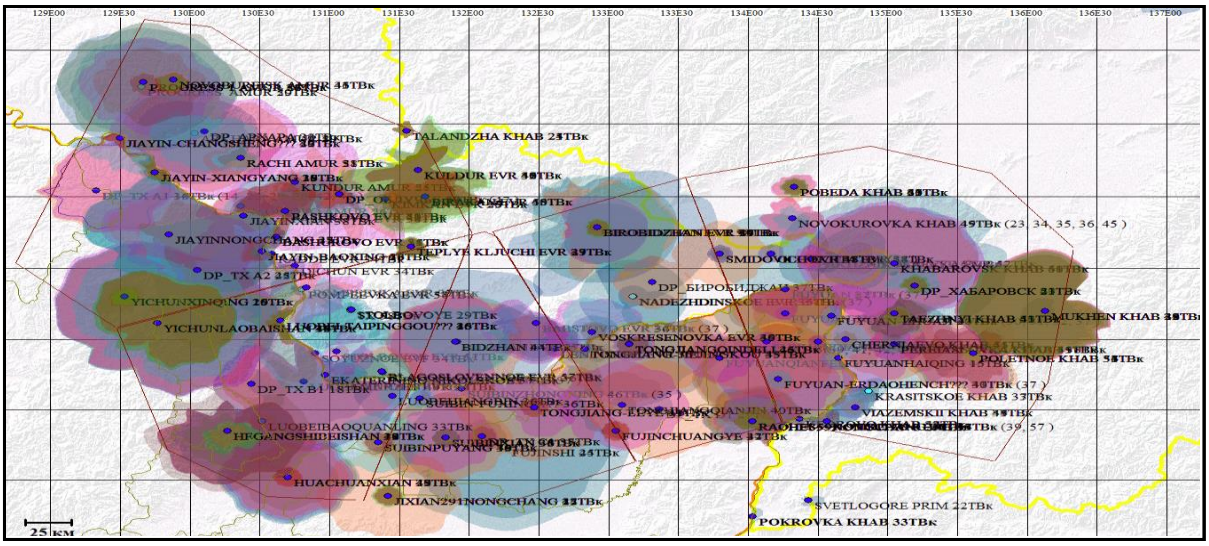
7 Geographical information

RAKURS possesses a full and flexible cartography system. Its basic features are:

- Use of matrices of free altitude data (ASTER GDEM, SRTM, GLOBE), as well as data provided by the user;
- Use of IDWM maps of the coastal areas and earth conductivity;
- Use of cartographical data OpenStreet;
- Creation of user maps from any raster or vector image;
- Use of free data on flora (GlobeCover), as well as data defined by the user;
- Use of data on the area features (Figure A6-1);
- Use of information on the boundaries of towns for the assessment of the population in the coverage area.

FIGURE A6-1

Survey of all analogue stations protected in the process of implementing digital TV with their coverage areas at a small border area between two countries



Cat-A06-01

FIGURE A6-2

Survey of the problem region in the border area

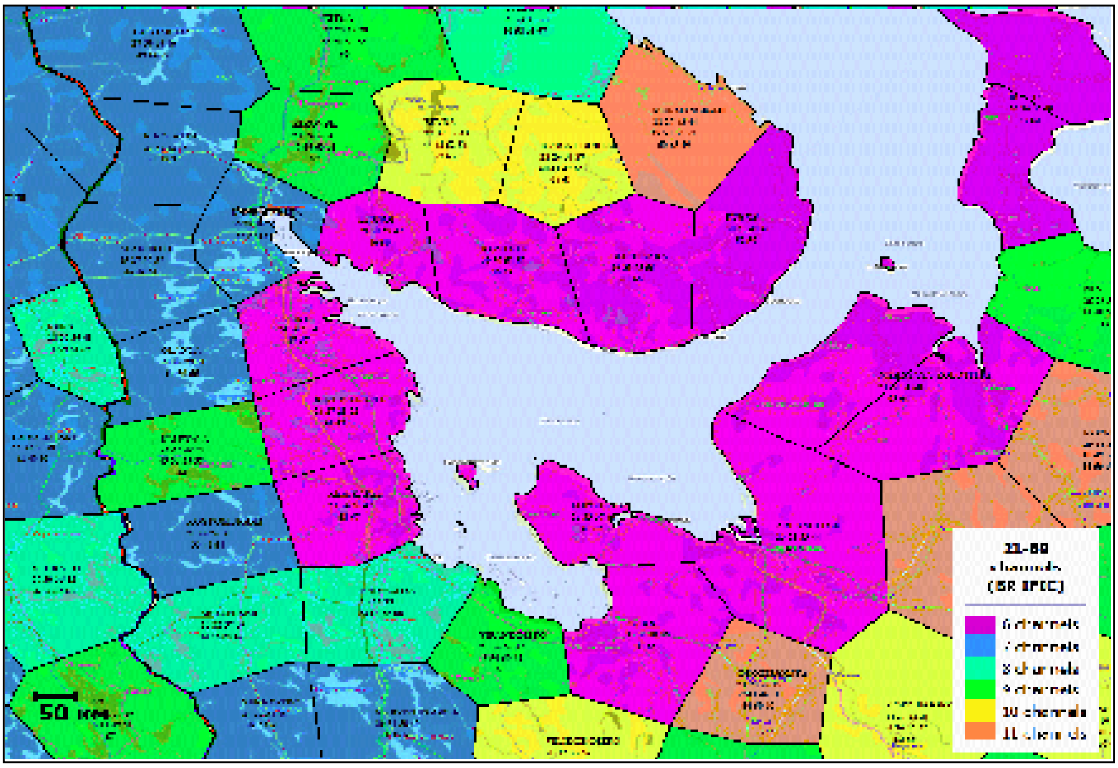


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FIGURE A6-3

Virtual LTE network. Analysis of the interfering effect on the frequency allotments of a neighbouring country. LTE stations compatible with frequency allotments of an adjoining country are coloured in blue

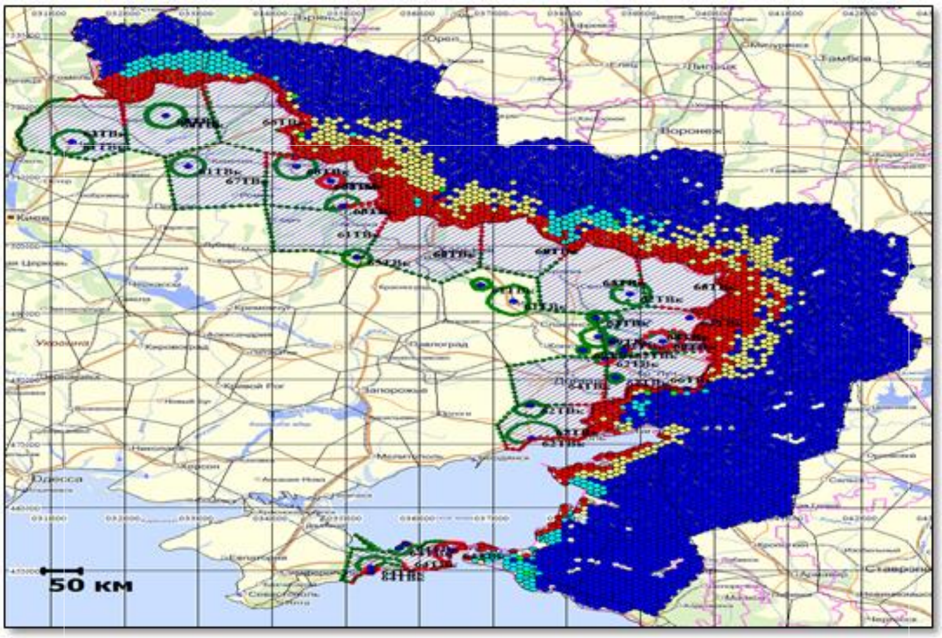

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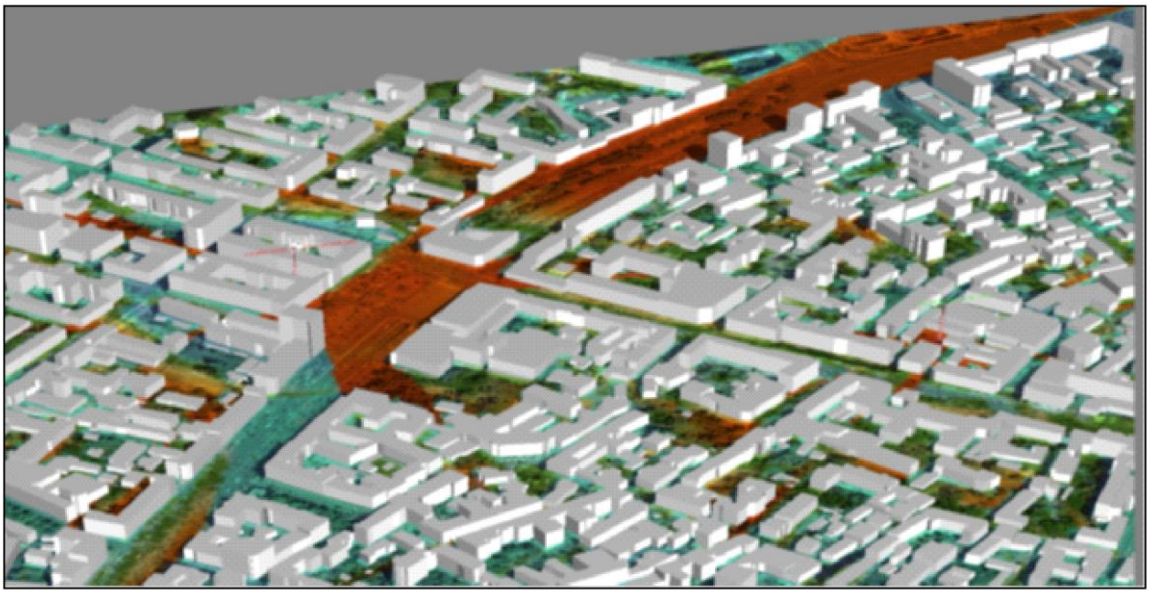
FIGURE A6-4

Calculation of the coverage area of a DVB-H station in the condition of urban development



Cat-A06-04

REFERENCE

[1] Dotolev V.G., Krutova O.E., Smolitch L.I. Software package for spectrum management in the broadcasting service. Electrosviaz, 2003, No 7 (in Russian).

ANNEX 7

ICS suite, automated spectrum management system

1 Introduction

The ICS suite, automated spectrum management system developed by ATDI S.A, France, is already installed and operational in a significant number of Regulation Authorities.

The main objectives of this solution is to help the regulators to manage the administrative procedures, to optimize the spectrum (for all radio services), to validate the new services and avoid interfering with existing systems and to secure administrative and technical data storage

ATDI's regulatory tools are threefold: a set of desktop tools operating under client-server architecture; a range of tools for embedding into other systems; and a range of web-based utilities that provide specific spectrum management services.

The deployment of the ICS suite is not only the tools delivery. Numerous services are also provided like the data migration, the software customization and integration, the training, the technical support and the software updates.

2 Software

The Automated Spectrum Management System developed by ATDI consists of three main applications:

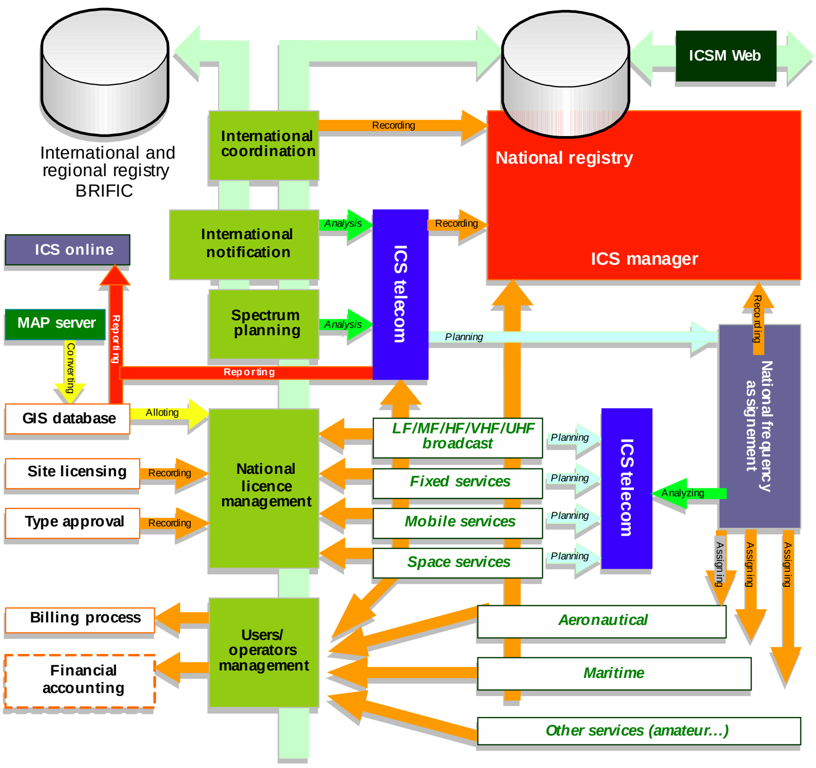
ICS manager, the Spectrum Management Software;

ICS telecom, the Radio Planning and Technical Spectrum Management software

ICS online, publishing tool allowing sharing the network and radio planning map reports online.

FIGURE A7-1

ICS Suite: automated spectrum management system of ATDI



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2.1 ICS manager

ICS manager is a flexible platform developed to meet current and future needs of regulators in all areas related to spectrum management and control.

ICS manager is the backbone of a regulator's spectrum management division.

Its data engine manages all data related to spectrum management, while continuously monitoring the coherence of the data.

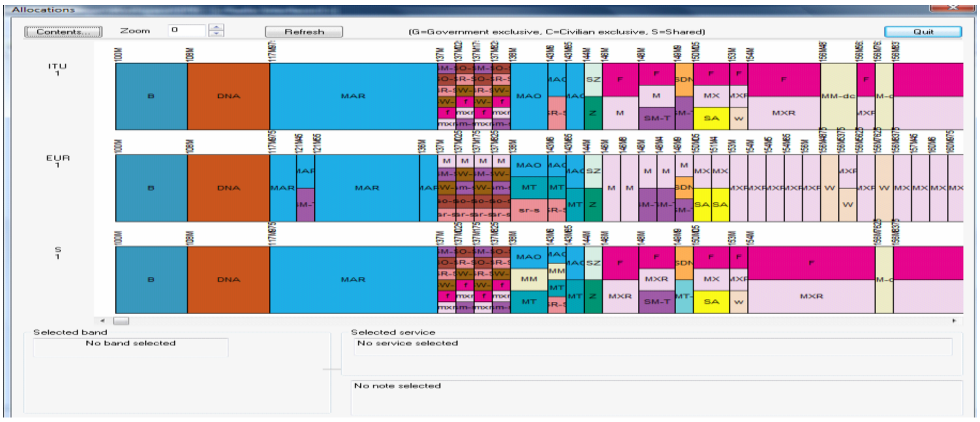
Its process control engine allows the implementation of automated processes. The main features of ICS manager are:

– Management of administrative procedures (Licence management, operational management) in accordance with the national, regional and international rules and processes in force.
– Calculation of fees following the technical and administrative parameters of the frequency assignments and the licences.
– Generation of documents (report, invoices, receipts), billing, and payment follow-up.
– International notification, international coordination.
– Spectrum planning, frequency assignments.
– Zone allotments or band attributions.
– Management of data: antennas, equipment, site, frequency plans, allocation charts (foot notes, services ...) etc.
– Interface with the Spectrum Monitoring Systems.
– Allocations, Applications, Radio Interfaces & Rights of Use Management.
– Operational Management for All Services (technical, administrative, frequency, location, antenna and equipment parameters).
– ITU Notification Management.

ATDI's Automated Spectrum Management System is based on the guidelines of Recommendation ITU-R SM.1370 and is covering the administrative and technical activities mentioned above. The full list of features is available on the site www.atdi.com.

FIGURE A7-2

Table of Allocations in ICS manager



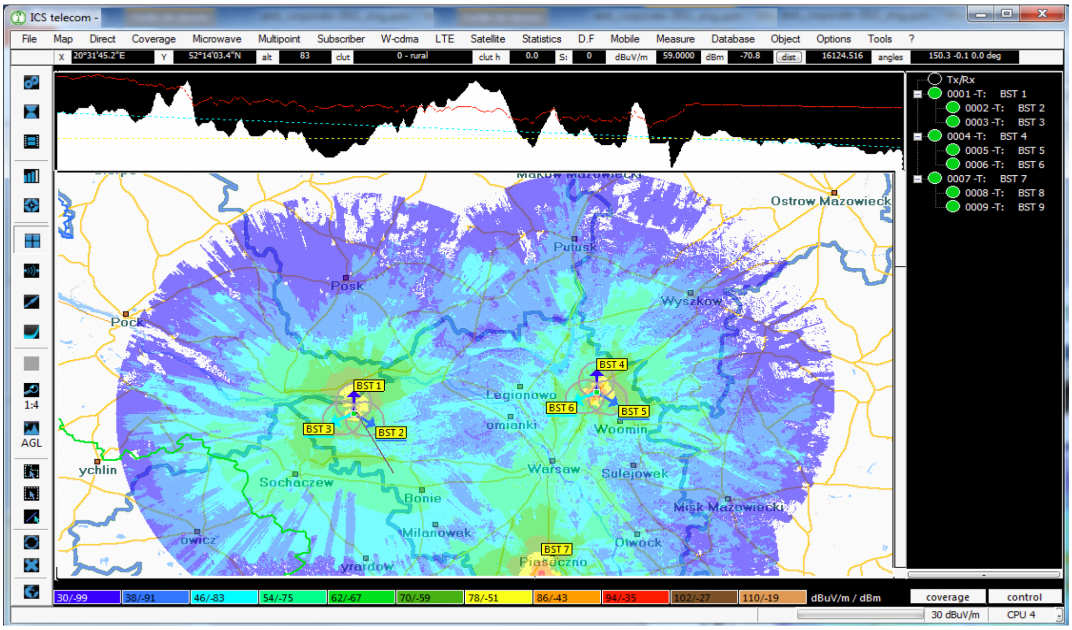
Cat-A07-02

2.2 ICS telecom

ICS telecom allows engineers to plan and model radio communication networks and to manage network development. Technology-neutral, ICS telecom also informs decisions made on spectrum management.

FIGURE A7-3

Example of Coverage calculation in ICS telecom



Cat-A07-03

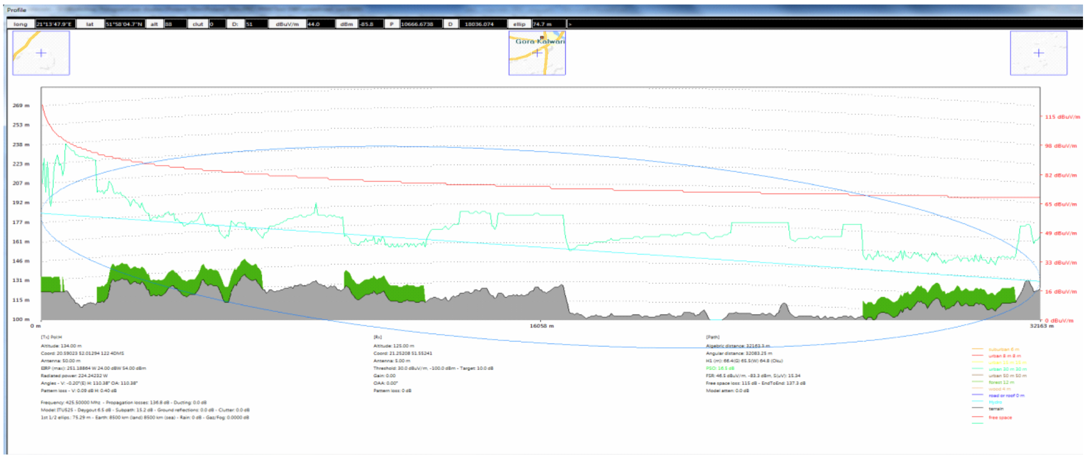
ICS telecom is capable of modelling any size of radio system from intensive local area to extensive countrywide.

ICS telecom is used by network ownership and regulation bodies. The list of ICS telecom features is available to the link www.atdi.com but concerning the Spectrum management, the calculation is mainly used to evaluate a new technology (for example the LTE vs DTT compatibility); the spectrum optimizing and monitoring; the Regulation and environment constraints and the International, bi-lateral and national coordination. The Human hazard calculation is also an ICS telecom feature useful for National Regulators.

ICS telecom has applications throughout all modern radio networks, both fixed and mobile and across the frequency range 10 kHz to 450 GHz, including Radio analogue and digital, TV analogue and digital, PMR analogue and digital, Mobile 2G/3G/4G, WIFI, WIMAX, Radar, Satellite, Microwave-links, Broadband wireless access, AMR, Smart grids, Point to point, Point to multi-points, HF, Aeronautical, UAVs.

FIGURE A7-4

Example of Profile view in ICS telecom



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This also includes coexistence studies between different technologies:

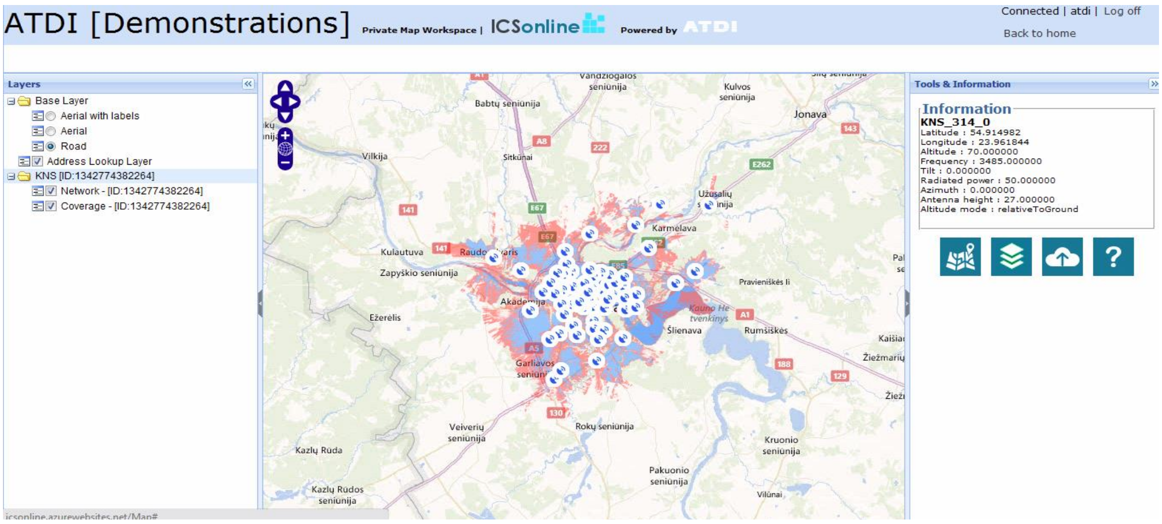
AM, FM, TVA, PMR, TETRA, DAB, DMB, DTV, DVB, VOR, ILS, COM, GSM, GSM-R ETCS and non ETCS, DCS, LTE, RLAN, DRM, MFAM, WIMAX, CDMA, WCDMA, CDMA 2000, WIBRO, ISDB, ATSC, CMMB, DME, DMR, WIFI, MLAT, SCDMA. HF, Satellites (GSO, NGSO, constellations), Microwave links, Mesh, Smart-Grid, AMR, P2P, P2MP, Wind turbine, Radar (Ground, Air), Direction finder, User defined technologies. Fixed modulation, Adaptive modulation, SISO, MIMO, AAS, TDD, FDD, COFDM, SFN, MF.

2.3 ICS online

ICS online allows to make the relevant data accessible to the people (internal and external customers) who need this information.

FIGURE A7-5

ICS online main window



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ICS online is a cloud service allowing using an unique account and associated URL to access the data to be shared. Those data can be available in a public mode, public restricted mode (only users owning a key are able to view the data) or in a private mode (login/password protected).

3 Examples of process control in ICS manager: completion and store of a licence application request and licence issuing

3.1 Completion and store a licence

All these actions are made of different steps that are specific to each administration and that can involve different departments (financial department, technical department, type approval department, monitoring department).

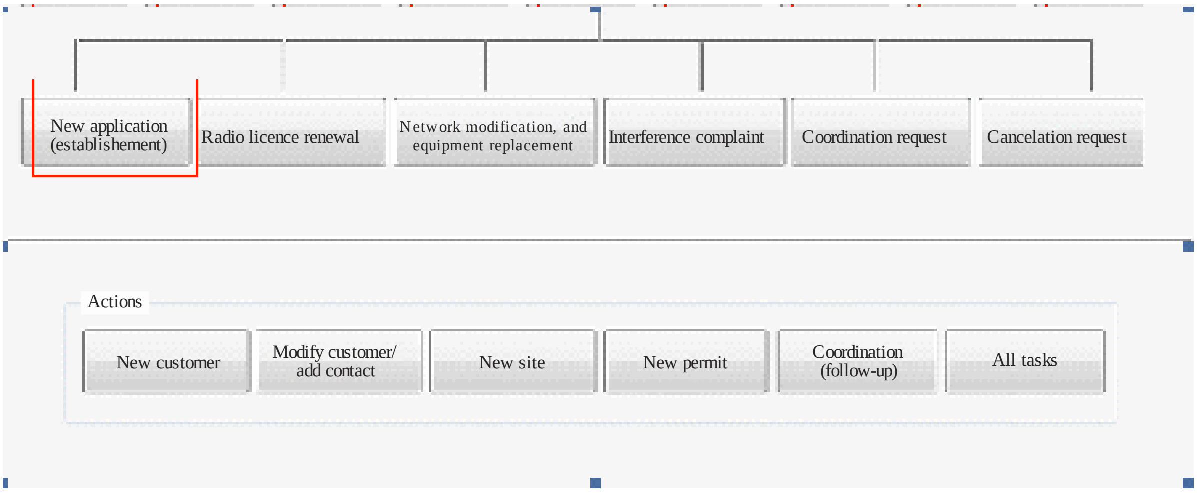
In consequence, the different steps that are given below must be considered only as example.

In ICS manager, the workflow process can been created based on the different application request forms.

This process can be called from a start screen including all the necessary shortcuts to handle main processes.

FIGURE A7-6

Customized start screen for spectrum management process in ICS manager



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Any types of forms can be implemented in ICS manager; this is why the notion of application form described below is given as an example and can be modified if necessary.

An application form for one licence could consist on three different forms: the applicant identification form, the site identification form, and the main form.

Applicant identification form:

This application is required in 3 different cases: application from a new costumer/operator, in case of modification of applicant information and in case of addition of a new contact belonging to the same costumer/operator.

Site identification form:

This application form is usually requested whenever the site mentioned in the main application form is not found within the database. Even though this form is not mandatory for technical analysis; it is required for the completion of the database.

Main form:

This form might differ based on the application type, e.g. Planned VHF Sound broadcasting Stations, Planned VHF/UHF TV Broadcasting Stations, LF/MF Sound Broadcasting Stations, FX Point-to-point and Point-to-multipoint systems.

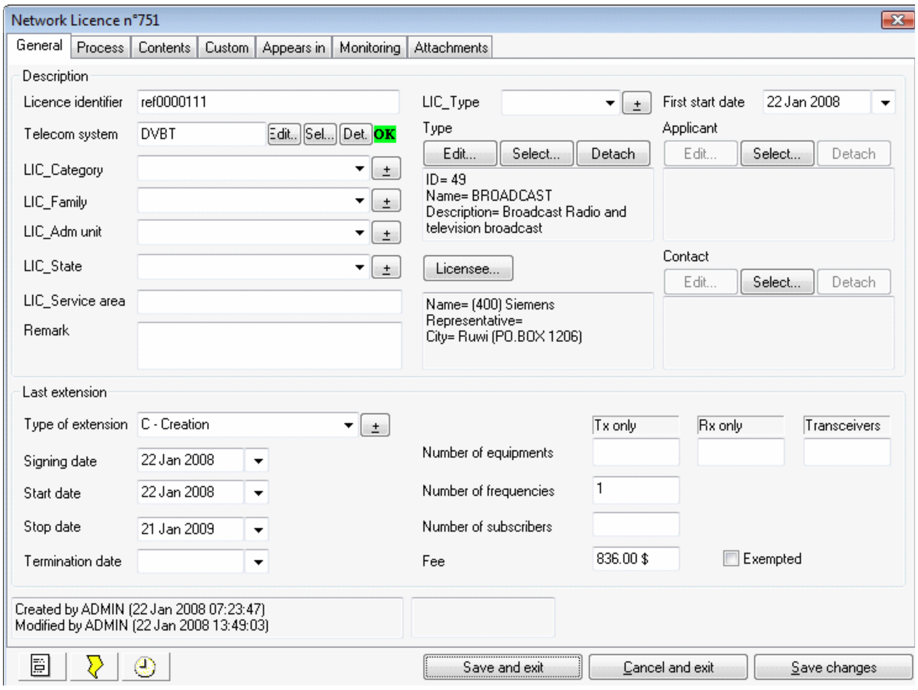
This form is mandatory in order to be able to start the processing of any kind of application whether it is a new one “Add”, Modify, Suppress or Renewal.

It includes the minimum required information, mainly technical information permitting the continuity of the technical analysis while giving the user the chance to complete his licence application requirements for the previous forms in parallel thus avoiding delays and not affecting the technical analysis.

Once the application form has been completed, automatically a licence record is created and stored in the database with the associated input parameters.

FIGURE A7-7

View of the licence record in ICS manager



Cat-A07-07

All the licence information can be retrieve just by editing the licence record:

– The type, family, category of the frequency request;
– The applicant details;
– The station or network parameters;
– The frequency parameters;
– The antenna parameters;
– The location parameters.

3.2 Issuing a licence

Once the application(s) have been completed, ICS manager directly creates necessary parameters to establish a licence, the network licence screen is displayed, and the new licences establishment can start.

ICS manager organize the sequence of the steps and the distribution by department for each step.

For steps with conditions, the users will be given the available options to proceed with the workflow, data completeness and error handling is automatically done by the system to give the system the best performance and data correction ability.

Some of these steps are described hereafter.

Step 1: Application fee request managed by the financial department:

The user can print out the form to be sent to the applicant just by clicking on the Process Action button:

ICS manager automatically detects which report should be printed:

The user can check if the fee has been totally paid or partially paid by checking the journal invoice of the client.

Step 2: Attachment of station(s), network(s) and/or of equipment(s):

The user can attached all the stations and equipment linked to the station.

After attaching all necessary stations and equipment to the licence ICS manager checks data completeness.

If some data are missing a detailed message of the missing data is given so that the user has the possibility to fill in any missed information.

By double clicking on the error the relative page is automatically opened to correct the missing information.

Step 3: Type approval investigation (done by the type approval department):

The department checks if a type approval is needed or not, as well as if an import permit is needed or not.

Step 4: National/international frequencies checking for availability of spectrum:

After data completion, the national and international coordination steps are ready to be done and all necessary steps will be followed until the coordination actions are completed: interference analyses, coordination analyses (areas, countries, etc.).

The technical analyses will be done within ICS telecom.

Once the equipment/stations have been technically validated, the process of issuing the licence could continue.

The final steps will be mainly fees calculation steps (spectrum fee, registration and utilization fees).

Invoicing (fees calculations) is not detailed in this document.

The sequences of steps will appear until the final step where the system will issue the appropriate licences and put all the licensed equipment as valid/issued licences.

The status of the licence is automatically updated.

All licences are considered as valid licences until date expiration or a renewal, modification, cancellation tasks take place and smart a new workflow for renewal, modification or cancellation…

4 Services

The deployment of an Automated Spectrum Management System at a regulator consists in much more than delivering tools. In particular, the following activities must be accounted for:

- Conversion of existing database into the new database format.

  This seemingly easy task can be time-consuming, as customers often have several databases (for several services for example), and the import of the data may reveal inconsistencies and errors (for example several names for the same site with sometimes differing coordinates, etc.).
- Customization of the platform to the customer's process and needs (including the web services).

  This includes the preparation of form templates, entering all fees calculation formulas, entering the specific process controls, preparation of reports, defining user profiles with the appropriate rights, etc.
- Integration of the platform with existing customers' applications.
- Installation of the system, training and on the job training.
- On-site assistance during System switchover to the new system.
- Training.

ANNEX 8

Rohde & Schwarz – Integrated automated spectrum management and monitoring systems solution

1 Exigency

Recommendation ITU-R SM.1537 recommends that administrations which perform both spectrum management and spectrum monitoring should consider using an integrated, automated system with a common database which provides the following functionality:

– Remote access to system resources
– Automatic violation detection
– Frequency assignment and licensing
– Tools to support spectrum engineering
– Automated measurement of signal parameters
– Automated occupancy measurements coupled with optional direction finding measurements
– Scheduling of measurements for immediate or future execution
– Modern GUI

This functionality can only be provided by the Spectrum Management and Monitoring System if a well-defined bidirectional data exchange between the management part and the monitoring part of the system is available.

To achieve the best solution for administrations the implementation of a fully-defined open interface between the spectrum management systems and the spectrum monitoring systems is recommended. As a result, each administration has the opportunity to select from both areas – Spectrum Monitoring and Spectrum Management – and different suppliers the best solution fitting to her requirements and is not forced to any compromise. Also if there is a need for change due to technology innovation or changed workflow, no exchange of the complete overall system will be necessary.

2 Solution

To enable optimum utilization of the frequency spectrum and to provide the necessary bidirectional data exchange between spectrum management and spectrum monitoring Rohde & Schwarz has developed with the experience of more than 25 years on realization of Spectrum Monitoring Systems an open interface that allows integration of any spectrum management system.

Successful reference projects have been underway with the following spectrum management companies.

• **LS telcom** (including Spectrocan and CTS),

  for instance the National Spectrum Management and Monitoring System (NSMMS) of Czech Telecommunication Office (CTO)

• **ATDI**,

  for example the Nation Spectrum Monitoring System for the Superintendence of Telecommunications of Ecuador.

• **ITU SMS4DC application**

  is also fully integrated (please refer to Annex 6 of Chairman´s Report from Study Group 1 Working Party 1C dated 18.10.2010) and implementation such as the "National Spectrum Management" of Monaco are in operation.

• **Customer specific solutions**

  Due to the open architecture of R&S®ARGUS, integration of additional customer specific database applications is straightforward, regardless of the operation system or database. The smooth integration and data exchange possible with an application develop from the

Communications and Spectrum Management Research Centre of the Bilkent University is just one good example.

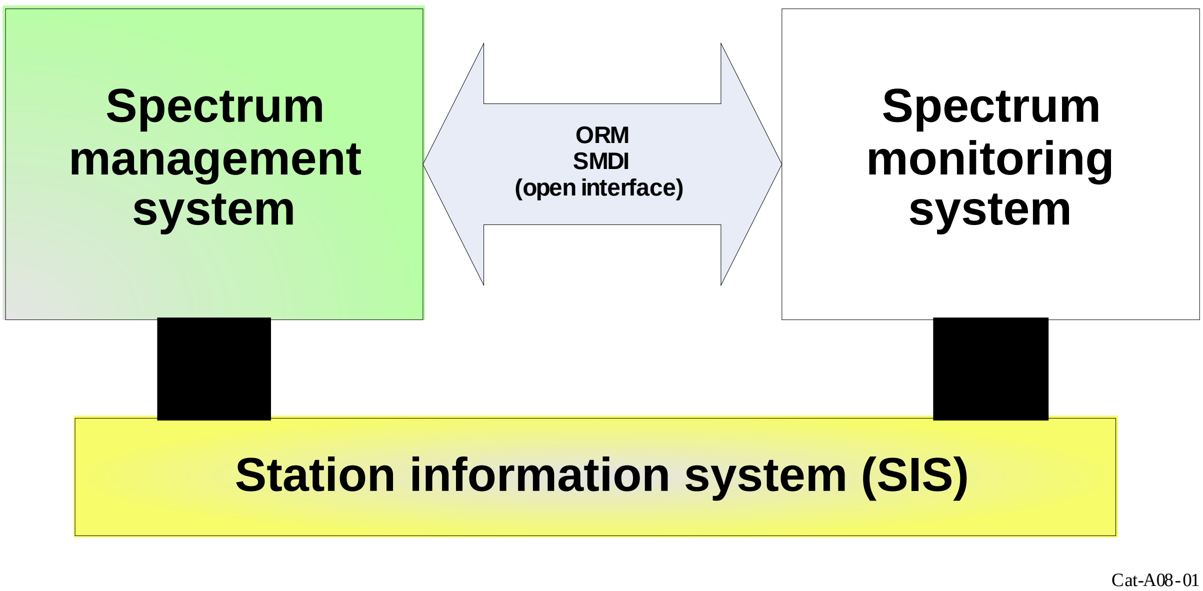
Reference system: The National Spectrum Monitoring System "SIMON" for the National Communications Authority of Hungary.

The open interface for integration of Spectrum Management Systems offers also all functionality to fully integrate the ARGUS Monitoring System in Chinese Spectrum Management Systems based on the Chinese standard protocol "RMTP".

3 System Integration

FIGURE A8-1

Overview of an integrated system



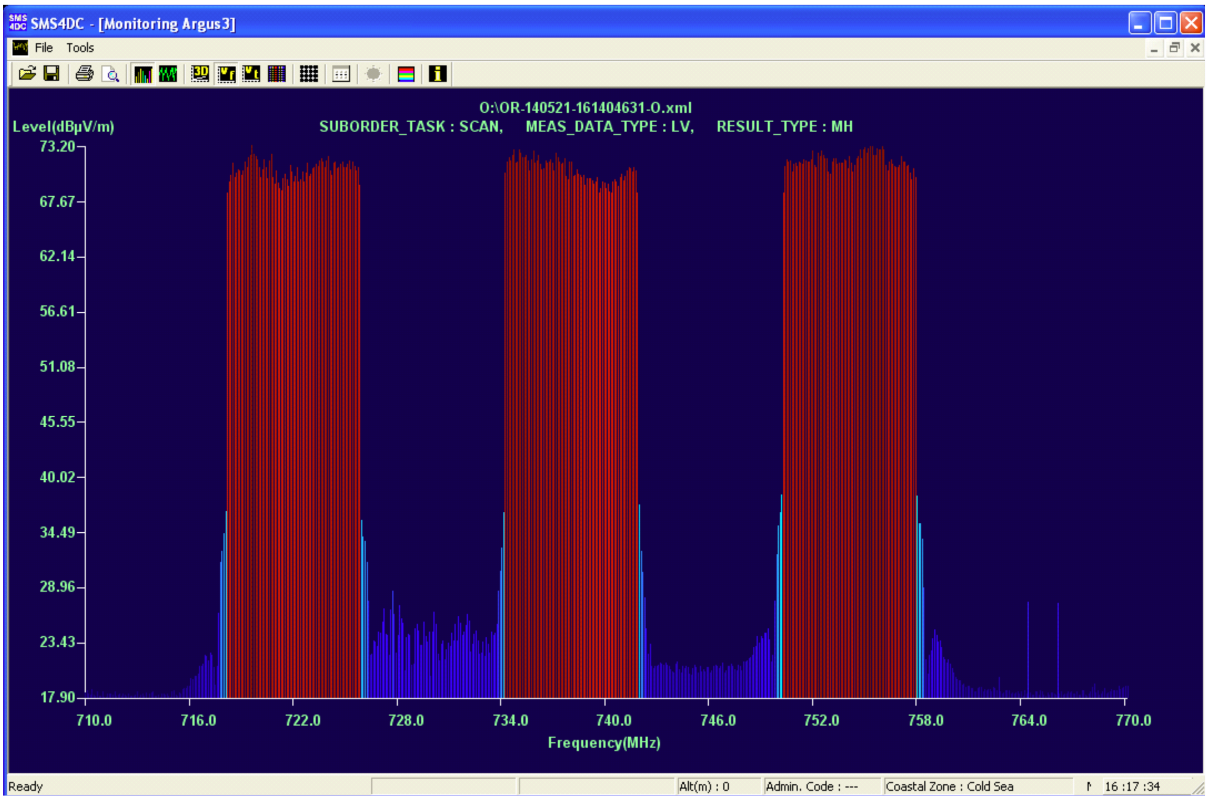
The open interface enables the bidirectional data exchange between the Spectrum Management System and the Spectrum Monitoring system.

ORM (Order Report Module)
Defines all data structure and commands to control the monitoring system by the spectrum management system. This can be used to command measurement tasks which will be processed by the monitoring system automatically or if requested the task can be processed by an operator of the monitoring system. The measurement results are transferred to the management system automatically.

SMDI (Spectrum Management Data Interface)
Provides all data structure and commands to enable the spectrum monitoring system to access data stored in the data base of the spectrum management system.

FIGURE A8-2

Monitoring measurement results gathered with R&S®ARGUS and displayed at the spectrum management system SMS4DC



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Spectrum Management System

Due to the open fully-defined interface any Spectrum Management System can be connected to the Spectrum Monitoring System to form an integrated overall system. The automation coming with each system is still available.

The Spectrum Management System serves the request of the Spectrum Monitoring System on information stored in the spectrum management database about par example on transmitter technical parameter and licence conditions.

The Spectrum Monitoring System serves all the measurement tasks necessary for the Spectrum Management System to grant an optimum utilization of the limited resource of the frequency spectrum.

As an example of gathered measurement result please refer to Figure A8-2.

This measurement task can be done automatically or by an operator of the monitoring system depending on the request coming from the Spectrum Management System and on the measurement task itself.

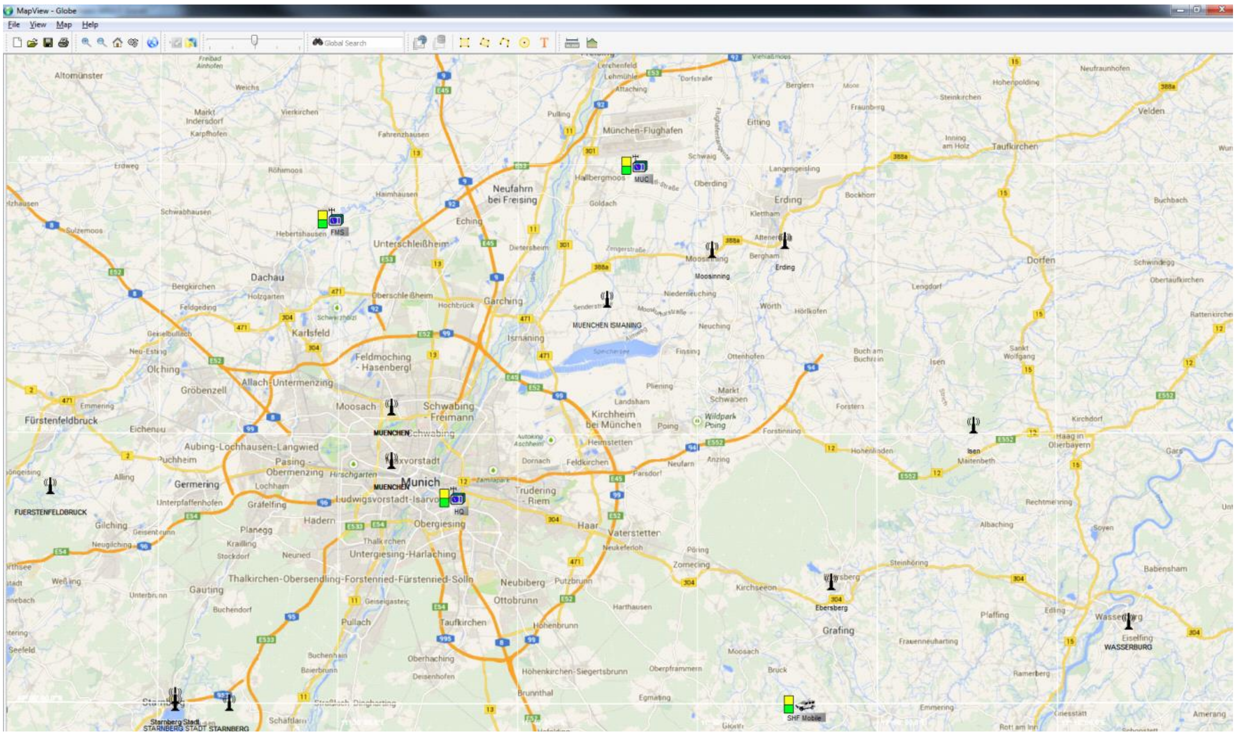
Station Information System (SIS)

A very import component for an integrated System is the Station Information System which gives information about the current status of the monitoring stations and the equipment installed and the current availability and utilization. Such information is critical for management purposes and can be monitored with the R&S®ARGUS station information system (SIS).

The SIS provides always up-to-date information about all monitoring stations in the network. On a map all measurement station of the entire monitoring network are displayed with all relevant information about the current state of the station (e.g. type, users logged in, measurements running, status of the devices, etc.). Additionally all known transmitter will be shown (see Figure A8-3).

FIGURE A8-3

Monitoring station overview with current status and known transmitter



Cat-A08-03

Spectrum Monitoring System

The part of the Monitoring System can be excellent covered by the R&S®ARGUS, the Eyes of Spectrum Management.

R&S®ARGUS Spectrum Monitoring Systems offers all functionality to fulfil the needs of the spectrum management and recommendations of the ITU-R Spectrum Monitoring Handbook (Edition 2011) and the relevant ITU-R Recommendation. Especially the requirements stated in Recommendation ITU-R SM.1537-1 (08/2013) are completely covered.

FIGURE A8-4

Typical mobile monitoring station

Cat-A08-04

FIGURE A8-5

Monitoring station for harsh conditions

Cat-A08-05

As an excerpt of all the functions and functionalities which are offered by Rohde & Schwarz Monitoring Systems and which are based on 25 year of experience working in the field of spectrum management and monitoring and due to a continuous process of development and improvement, a small amount will be summarized below.

- **Automatic Measurement Mode (AMM)**

  The automatic measurement mode serves two main purposes:

  Perform automatic measurement tasks in line with a specific time schedule

  - The automatic measurement mode is used to automatically perform measurements according to a schedule. The user defines the measurement tasks and starts them. The measurements will be performed automatically, exactly as defined by the user. The measurement results can be evaluated while the task is being performed or after it has been completed. Cyclic measurements can be performed at certain times of the day and over a period of days, months or even years.
  - Automatically detect if a live result is outside a user defined value range (i.e. an alarm occurred) and if user has defined, trigger additional measurement for a detailed examination of the frequency that triggered the alarm.

  For each frequency and parameter, an upper and/or lower limit can be defined. If one of these limits has been exceeded during measurement, several options are available. It is possible, for example, to perform various modulation measurements; the audio data can be recorded or additional measurement stations with DF or TDOA equipment can be integrated in order to determine the emitter location. Rotators and masts can also be controlled so that the measurements are also performed at certain azimuths, elevations, polarizations and heights. If the measurements are defined by a regional or national headquarters but run on a remote monitoring station, no permanent connection is required during the measurement, which drastically minimizes network costs.

- **Interactive Measurement Mode (IMM)**

  The interactive measurement mode is used for obtaining an overview of a spectrum, for analysing and identifying electromagnetic emissions, for obtaining results when an antenna is moved, for analysing intermodulation, for performing coverage measurements and for automatic detection of unknown signals. The following IMM modes provide direct access to various activities:

  - Spectrum overview
  - Signal analysis
  - Antenna analysis
  - Intermodulation analysis
  - Coverage measurement
  - Violation detection

  The measurement results can be saved for further evaluation or printed out. A report can be printed out directly from the IMM.

- **Occupancy Measurement**

  The ITU recommends which measurements to make, how to make them and how to evaluate the measurement results.

  The following ITU-compliant analyses are implemented:

  - Frequency band occupancy
  - Frequency channel occupancy
  - Frequency occupancy by user
  - Measurement value statistics
  - Transmission statistics
  - Sub-audio tone occupancy statistics
  - Violation detection

- **Location Measurement Mode (LMM)**

  The location measurement mode provides different techniques to precisely locate a transmitter. The traditional angle of arrival (AoA) principle combines lines of bearings from direction finders. The time difference of arrival (TDOA) method correlates I/Q data from several suitable devices. The hybrid approach of combining AoA and TDOA delivers a best-of-both-worlds solution, benefiting from the advantages of the two location techniques. Additionally, the LMM provides the functionality of the parallel mode of previous R&S®ARGUS generations to yield a powerful multi-station operating mode.

- **Guided Measurement Mode (GMM)**

  Guided measurements include the following monitoring capabilities:

  - Analogue signals (GMM)
  - Digital signals (DM)
  - Pulsed signals (PMM)
  - Coverage measurements (CMM)

The main objective of the R&S®ARGUS approach is to provide optimum support for the user and enable straightforward, efficient and goal-oriented working. Selection options that are temporarily illogical or unavailable are deactivated. Informative error messages are also implemented to provide information on solving and avoiding problems. Accidental deletion or loss of data is practically impossible.

However, R&S®ARGUS goes one step further since it is the only product of its kind to offer guided measurement modes, providing the ultimate in user support. The user only needs to select the frequency or frequencies of interest along with the measurement parameters, e.g. level, offset, bandwidth and band occupancy. Using an internal knowledge database, R&S®ARGUS automatically proposes suitable instruments and device settings, e.g. IF bandwidth, detector and measurement time. This enables even less experienced users to immediately perform ITU-compliant measurements quickly and reliably.

The settings from the knowledge database are based on the corresponding ITU recommendations and guidelines. Authorized users can edit the database and create custom extensions, for example. The values that are set automatically are suggestions. The user can, of course, modify the settings. Any values that do not conform to the recommendations are highlighted in red, and a suitable warning is generated at the start of the measurements. If the user decides to override the warning and proceed with the settings, an appropriate entry will be included in the header of the result file.

ANNEX 9

Iris – Automated Spectrum Management System

1 Introduction

Iris is a high-tech, highly reliable Spectrum Management system that is comprised of Spectrum Engineering tools, Administration capabilities, Monitoring Support, and a Financial/Billing module. Together they form an integrated system that supports nationwide frequency management administration, including spectrum licensing. The users of Iris access a central database via LAN/WAN data communication network, thereby providing the national spectrum licensing authority with all of the tools needed to support its Spectrum Management activity.

Elbit Systems BMD and Land EW – Elisra Ltd. (formerly Tadiran Electronic Systems-TES) is a system house with 20 years of experience in developing customized Spectrum Management and Spectrum Monitoring solutions, that meet the specific requirements of communication authorities throughout the world.

Iris is the Spectrum Management software package developed and refined by TES Spectrum Control Systems. Iris is based on real world experience in providing solutions in the fields of Spectrum Management and Spectrum Monitoring. Iris allows administrations, operators and service providers to manage the engineering, economic, and administrative aspects of the electromagnetic spectrum. It supports planning and optimal assignment of frequencies to users, handles all stages of the licensing process and supports fee collection for spectrum usage.

Iris is fully compliant with ITU-R Recommendations. The data structures and fields defined in the Iris system for equipment types, station types and other technical parameters, are based upon ITU-R Recommendations.

TES provides a complete solution for integrated Spectrum Management and Spectrum Monitoring systems. The Elbit system provides state-of-the-art turnkey systems backed-up by comprehensive logistic support to ensure customer's satisfaction. The delivered systems provide tailor-made solutions with open architecture meeting the latest standards, and guaranteeing an efficient and seamless interface, thereby providing an additional value to the regulator.

When combined with the Elbit Spectrum Monitoring System, the Iris Spectrum Management system provides a seam-less interface to the Monitoring System. The headquarters of both systems can be configured to share a common database, thereby supporting immediate transfer of data between the two applications. The management system provides spectrum licensing and station information to monitoring systems thereby allowing the comparison of the monitored signal measurements to the licensed data to help identify violations and discrepancies.

The Management system can generate Monitoring missions that assist in the validation of licence requests and resolution of complaints. When monitoring results are available, the Spectrum Management system supports the display of the results so that the information is readily available to the Spectrum Licensing staff.

2 Primary Iris Functions

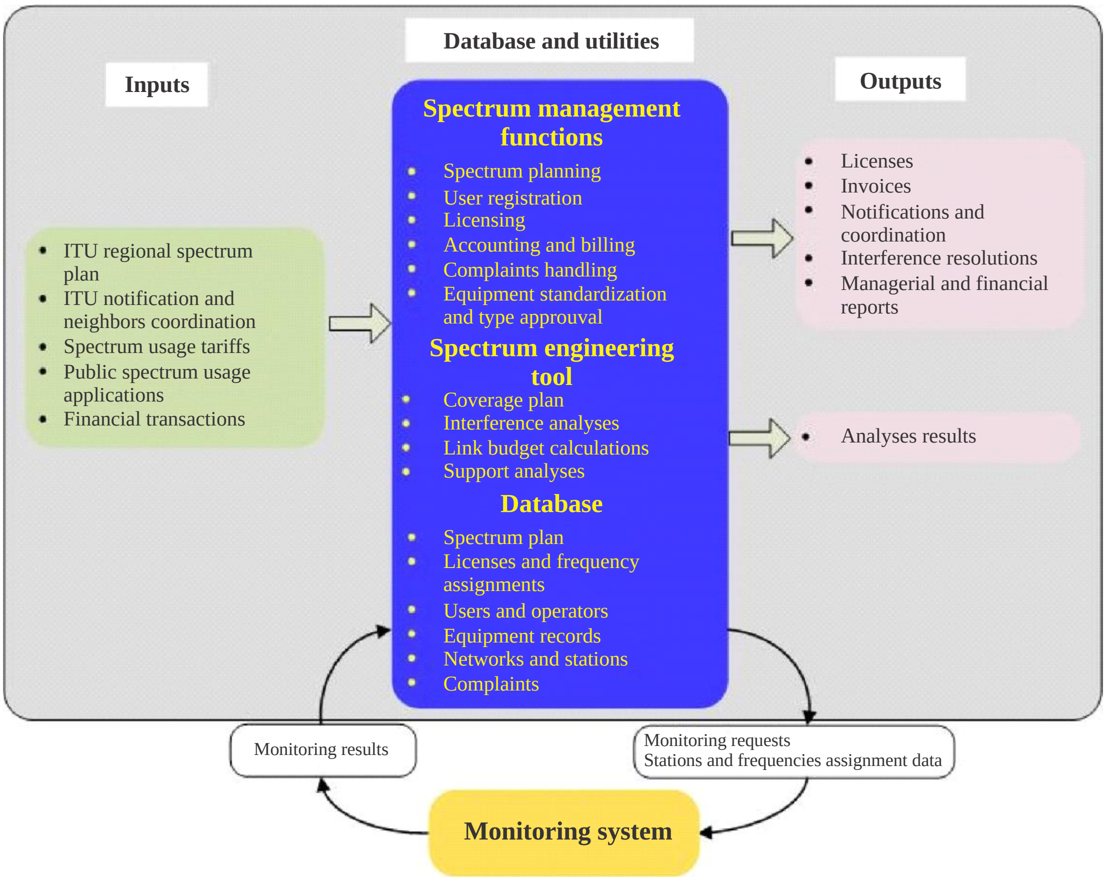
The primary Iris functions, its inputs and outputs, are illustrated in Figure A9-1 below.

2.1 Spectrum Planning

Spectrum allocation plans (ITU, Regional and National) and channel plan definitions provide the basis for spectrum assignments. A table of all assigned frequencies, together with customer defined channel tables allows for the efficient allocation of unused frequencies. The used frequency table supports the sorting and searching of frequencies on a global basis, with the ability to link back to the specific station that was assigned a specific frequency.

FIGURE A9-1

Iris Functions



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2.2 User registration

Advanced database capabilities support the one-time definition of each customer, with all of their address and contact information in a single location. All associated stations, networks and licences are linked to the single record. Relevant documents can be attached to the user record and stored in the database for easy access and reference.

2.3 Equipment Standardization and type approval

The system supports the definition of all data required for equipment standardization. This includes the definition of Antenna pattern (horizontal, vertical and axis), Terrestrial antenna characteristics, as well as more complex satellite antenna configuration.

The system supports the recording of all types of RF equipment, as well as non-RF equipment that an authority may wish to register.

2.4 Network and Station Definitions

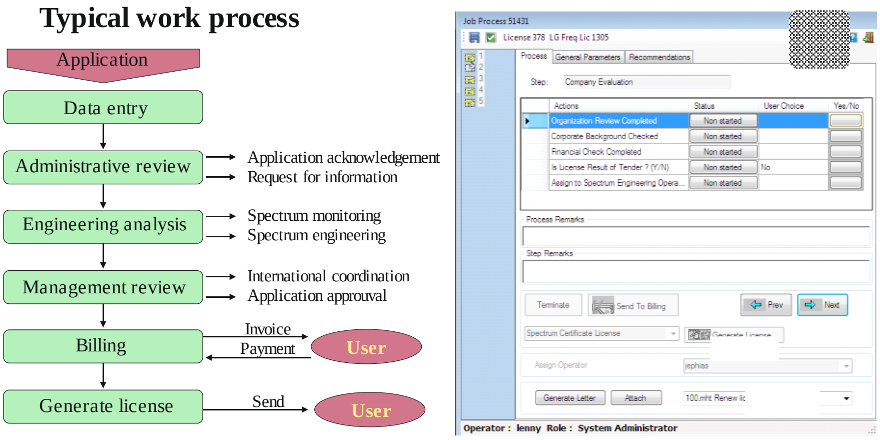
The heart of the database system lies in the definition of all elements that are used to define spectrum licences. This includes the definition of geographical sites, the definition of various types of stations – fixed stations, mobile station, radio-link pairs that implement point-to-point configurations, and satellite earth stations. The definition and registration of networks is a very flexible entity that can be defined to support the communication authority's regulations and licensing policies.

2.5 Licence Approval and Certificate Generation

The Iris system provides full support for the processing of licence requests. The guidelines mandated by the authority are encoded into the application so that the system assists the execution and tracking of all types of Operational Authorizations, Spectrum Licences, and Equipment Type Approval. By automating the approval processing workflow according to customer requirements, the system helps to eliminate the need for manual paper operations, while at the same time providing a full audit trail for the entire approval process. At the end of the approval process, customized licence certificates are automatically generated. The licences are saved in the system database, and can be printed as required for signature and distribution to the customer. The following pictures depict a typical workflow, and its implementation in the Iris system.

FIGURE A9-2

A Typical Workflow and Approval Processing Step



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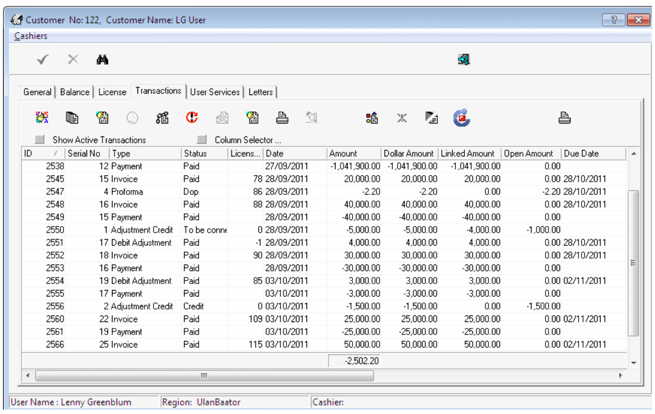
2.6 Billing

The system supports the management of financial tasks, including the definition of fee calculations based on formulas using technical parameters from the database (such as frequency, bandwidth, power, geographic location, and antenna height). The system generates invoices and produces receipt to acknowledge payments. Invoices can be generated in batch mode, and tracked to identify delinquent users. A full set of financial reporting tools are available. Tariffs modification can be made by an authorized Billing System Administrator.

FIGURE A9-3

Billing Transaction List



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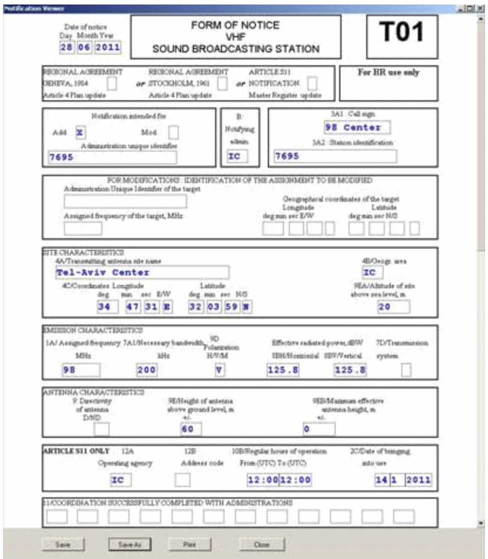
2.7 Frequency Coordination and ITU Notification

The system supports the Automatic generation of Notifications in formats specified by the ITU, in order to support coordination with neighbouring authorities, and notification to ITU.

FIGURE A9-4

International Notification



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2.8 Complaint Handling

Both administrative and interference complaints can be managed using Iris. This includes the tracking of activities required to resolve interference complaints and consumer complaints against telecommunication operators. The details of the complaint are recorded, plans of action are defined, and monitoring activity is initiated when necessary. A record of all activity is maintained in the database.

2.9 Report Generation

Iris uses Data Management facility to manage the collection of data and produce clearly understood Spectrum Management reports. The system generates both tabular and graphic reports. It is capable of exporting summaries and results to other standard tools, including Excel data files and HTML summary files. In addition, Customized Reports can be defined using a flexible Template Generator.

2.10 Administration

Iris includes administration tools and features that are available to authorized system administrators. Administration functions include:

- System configuration control – Support the contents of over 100 system tables.
- Access control – Defining operator authorization codes and access.
- Data manager configuration – To customize data displays.
- Map registration – Supports the addition of maps to system.
- Event logging – Provides a full audit trail of all activity.
- Template definitions – Allows editing of licence, system documents and report formats.
- Translation Tables – Allows the modification of text used on display screens.

The extensive administrative capabilities allow the system to be maintained on an ongoing basis, as the functional requirements continue to evolve.

3 Advanced Spectrum Engineering

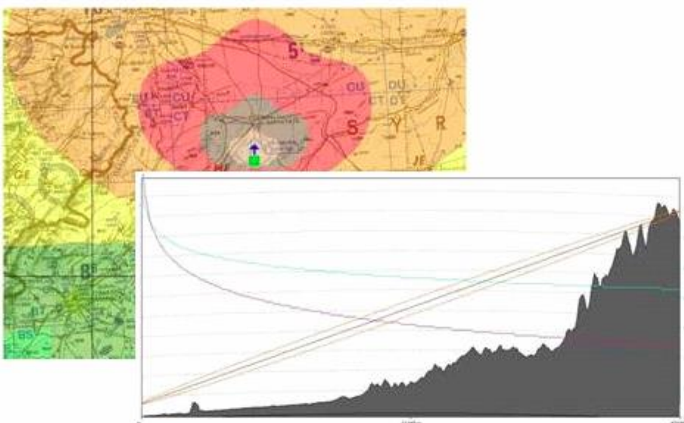
Calculation of radio propagation supporting among others: coverage area calculation, interference analysis, field strength calculation, micro-wave link budget, and best server calculation. Analysis is according to ITU-R Recommendations.

The system provides the following spectrum engineering support facilities:

- Transmitter station area coverage for one or more stations – composite coverage, best server coverage, power sum display, margin display, simultaneous or overlapping display, reliability coverage, DF coverage, mobile coverage for vehicles, ships, airplane or mobile services (can be used for many modern services; video links, Cellular networks, UMTS, etc.)
- Engineering analysis is available according to the latest versions of ITU-R Recommendations. Supported propagation models include: P.368, P.525/526, P.528, P.1147, P.1546 and other models (Okumura, Cost 231, and LTE). Supported diffraction models include: Deygout, P.526 round, P.526 cylinder, P.1225 etc.
- The system calculations may reflect clutter effects. Clutter data may be inserted as a map layer.
- Relevant analysis takes into account atmospheric conditions according to ITU-R Recommendations (P.840 for fog and P.838/530 for rain).

FIGURE A9-5

Transmission Coverage and Path Profile



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- **Interference analysis** – Three possibilities are supported**:** (1) co-channel (C/I mode), (2) adjacent channel (IRF mode), (3) coverage + interference.
- **Network and microwave assignment and planning** – This tool enables user to evaluate the potential interference of a selected candidate fixed terrestrial microwave network against other fixed terrestrial

  Microwave stations and checks interference using three methods (1) C/I rule, (2) threshold degradation rule, or (3) by analysing all MW stations.
- **Analysis of human hazards and electromagnetic risks** – Basic option is ICNIRP for the field strength calculations, but other standards can be performed with field strength results.
- **Satellite Coverage** – GEO or non-GEO (MEO or LEO satellite orbits) coverage analysis, coverage on map, space to earth interference. The program provided functions dealing with satellites: Satellite database functionalities; Spatial coverage and PTP calculation with: user defined attenuation or Recommendation ITU-R P.618 attenuation component.
- **Network Planning** – Assignment with minimum interference, increasing network efficiency according to polarization, bandwidth and RF equipment features.
- All propagation analysis activities are performed using Digital maps with high accuracy in the horizontal plane (minimum 200 meter resolution), 15 meter in the vertical plane, and 90 meter DTM (Digital Terrain Model). The maps support GIS functions including: (1) Filter based on elevation (above sea level or ground level), (2) Display field Strength and (3) drawing polygons of clutter.
- Comparison of engineering calculations with monitoring results.

4 Iris Customization

Although ITU-R Recommendations provide a generic framework for implementation of Spectrum Management System, each national regulatory authority is bound to the regulations defined on a national basis. It is therefore imperative that the system be flexible enough to provide for customization that meets local requirements. The ability to customize the system insures that the system supports the customer's requirements, so that the integration of the system can be accomplished quickly, without major dislocation to the daily operations of the authority.

Iris can be customized to specific buyer’s needs. The customization capability includes the ability to define the following:

- Geographic definitions – Regions, Province, Cities, etc.
- Licence forms and system letter templates.
- Spectrum allocation policies.
- Licence – Network – Station hierarchy.
- Licence approval procedures – Work flow.
- Billing tariffs and fees.

5 Iris Technical Characteristics

- **Flexible and Modular**

Iris features a flexible, modular and open architecture enabling effective customization to comply with regulator’s procedures and allowing easy expansion and modification to anticipate future needs.

- **Hardware and Operating System**

Iris can be installed on various models of PCs either in independent workstations or in client/server environment. The latest version of the MS Windows Operating System is utilized on both servers and workstations. The latest technologies are used to provide to highly reliable operations, with redundant disk configurations and automatic backup being done on a regularly scheduled basis.

- **Database Management System**

The Spectrum Management Database is stored on a central server, running the Oracle Database Management System. The operator workstations are connected using either a LAN or WAN interface, in a client-server configuration. The efficient database interface provides for quick responses and reliable support of all operations.

Iris database includes user administrative data, station and network definitions, licence applications and approvals, frequency allocations and assignments, service and accounting information, technical equipment definitions, as well as notification and coordination data. The Iris database stores reference information including Resolutions, Regulations, and Legal Texts related to Spectrum Management and Monitoring.

- **Online Reference Manual**

Iris is accompanied by an online Reference Manual that serves as a built-in HELP Facility.

- **User Friendly**

Iris is highly efficient and user friendly owing to its Man/Machine Interface (MMI) that provides intuitive and easy to learn operation.

- **Geographic Map Display**

Display of raster maps are used to define and display geographical locations. Digitized Terrain Maps (DTM) mapping information allows for the automatic entry of altitude information that can be used for recording station data and spectrum engineering calculations. Different resolution of maps (e.g. National and City maps) allow the overlay of data elements to help in the visualization and verification of site and station location.

Advanced map tools for the operator including zooming, distance and direction measurement, panning and scrolling.

FIGURE A9-6

Iris Typical "Data Manager" & Station's Record Screens

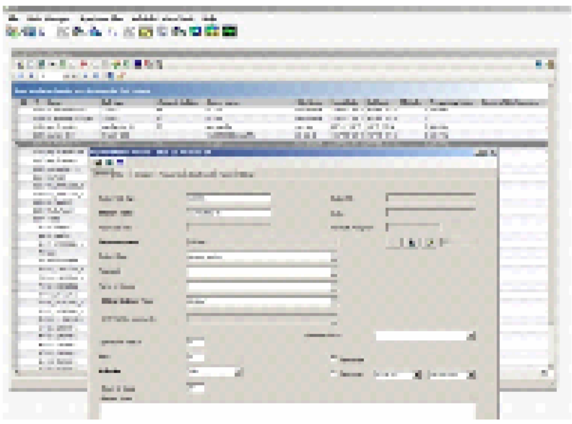

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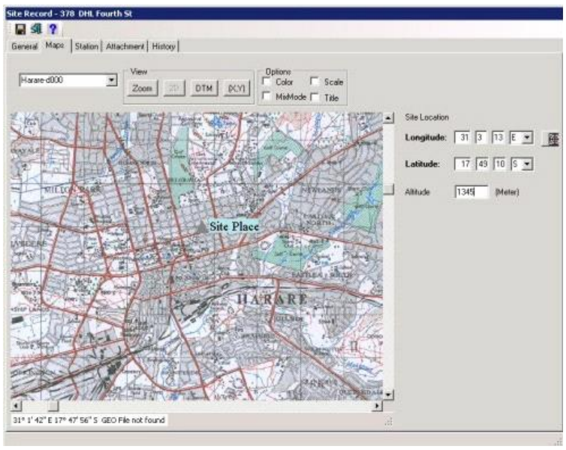
FIGURE A9-7

Iris Map Display



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- **Web Interface**

Option exists for Internet based operations, including remote operator access, customer data entry and reporting, and payment of fees via internet.

- **Dual-Language Support**

IRISIris operational screens, as well as the documentation, may be translated to the buyer's local language. The system is then available to be operated in either English or the local language. The translation is accomplished using flexible Translation Tables, thereby ensuring that the administrator can continue to refine the terms used to conform to the local language.

Further information is available by contacting:Elbit Systems BMD and Land EW – Elisra Ltd., Spectrum Control Department E-mail: marketing@elisra.com

ANNEX 10

SPECTRA – Integrated and Automated Spectrum Management Solution

1 General information

The SPECTRA system, developed by LS telecom AG, Germany, covers the whole range of administrative and technical functionalities for all radio services. Numerous SPECTRA system installations are operational all over the world in a significant number of countries typically at regulatory authorities. Proven integration with radio monitoring systems provides additional benefit to administrations. The system is continuously supported and further developed, i.e. kept up to date both in terms of functionalities and modern IT technologies.

1.1 Task and procedures of the SPECTRA system

The task of the system is to carry out all required frequency management related activities in a country on strategic and operational level. SPECTRA covers the full spectrum management lifecycle process starting with identifying the frequency requirements, planning, allocation, allotment, assignment and clearance.

All procedures and all calculations are strictly in line with the latest ITU, CEPT/ECC, ETSI, etc. resolutions, recommendations, decisions, standards and all relevant bi- and multilateral international coordination agreements. Possible future changes in these procedures are usually introduced to the SPECTRA system by module upgrades even for systems, which are already in operation.

In addition the formats of all output documents can be customized within the system in order to meet specific client or administration requirements.

1.2 Modularity

The SPECTRA system is based on a highly modular client server architecture allowing functional and geographical splitting between the database server and the various application modules. This scalable architecture allows projects to be started with basic system configurations, which may be extended to more complex and comprehensive configurations in later project phases when required. In this way, the modularity of the system may help to find an optimum balance between need, urgency and financial considerations in the country.

1.3 Project and Test Management

Within the implementation of SPECTRA projects LS telcom always makes use of widely accepted and practiced project management techniques to ensure the most effective and sufficient outcomes for the customers. It includes scope, time, cost, quality, change and risk management, and is always lead by dedicated project managers. Certified education according to the PMI (Project Management Institute) or PRINCE2 (Projects in Controlled Environments, version 2) ensure the needed capabilities. At the same time, LS telcom's Solutions and Service & Quality Management divisions follow ITILv3 best practice (Infrastructure Technology Information Library).

Throughout an entire project a special team of qualified testers ensures the functionality and reliability of the implemented system. In the course of the implementation specific test cases are created and run covering the full scope of the customer's system. These test cases are then consistently reviewed with regression tests for every maintenance update.

1.4 Training, maintenance and documentation

Training is very important for the SPECTRA users. A part of the training usually is provided at the supplier's premises in addition to detailed hands-on user trainings at the Administration's premises because of greater efficiency. Annual refresher training is advisable in order to use and practice the whole set of possible features, learn about updates and bring in new user staff.

Maintenance schemes are established with clients in order to secure investments made on the system. Standard maintenance services include keeping the system operational, the updating of modules in terms of general technological improvements and in accordance with the latest resolutions, recommendations, decisions and international agreements.

LS telcom provides comprehensive up to date documentation for the SPECTRA system. Each module features its own user guide that contains general descriptions and typical operations to help the user handle it correctly and efficiently. The user guides are available as printable PDF files and as context sensitive online help.

1.5 Usage of local programs and migration of existing databases

A Site Plan / Site Survey will be carried out if required so that the SPECTRA system can be localized accordingly. In case of existence of locally developed modules at client side, which need to be used without change also in the new environment, the SPECTRA system offers and supports various interfaces for their integration. Migration of existing client databases is a key issue when putting into operation a new spectrum management system. This task may include also developments of jointly agreed rules for data validation, data completion and data consistency checks. Advanced migration tools and comprehensive experience are available for successful completion of this crucial and difficult task.

1.6 Digitized maps

Digitized Terrain Maps (DTM) are used in the SPECTRA system as basis of administrative and technical procedures. Commonly used commercial GIS data formats can be migrated to internal formats for efficient data access. The system can handle different types of layers, among others topographical, land usage and population data. For LF and MF calculations ground conductivity maps are used. In case sufficiently detailed maps are not available for the country, these can be supplied together with the SPECTRA system.

1.7 Integration with radio monitoring systems

The SPECTRA system offers interfaces for integration with national radio monitoring systems (NRMS). The detailed functions depend on the NRMS, but typically exchange of data is supported bidirectionally. The operator of the NRMS queries detailed administrative and technical data from the central database as basis for setting up dedicated monitoring missions. On the other hand, the operator of the spectrum management system can order monitoring data to support various procedures as frequency assignment, spectrum planning, complaint processing, etc. All requested ITU measurements are processed manually or fully automatically depending on the capabilities of the NRMS. The data provided by the NRMS, which correspond to ITU measurements, can be stored in the central database for later analysis by any authorized user of the system.

Beside the possibility to connect via vendor specific interfaces, SPECTRA offers the adaptable Open Live Monitoring Interface (OLMI) to initiate and record live measurements, and the Open Monitoring Storage Interface (OMSI) for simultaneous access on stored measurements from several monitoring systems or devices of different vendors.

The existing direct link between the monitoring results and the licence database allows correlating monitoring and licence data. In this way, SPECTRA supports the typical monitoring tasks of a regulatory authority such as monitoring the spectrum usage, identifying interferers and searching for transmitters, that are unlicensed or working outside their licensed parameters and thereby features the option of automated violation detection (AVD).

1.8 Localization / customization of the system

The SPECTRA system has already been localized to a large number of languages including completely different character sets (e.g. Chinese, Sanskrit, Cyrillic, Arabic). This localization often includes the major functions of the system and also documentation. The documents created by the SPECTRA system can be localized in case they are used for national procedures. In case of international frequency coordination the language is usually English, French or Spanish. The standardized localization of the document can be performed by the client.

2 Description of the SPECTRA system

LS telcom's Spectrum Management System SPECTRA provides a comprehensive integrated solution for the licensing procedures of all radio services.

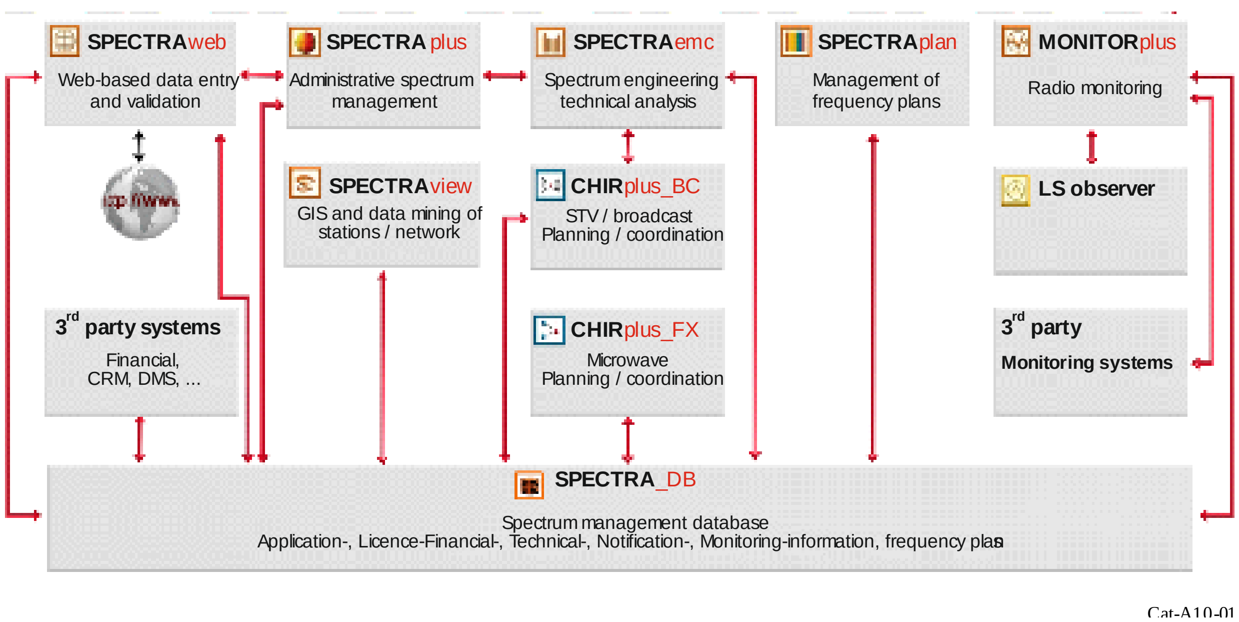
The main features of the Spectrum Management System can be summarized as follows:

– Highly modular client-server-architecture
– Adaptation of the system to customers' needs
– Extension of capabilities by including new modules for specific tasks
– Central Spectrum Management database
  ○ Administrative data
  ○ Technical data
  ○ Frequency allocations
  ○ Monitoring data
– Frequency assignment procedures based on calculations (propagation models) and technical data specific for the particular radio service
– Coordination procedures based on ITU recommendations or other international/national agreements for the particular radio service
– Specific workflows for the licensing procedures of different radio services
– Deadline management/set up of user roles with specific permissions on workflow actions
– Administration of national and international frequency plans
– Analysis of monitoring data from radio emissions to be in compliance with licences

Figure A10-1 illustrates the general overview including modules for licence administration, technical analysis and coordination for all radio services, administration of frequency plans and interface to radio monitoring with analysis of measurement data. The modules are described in the following section.

FIGURE A10-1

LS telcom Spectrum Management System – SPECTRA



2.1 Brief module description

SPECTRA_DB – Database Management

The central module of the SPECTRA system is the spectrum management database SPECTRA_DB. Based on the Oracle platform, SPECTRA_DB stores and centralizes all licence, billing, technical and monitoring data, radio equipment, frequency plans, as well as ITU and other relevant notifications. The unique database concept guarantees consistent up-to-date data to all users of the system and allows hierarchical data management with task oriented information access.

FIGURE A10-2

SPECTRAweb – Web-based Data Entry and Validation

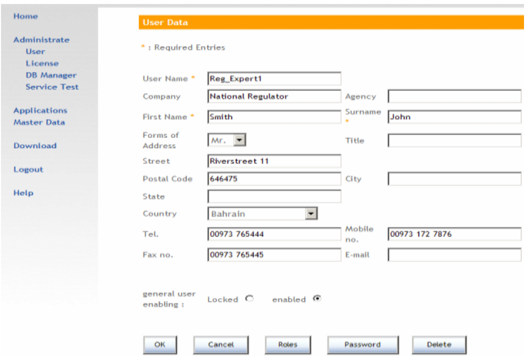


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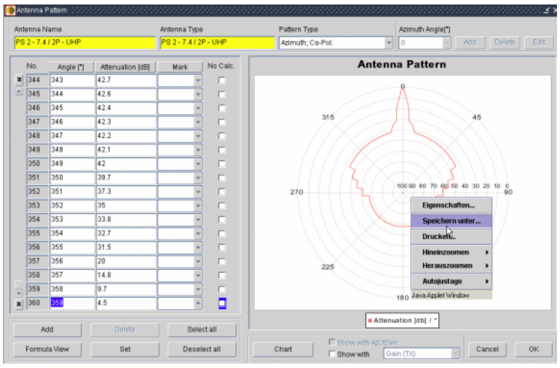
FIGURE A10-3

SPECTRAplus – Administrative Management



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SPECTRAweb – Web-Based Data Entry & Validation

SPECTRAweb offers customizable E-licensing and E-reporting via the web browser, supports a role based user management and allows electronic entry of validated licence application data by any web browser. The bi-directional, secure web-service-based data exchange between SPECTRAweb and SPECTRA_DB enables the outsourcing of data entry to the end-customer and ensures at the same time a high data quality. The validated high data quality is one requirement for process automation.

With the optional Online Frequency Information Portal information and content on frequency bands, licence data and conditions, monitoring and geographical data can be presented online. The portal can for example be interfaced to EFIS (European Radio-communication Office Frequency Information System).

SPECTRAplus – Administrative Spectrum Management

Administration of licence data for all radio services, project tracing, workflow management, user guidance, automatic printing of licences and other documents, deadline management, complaint processing, type approval, statistical and management reporting capabilities. All licence processes can be customized to the national rules and regulations.

Fee calculation is based on national fees decrees and allows for bookkeeping, automated invoice generation, credit notes reminder and income prediction. All billing procedures can be customized to the national financial rules and regulations.

FIGURE A10-4

SPECTRAplan – Example Management of Frequency Plans[7]

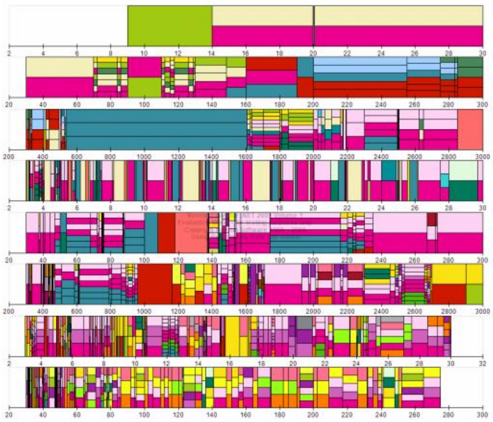

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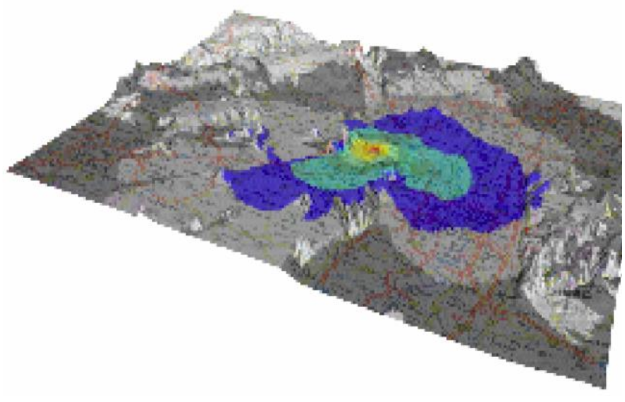
FIGURE A10-5

SPECTRAemc – Engineering and Planning



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SPECTRAplan – Management of Frequency Plans

Creation and administration of national and international frequency plans including channel allotments. Worldwide ITU and European CEPT frequency plans are available in standard configuration. Interfaces to ERO/EFIS and BR-IFIC and a notification editor with export to T01-T17 ITU notification forms in electronic ITU formats are included.

SPECTRAemc – Spectrum Engineering / Technical Frequency Analysis

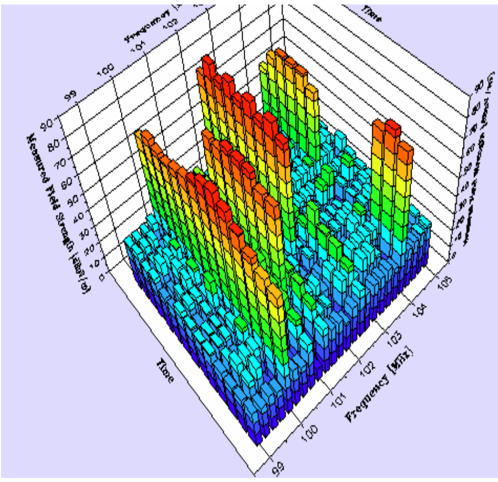
Intra and inter-service compatibility calculations for all radio services. Wave propagation models from 9 kHz to 300 GHz. Interference calculations based on spectral densities. Two and three signal intermodulation calculations up to fifth order. Safety zone calculation according to the European Recommendation 1995/519 CE. Frequency assignment and desensitization for inter service scenarios.

Several AddOns are available to extend and adjust the SPECTRAemc capabilities to specific client requirements: HCM LM and HCM FX for planning and coordination of land mobile and fixed services including HCM calculations according to the Vienna/Berlin Agreements. ITU notification and coordination for space and terrestrial services. SALT for spectrum licensing supporting spectrum licence allocation planning (for auctions), spectrum licence build (from auctions or other input) and spectrum licence trade. ATC for ICAO compatibility calculations and other dedicated functions for aeronautical radio services. MSEP for frequency planning for major special events, e.g. Olympics.

7 http://www.ntia.doc.gov/files/ntia/publications/spectrum_wall_chart_aug2011.pdf .

FIGURE A10-6

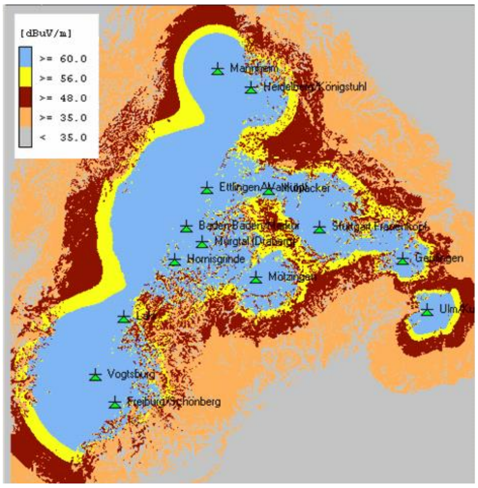
MONITORplus – Radio Monitoring



Cat-A10-06

FIGURE A10-7

CHIRplus_BC – TV/Broadcast Planning and Coordination



Cat-A10 -07

MONITORplus – Radio Monitoring

Interface functions to connect the SPECTRA system with radio monitoring systems, for example including ARGUS by Rohde&Schwarz, SCORPIO by TCI and ESMERALDA by Thales, as well as the LS Observer, which represents LS telcom's internally developed and fully integrated monitoring system solution. Advanced 2D/3D visualization and cross correlations of technical licence data with monitoring measurements for investigation of spectrum usage, detection of unlicensed emissions and detection of emissions that are not working with licensed parameters. Inspection AddOn for setting up and managing (regular) inspections of stations and equipment for all radio services.

CHIRplus_BC – TV / Broadcast Planning and Coordination

Covers all planning and coordination tasks for broadcast services FM, AM, DRM, T-DAB, DRM+, DVB-T, DVB-T2, ISDB-T, DTMB and DMMB. Main features include fully automated coordination calculations, network and coverage analysis considering population data, wide variety of 2D and 3D propagation prediction models, powerful GIS, automated frequency search, interference contours, day and night coverage for AM and DRM, MFN and SFN planning for T-DAB, DVB-T, DVB-T2 (including T2 Lite profile), ISDB-T, DTMB, DMMB, DRM+. Synchronized FM as well as LEGBAC aeronautical compatibility calculations are available as special options. Extensions concerning special propagation models are available.

CHIRplus_FX – Microwave Planning and Coordination

CHIRplus_FX is an advanced network planning, design and optimization software for well-engineered and economically optimized wireless backhaul solutions. It supports the end-to-end engineering of backhaul networks including site selection, line-of-sight (LOS) analysis, detailed link engineering, channel assignment, coordination & interference analysis, as well as automated generation of licence applications and bills of material (BoM). Furthermore, CHIRplus_FX supports the native integration of OpenStreetMap.

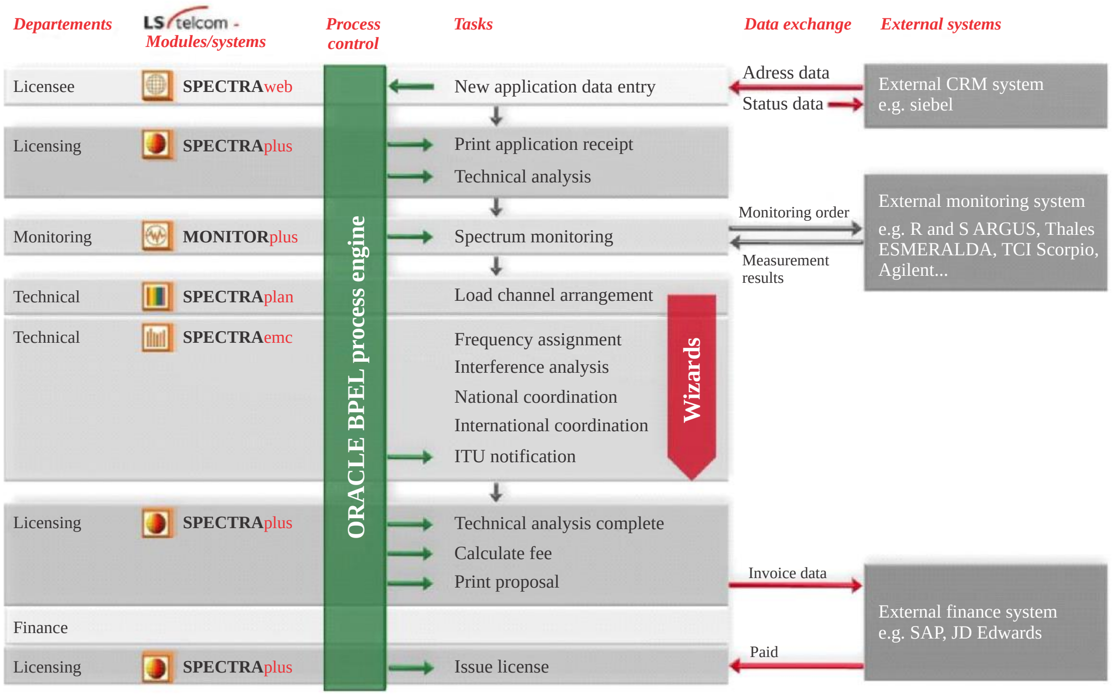
2.2 Cross-functional business processing

The SPECTRA system provides support for automating the cross-functional processing of typical business tasks such as: new licence process, renewal process, modification process, cancellation process, trade process, type approval process.

The corresponding workflows can be individually designed and configured, and are based on the Business Process Execution Language (BPEL). Figure A10-8 illustrates how the SPECTRA system exemplary supports the automation of a new licence application process. Table A10-1 describes step by step the features in the automation that are available for implementation within this workflow.

FIGURE A10-8

Process Example – New Licence Application



Cat-A10-08

TABLE A10-1

Process Example – New Licence Application

Business Workflow step	**SPECTRA Enterprise Supporting Features**
Application data entry by customer or administrative user in the organization	Application process starts at SPECTRAweb Highly configurable data capture and validation processes supporting accurate data capture first time reducing time and customer contacts
Application receipt is generated and/ or printed	Integrated customisable workflows via Oracle WebLogic BPEL for administrative business processes Automated document generation and dispatch of documents
Application is handed over to another team for processing	Team management and service standards (key performance indicators) reports based on workflow history table Seamless integration of administrative and technical processes
Technical analysis is performed for the requested frequencies	Customisable technical procedure via XML based wizard technology Advanced GUI definition for technical workflow processes automating wizard creation
Fees are calculated and a proposal is printed or generated and sent by email	Configurable fees calculation and integrated billing engine Integrated customisable workflows via Oracle WebLogic BPEL for administrative business processes

The customer pays the correct fee amount either by post or online	Online integration with 3rd party payment solutions
The licence document is issued either by post or email	Automated document generation and dispatch of documents

2.3 Automation of technical tasks

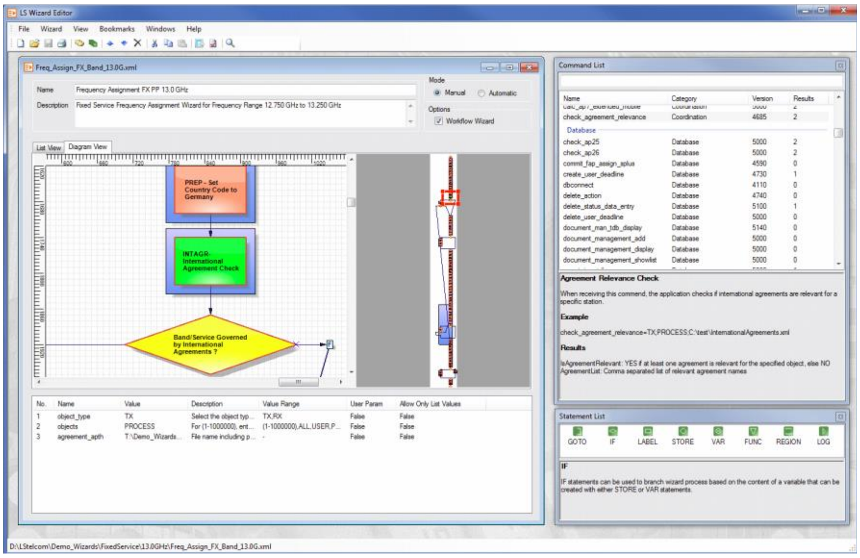
With the wizard workflow technology for SPECTRAemc and MONITORplus, complex technical analysis can be implemented in an automated macro type manner for any kind of service and frequency range. However, the user still retains functionality to run these wizards on a step-by-step basis particularly where human intervention by skilled technical engineers is required. The wizards allow the user to carry out both simple and very complex technical and coordination analysis tasks in manual or automatic mode.

A specific wizard editor assists in creating and customizing individual wizards for the different tasks. It lists available commands and statements for quick and easy use and provides multiple display possibilities to keep track of the overall workflow logic while creating.

Figure A10-9 shows how the editor enables the user to graphically visualize wizards in flow charts, where logic connections between commands and statements are highlighted by arrows for better overview especially of complex workflows. Wizards can also be displayed in a list view. At any time the editor provides additional information on every command and statement available and their effect within a workflow to facilitate the creation process.

FIGURE A10-9

Wizard Editor – Flow Chart



Cat-A10-09

ANNEX 11

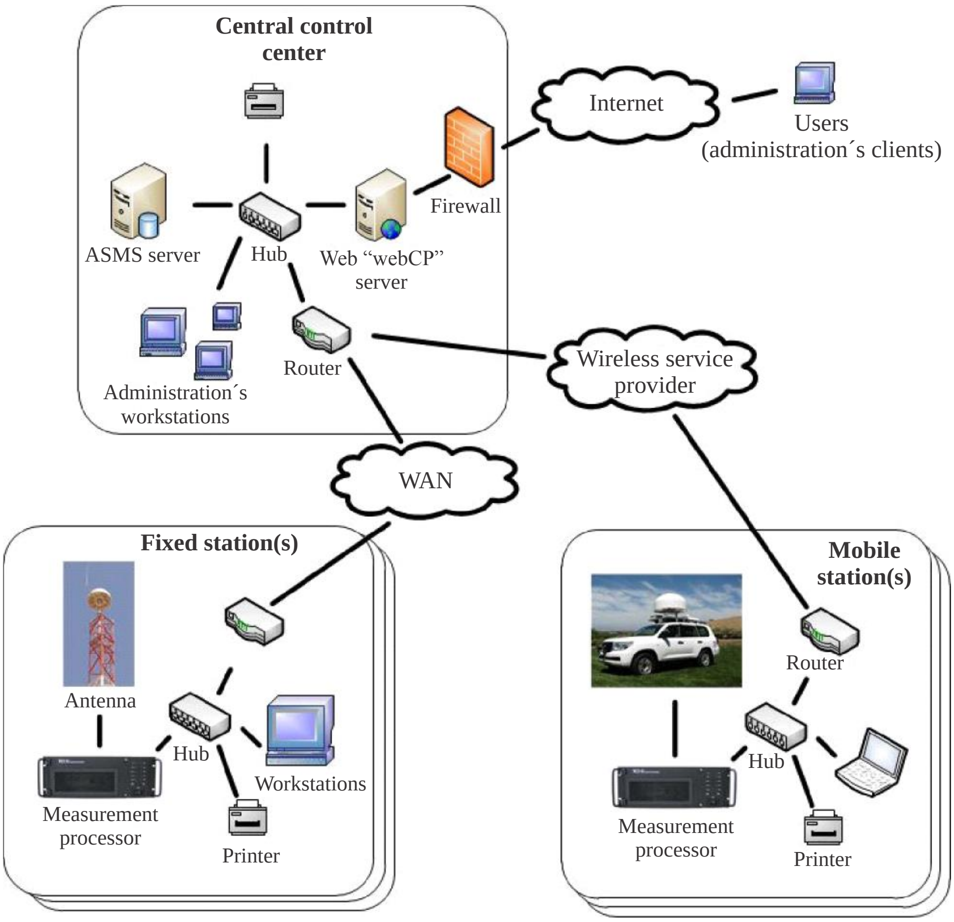
TCI – Automated Spectrum Management and Monitoring System

TCI International, Inc. provides integrated, automated spectrum systems management and spectrum monitoring systems. Designed to comply with ITU Recommendations, these systems have evolved with advances in technology and can be readily adapted to meet specific requirements of national regulations and procedures.

A complete system typically consists of a national spectrum management centre, with its management system database servers supported by workstations, and multiple fixed and mobile monitoring stations, each with a measurement server and one or more workstations. The central and remote stations are typically interconnected via a network to allow data communications. The block diagram of such a system is shown in Figure A11-1.

FIGURE A11-1

Typical TCI Integrated Management and Monitoring System



Cat-A11-01

1 Management system summary

The Automated Spectrum Management System (ASMS) uses a client-server configuration with Microsoft® SQL Server® Relational Database Management System as the database engine and the current Windows® operating system as the GUI interface.

1.1 Functions automated by the system

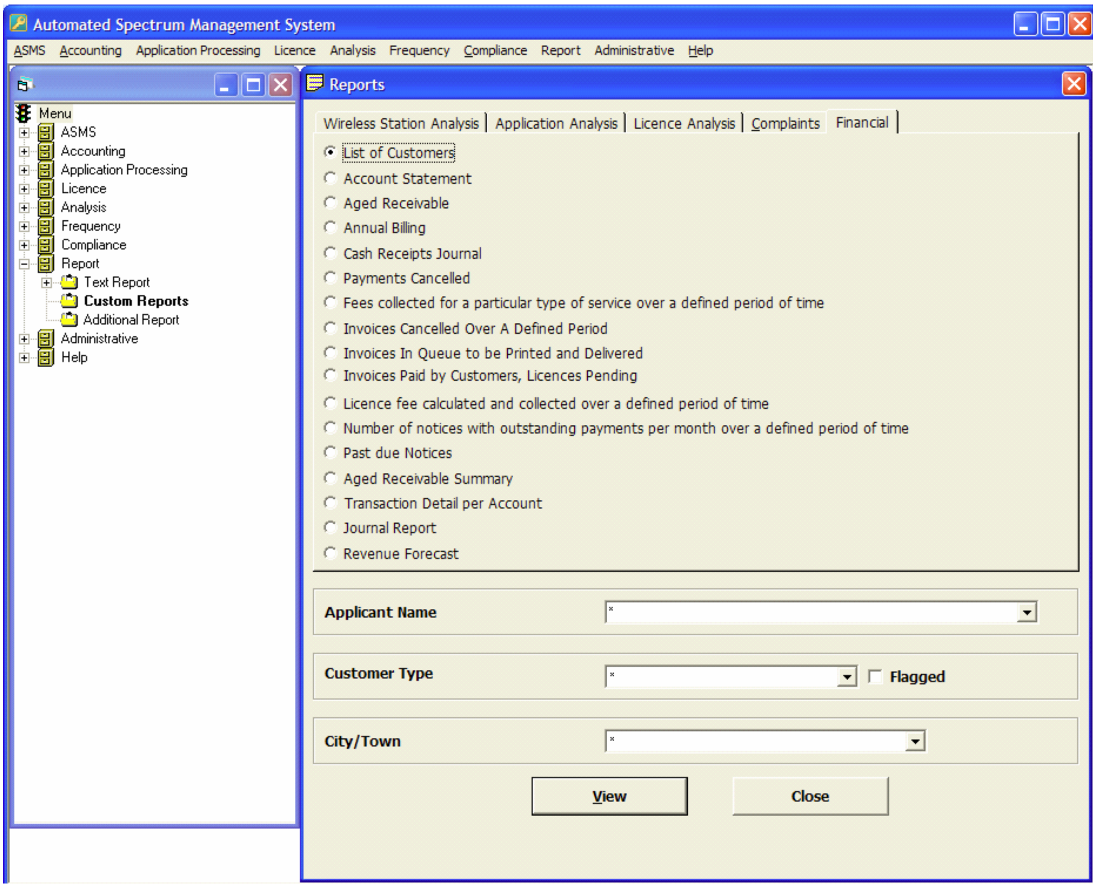
In accordance with ITU Recommendations, the TCI system supports automation and/or automates the following spectrum management functions:

– Planning the use and assignment of frequencies, through a complete set of engineering analysis tools covering all frequency ranges from LF/MF/HF up to microwave frequencies.
– Maintaining national and international frequency allocation plans.
– Reviewing applications and granting radio operating licences.
– Making computer-assisted frequency assignments.
– Renewing radio licences; modifying radio licence content.
– Automating ITU notification.
– Handling border coordination, including import of neighbouring countries' frequencies.
– Creating a record of applications, licences, complaints, violations, inspections, type approved equipment, ITU documentation and other data related to frequency management.
– Monitoring licensees and concessions to ensure compliance; maintaining billing history and fee payment history.
– Updating fee schedules and calculating and recording collection of fees and fines, including the flexibility to change fee calculation formulas in compliance with changing laws.
– Generating a large variety of text and statistical reports on applications, licences, financial and technical issues, including customized reports and historical reports.
– Printing licences, reports, bills/invoices, and notifications.
– Providing integration between the spectrum management system and the spectrum monitoring system.
– Performing automatic violation detection (AVD), where licence information from the management system database and measurements from the monitoring system database are combined to alert the operator those stations that are apparently operating without a licence or are operating outside their licensed parameters.
– Providing robust security, with views tailored to the security privileges of each user.
– Providing internet access to allow for radio licence application, dealer licence application, equipment type approval certification, and complaint reporting via the internet.

As a result of this automation, many management reports are possible. Figure A11-2 shows the standard financial reports offered with the ASMS. Most reports include filters to narrow the results to specific customers, application statuses, geographical areas, or time periods.

FIGURE A11-2

Standard financial reports



Cat-A11-02

1.2 Use of the system

The spectrum management system facilitates data entry and management of application and licence information, including site and equipment information. The system draws upon its database of clients, equipment, geographic locations etc. to help with this process. After equipment and site specifics are stored, the Spectrum Manager uses the system to help assign frequencies. The manager can request the system to search its database containing the National Frequency Allocation Plan to display all the channels in the appropriate band, and any existing assignments on those channels. The manager can assign a clear channel if one is present, or can select a channel assigned to a distant transmitter and perform an interference calculation to determine whether or not either use of the channel would create interference for the other use of the channel. The spectrum manager uses the frequency assignment screen illustrated in Figure A11-3 for these tasks. To assure that a frequency will support propagation, the spectrum manager can task the system to perform an engineering analysis (such as link analysis, field strength contour, or service area analysis) to determine whether the received field strength is acceptable.

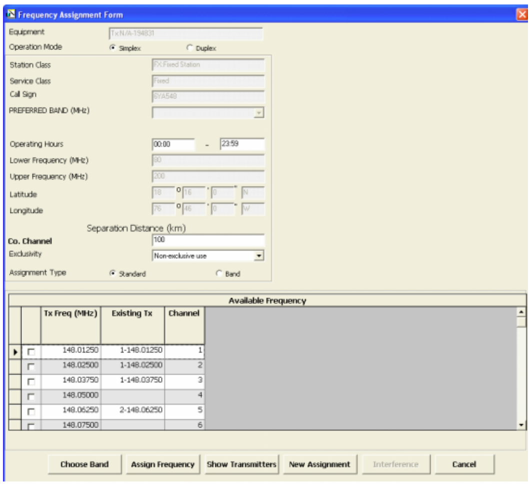
In a decentralized office environment, management tasks can be handled by distinct user groups with appropriate access levels. Accounting departments can manage the administrative and financial details of radio users, while spectrum engineers plan frequency assignments. Administrative users can run reports or issue renewal notices, while data entry personnel upload new licence applications or reports of interference.

1.3 Navigation through system screens

The system has standard forms for entry and display of site, operator, equipment, assignment and other data. The system has a convenient graphical user interface with navigation tools to access this data. An example of the use of a wizard to easily navigate through the various data entry and analysis forms required for an application for a radio station licence is given in Figure A11-4. The wizard minimizes training time and greatly facilitates use of the system.

FIGURE A11-3

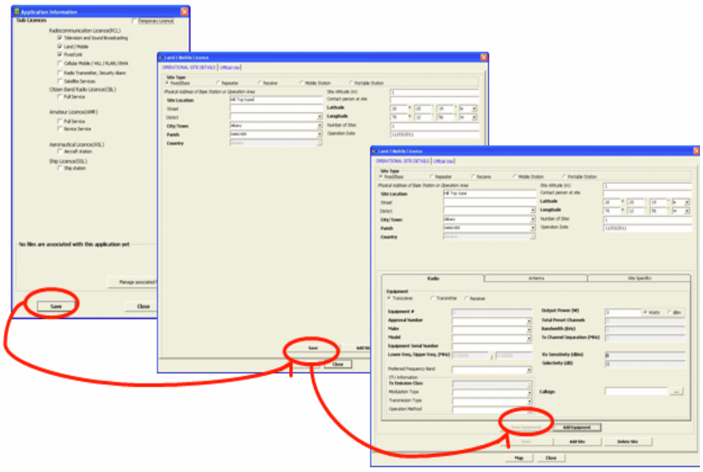
Frequency assignment screen



Cat-A11-03

FIGURE A11-4

Example of wizard for navigation



Cat-A11-04

1.4 Localization, accounting interface, and ITU compliance

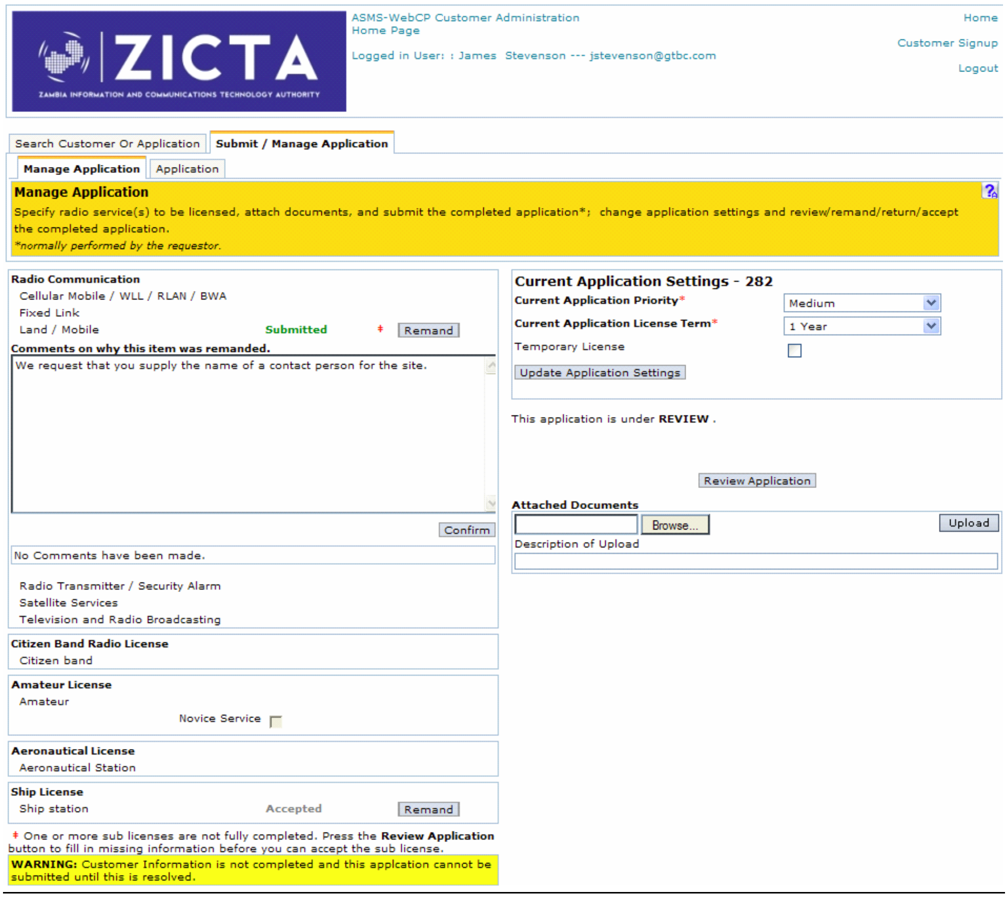
The system has the capability of running in the native language of the spectrum manager, having already been provided in English, French, Spanish and Arabic. The system also includes an interface to an accounting package, to allow central invoicing for licence and renewal fees and processing of payments. The ITU recommendations on design guidelines for advanced automated spectrum management systems are contained in Recommendation ITU-R SM.1370-2, and the system complies with those recommendations.

1.5 Web Interface

An optional module for the ASMS, called “WebCP” (Web Customer Portal), enables the system to safely and reliably import licence applications and supporting documents submitted over the Internet. In a standard browser window, WebCP displays the same data-entry forms with the same dynamic field validation behaviour incorporated into the ASMS. Since the applicant enters all required information on these dynamic forms, applications are complete and accurate upon submission. The administrator of the WebCP reviews the submitted application and adds Official Use information, such as service class and call sign. The application can be released back to the applicant with comments, if necessary. An example of this is shown in Figure A11-5. Otherwise, the completed application is then ready for the official review process inside the ASMS. After the licence is issued the applicant can apply for a licence modification using WebCP, if desired.

FIGURE A11-5

Entering a return to applicant comment in the WebCP admin screen



Cat-A11-05

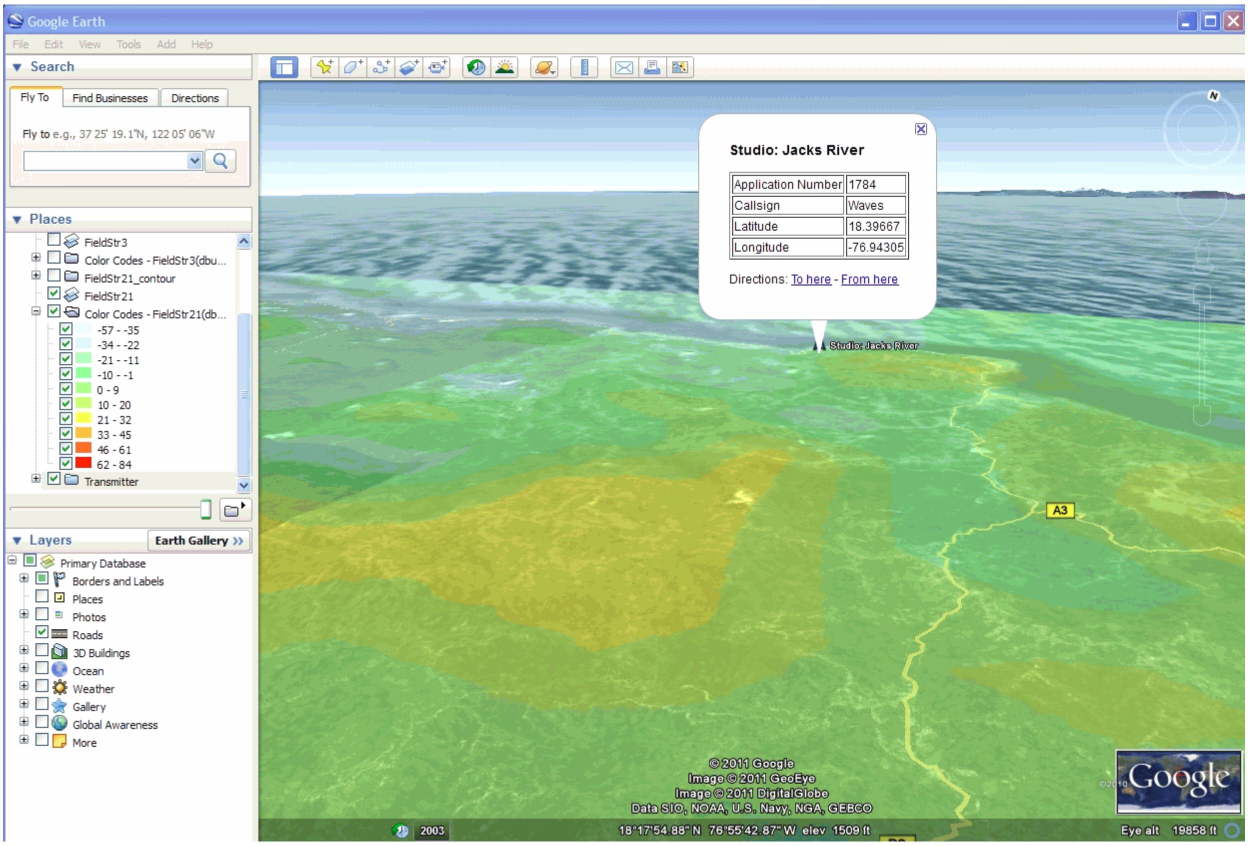
1.6 Map Interface

TCI provides an optional mapping module that extends the GIS capabilities of the ASMS. It enables features from the database such as stations, microwave link paths, and field strength patterns to be exported to mapping software, as illustrated in Figure A11-6. The user can then use the navigational controls of the mapping software to perform functions such as zoom, pan, and fly over the data set in three dimensions. The data set can be saved to a layer in the mapping software or to an external file.

Typical uses include verifying station coordinates against surface landmarks, visualizing broadcast field strengths in relation to population centres, and verifying line-of-sight visibility between stations.

FIGURE A11-6

Example of map display with exported field strength and transmitter data in Google Earth™



Cat-A11-06

1.7 Accounting Interface

The Accounting Integration Module (AIM) option provides ASMS with the capability to exchange customer, invoice, and payment records with external accounting systems.

With ASMS-AIM, customer records, invoice records, and payment records can be updated in either direction at those times and under those conditions that support the customer's particular accounting process.

ASMS-AIM makes all calls to the external accounting system using interface modules written by the accounting system provider specifically for this purpose. It does not write to the database directly.

2 Monitoring system summary

2.1 Functions performed by the system

Functions that the monitoring system performs include:

– monitoring, recording, demodulation and optional decoding;

– technical parameter (metrics) measurements and analysis including frequency and frequency offset, level/field strength, modulation parameters and bandwidth;

– spectrum occupancy;

– direction finding and geolocation using Angle-of-Arrival (AOA), Time-Difference-of-Arrival (TDOA) or both (Hybrid);

– automated detection of illegal or unknown transmissions (AVD).

A client computer, which can be located either locally with the spectrum monitoring equipment, or remotely, controls the equipment. One client can control multiple monitoring stations, and can control different sets of monitoring equipment regardless of the monitoring equipment's hardware/software configuration. Measurements are performed using digital signal processing technology. The system runs in either narrowband or wideband mode with RF receiver selections of 2 and 20 MHz or 4 and 40 MHz of instantaneous bandwidth in order to receive low level signals in high level and crowded signal environments, and also modern wideband communications signals. Direction finding (DF) is performed with a large-aperture antenna and a multi-channel receiving system to make the greatest use of the information in the arriving signal and to provide high accuracy.

2.2 Modes of operation

The system performs these functions with three modes of operation – interactive mode, automatic or scheduled mode, and background mode.

– Interactive mode: Allows direct interaction with various functions that provide instantaneous feedback such as monitor receiver tuning, demodulation selection, real-time DF display, automatic alarm notification, and pan-display selection. DF homing, to track down a source of interference, and field-strength mapping over a geographical area are important examples of interactive operation. DF and field strength measurements may be commanded in a mobile unit when the unit is either stationary or in motion without the need to assemble/disassemble antennas to make measurements.

– Automatic or scheduled mode: Tasks may be scheduled to execute immediately or to be executed at specified times in the future. Functions performed in scheduled mode include technical measurement and analysis, and direction finding.

– Background mode: Used for performing spectrum occupancy, DF scan and automatic violation detection – tasks where it is desirable to collect data over long periods of time. An operator commands an automatic scan on discrete frequencies or over a range or ranges of frequencies, to run either immediately or at some date/time in the future. The requested measurement results are stored locally, and may be recalled by the operator that initiated the task either while the task is still running or after the task has completed. These data may then be used to generate reports and may be combined with licence data in the management system database to perform AVD in order to detect possible licence violations.

2.3 Compactness and mobility

The spectrum monitoring system is very compact. The electronics may be contained in an equipment rack or a small transit case, depending on whether the equipment is to be placed at a fixed, transportable, or mobile installation. A mobile station including antenna and electronics may be installed in a small van, such as the example HF/VHF/UHF DF and monitoring mobile monitoring stations illustrated in Figure A11-7. Mobile monitoring stations are very useful to search for, identify, and locate sources of interference. The mobile station can make measurements with the antenna up, as illustrated in Figure A11-7, or down while the vehicle is either stationary or in motion.

FIGURE A11-7

Example complete mobile monitoring stations

Cat-A11-07

3 Integrated management and monitoring system

3.1 Integrated operation of hardware and software

TCI designs and manufactures all of the major hardware elements of its spectrum management and monitoring systems, including antennas, RF distribution and switching electronics, receivers and related equipment, and has developed the computer software for both management and monitoring systems. Since the hardware and software is all provided by the same company, TCI is able to provide the most fully integrated system, which allows proper interaction and operation of the complete system. TCI is also able to integrate its spectrum monitoring system with spectrum management systems provided by others.

3.2 Support, including customisation, data migration, training and maintenance

TCI provides the support that administrations need to utilize the system within their operations. Because the National Telecommunication Acts of different countries have differing provisions, and because different administrations have different practices and procedures, inevitably an automated spectrum management system is customized to a particular administration's needs. Automating existing computerized processes poses different challenges than automating all-paper operations. Programs may need to be developed to assist in data migration, so that data from existing systems may be automatically transferred to the system described here. TCI addresses all of these issues.

Training in the use of the system is facilitated by a training database, which provides representative applications for licences, frequency assignments and other data. Through these training aids, extensive classroom training can be conducted using just computers, without interfering with routine system operations and without the need for additional monitoring equipment. Maintenance of the system is facilitated through automated test procedures and built in test equipment and diagnostic programs support remote fault diagnosis of equipment in the field.

3.3 Compliance with ITU recommendations on automation and integration

The system described in this Annex meets the recommendations of Recommendation ITU-R SM.1537 on automation and integration of spectrum management and monitoring systems and the guidelines on automation discussed in Chapter 3, section 3.6 of the ITU 2011 Spectrum Monitoring Handbook. It is successfully being used by a number of regulatory agencies around the world. The application of this system to one administration is described in an Annex of Chapter 7 of the ITU National Spectrum Management Handbook. Further information is available at www.tcibr.com and in [Woolsey, 2000 and 2004].

REFERENCES

[1] WOOLSEY, R. B. [2000] Automatic Tools for Telemetry Test Range Spectrum Management. Proc. ITC/USA 2000.

[2] WOOLSEY, R. B. [2004] An Automated, Integrated Spectrum Management and Monitoring System. Proc. Seventeenth International Wroclaw Symposium and Exhibition on Electromagnetic Compatibility.

GLOSSARY

Algorithm	A statement of the logical steps to be followed in the program for solution of a specific problem.
Allocation (of a frequency band)	Entry in the Table of Frequency Allocations of a given frequency band for the purpose of its use by one or more terrestrial or space radiocommunication services or the radioastronomy service under specified conditions. This term shall also be applied to the frequency band concerned.
Allotment (of a frequency or frequency channel)	Entry of a designated frequency channel in an agreed plan, adopted by a competent conference, for use by one or more administrations for a terrestrial or space radiocommunication service in one or more identified countries or geographical areas and under specified conditions.
Alphanumeric data	Pertaining to a character set that contains letters and digits, and usually other characters.
Application program	A routine developed to perform a specific function or solve a particular problem of concern to the computer user organization.
AOA	Angle of Arrival.
ASCII	American Standard Code for Information Interchange – a numerical code used to represent letters, numerals and symbols.
Assigned frequency	The centre of the frequency band assigned to a station.
Assignment (of a frequency or frequency channel)	Authorization given by an administration for a radio station to use a radio frequency or radio-frequency channel under specified conditions.
ASMS	Automated Spectrum Management System.
AVD	Automatic violation detection.
BDT	Telecommunication Development Bureau.
BR	Radiocommunication Bureau.
CD-ROM	A type of data storage medium (a disc) that uses optical technology to read the data. Typically these discs are write once read many. Each disc can store 600 MB of data.
Computer virus	A software programme designed to affect and possibly catastrophically damage data held on a computer system and/or the computers operating system.
Data	A representation of facts, conceptions or instructions in a formalized manner suitable for communication, interpretation or processing by human beings or by automatic means.
Database	A file of data so structured that appropriate applications draw from the file and update it but do not themselves constrain the file design to satisfy a specific, limited application.
Data dictionary	A data dictionary describes the data elements contained in the data base.
Data element	Any item of data which for a given situation may be considered as a unit, e.g. field, record.
Data field	A subdivision of a record containing a unit of information.

Data file	An organized collection of data records. The organization of records on a file may be for a common purpose, common format or common data source, and may or may not be sequenced.
Data format	The term format explicitly applied to data and meaning the formalized manner in which the data is stored or represented.
Data record	A logical unit of data representing a particular transaction or a basic element of a file consisting in turn of a number of interrelated data elements or data items.
DBMS	Database Management System.
DF	Direction Finding.
DTM	Digital terrain model.
DSP	Digital signal processing.
DVD	Digital video disk.
EDI	Electronic data interchange.
e.i.r.p.	Equivalent isotropically radiated power; the product of the RF power supplied to the antenna and the antenna gain in a given direction relative to an isotropic antenna (absolute or isotropic gain).
EMC	Electromagnetic compatibility.
Format	A general term describing the structure or other details defining how information is stored or represented. It can be used for individual data values or for a complete data file, equally it could apply to the structure of a letter or other text document.
FTP	File Transfer Protocol – a standard for transferring files electronically.
GE06 Agreement	The Regional Agreement and its Annexes together with its associated Plans as drawn up by the Regional Radiocommunication Conference 2006 (RRC-06) for the planning of the digital terrestrial broadcasting service in Region 1 (parts of Region 1 situated to the west of meridian 170° E and to the north of parallel 40° S, except the territories of Mongolia) and in the Islamic Republic of Iran, in the frequency bands 174-230 MHz and 470-862 MHz (Geneva, 2006) (RRC-06).
GIS	Geographical Information System.
GUI	Graphical User Interface.
Hardware	Physical equipment used in data processing as opposed to computer programs, procedures, rules and associated documentation.
HF	High-frequency (decametric waves).
ICNIRP	International Commission on Non-Ionizing Radiation Protection.
ICT	Information and Communication Technology.
IDWM	The ITU Digital World Map.
IFIC	International Frequency Information Circular, published by the BR.
IFL	International Frequency List.
Input/output device	A device in a data processing system by which data may be entered into the system, received from the system, or both.
Internet	A public electronic network for providing access to electronic information.

IT	Information Technology – abbreviation for description of computer and communications systems.
ITU	International Telecommunication Union.
Item of data	Any data treated as a unit within a data record or a program or a process, e.g. a single entry in a record or a table.
ITU-D	Telecommunications Development Sector.
ITU-R	Radiocommunication Sector.
LAN	Local Area Network.
MB	Megabyte.
MF	Medium frequency.
MIFR	Master International Frequency Register.
MIME	Multipurpose Internet Mail Extensions – the 1992 Internet email standard.
Off-line	A situation where a device is not directly connected to the computer system.
On-line	A situation where a device is connected to the computer system and is readily accessible by the computer processing unit.
Operating system	Software for controlling the execution of computer programs that may provide scheduling, debugging, input/output, control, accounting, compilation, storage allocation, data management and related services.
Path profile	The topographic data along a line around the Earth's surface between two points represented in two dimensions.
PC	Personal computer.
Preface to the IFL (PIFL)	Preface to the International Frequency List, produced and distributed by the BR it describes the data used in the notification forms.
Program	The sequence of instructions, which is followed by the computer in performing a specific task.
Protection ratio	The minimum value of the wanted-to-unwanted signal ratio, usually expressed in decibels, at the receiver input determined under specified conditions such that a specified reception quality of the wanted signal is achieved at the receiver output.
PSTN	Public switched telephone network: the global telephone network.
RDD	Radiocommunication Data Dictionary – a set of rigorously defined data models describing the information needed by administrations and the BR in order to communicate electronically details of radio systems (Recommendation ITU-R SM.1413).
RAID	Redundant Array of Independent Disks. This system is preventing the disk corruption and associate losses using an arrangement of several disks working in parallel. It may also be used for system performance improvement.
RR	Radio Regulations.
Server	A computer whose main function is to provide service to other computers in the network; these could include data, calculation or application or might be a gateway service to external communication networks.

Software	Computer programs, procedures, rules and any associated documentation concerned with the operation of a data processing system.
SQL	Structured Query Language.
Storage (device)	A functional unit into which data can be placed, in which they can be retained, and from which they can be retrieved.
Subroutine	A sequenced set of statements that may be used in one or more computer programs and at one or more points in a computer program.
System	The computer hardware, its operating system and the associated data.
TCP/IP	Transmission control protocol/Internet working protocol
TDOA	Time Difference of Arrival.
TIES	Telecommunication Information Exchange Service – an ITU information service.
UHF	Ultra-high frequency (decimetric waves)
VHF	Very high frequency (metric waves)
UNIX	An operating system used on minicomputers and larger computer systems originally developed at Bell Laboratories in the United States of America.
WebCP	Web Customer Portal.
WAN	Wide area network.
Workstation	A computer, often more powerful than a PC, that provides multiple functions and usually includes specialized hardware for display or calculation purposes such as 3D computer aided design.
World Wide Web	A group of information resources accessible over the Internet.

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