*On future information system for management of radio frequency spectrum resource**

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SUMMARY
This article attempts to outline an information system that will provide data for decision-making by governments, their contractors, international consortia, private companies, and other entities interested in radiocommunications. The proposed system will harmonize national and international radio frequency spectrum management, and will integrate the existing computer resources within one computer network. It will contain the complete data on current use of radio frequencies around the world and offer specialized computer tools to facilitate the technical coordination analyses required when a new radio station is proposed. The system will help to manage the radio frequency spectrum resources and to satisfy the increasing frequency demand for new radio services and systems. It will affect strongly the spectrum management, independently of any other reform such as simplification of the International Telecommunication Union (ITU) Radio Regulations. The new system will be the expected "next step"after the decisions of the recent Additional Plenipotentiary Conference (APP-92). After presenting the background, we discuss current problems in radio frequency spectrum management such as the role of new partners, fragmentation and inefficiency. Section 3 outlines the concept of the system. Comments on implementation are given in section 4 and concluding remarks in section 5.

1. Background

Limits to growth

Mutual interferences among radio stations impose limits on radiocommunications. Suitable frequency bands are already occupied, and finding a place for a new radio service or radio station is more and more difficult. To continue and develop further radiocommunication services, an efficient radio frequency spectrum management system is necessary. It is the responsibility of each government to eliminate and prevent harmful interference to and from the stations under its authority. As a consequence, most countries have introduced the radio interference issues into their legal systems and developed national radio frequency spectrum management structures.

National developments

National spectrum managers are responsible for the satisfaction of conflicting frequency requirements and coordination of the domestic use of the radio frequency spectrum resource. An evaluation of the interference threat to and from a new radio station is an integral part of their function that requires an

* *Editor's note: The opinions expressed in this article are the author's personal views, and do not necessarily reflect those of the Radiocommunication Bureau (BR) or the International Telecommunication Union (ITU).*

examination of detailed characteristics of the station and its environment. Many countries have found it necessary to develop computer tools and databases for these purposes.①

The market approach to radio frequency spectrum, introduced in some countries and contemplated in others, involves extra tasks, in comparison with the traditional spectrum management, in response to requests from trade and business. In New Zealand, 'for example, computer services play an integral role in the government's sale by tender of radio frequency rights, in assuring fast, objective, secure and transparent processing of tenders, The computer-based Register of Radio Frequencies serves not only to store technical and operational information on radio stations, but also to register property rights and legal documentation. The computer services, available to the public, offer an immediate client access to up-to-date licensing and other information.②

The degree of computerization of national spectrum management is increasing rapidly. Recently, even the least developed countries were offered about one hundred personal computers for spectrum management applications,

International aspects

Many countries have to coordinate domestic radio stations with the neighbouring countries, within the coordination ranges reaching thousands of kilometers. Only few countries have such a geographical position that the probability of interference conflicts across the borders is low, but even they have to coordinate all short-wave, satellite and other radio stations that use the global radio wave propagation modes. When an international recognition of a station is sought, its frequency and orbital position assignments have to be coordinated, notified and registered at the ITU headquarters, in accordance with the Radio Regulations.

Computer impact

Personal computers and workstations have revolutionized the spectrum management. Due to the technological progress their speed and computing power is increasing continuously whereas prices are falling. In the 1970s, a PDP-11/70timesharing system with 15 terminals might have cost 150000 United States dollars. In the 1980s, a comparable microprocessor-based system could have been installed for about 25% of that sum. These factors, the cost, speed and power, contribute to fast proliferation of computers and computer networks.

Mainframes are giving way to networks of personal computers served by a mid-range computer, while workstation clusters are substituting for supercomputers. Multi-user systems allow several people at different terminals to use the common computer resources at the same time. Multitasking systems allow one user to run several computing jobs simultaneously. Multi-user and multitasking environment is increasingly popular, offering user-friendly and timesaving tools that improve productivity. UNIX is one of operating systems that offer such an environment.

More than 300 000 UNIX-based installations around the world are supporting over one million users, and their number increases rapidly, Decreasing prices contribute to proliferation of computer networks at international business, universities, libraries, airlines, insurance companies, banks, research centres and travel agencies. One of such networks, for instance, interconnects as much as 15 000 travel agencies distributed over 190 countries and territories with the network availability of 99.98% and response time of 2.1 seconds.③

① *See Karjalainen J.: National Frequency Management Experience from Finland, Telecommunication Journal, Vol. 59, No. V, 1992, pp. 240-247.*

② *See: Radio Frequency Service Communication Division: Corporate Profile, New Zealand Ministry of Commerce, 1990.*

③ *See: SITA: Activity Report 1991.*

2. Problems and solutions

The existing international spectrum management system has been created in 1947 to satisfy the basic needs of all ITU Member countries. These needs change, following the technological, economic, political and social development, and the system has to change accordingly. With a renaissance of wireless technology, the number of radio stations, operating and planned, is growing.

Growing also is the complexity of the coordination process and the volume of coordination data required to ensure their interference-free operation. Management of the radio frequency spectrum becomes increasingly difficult and expensive. On the other hand, we witness economic difficulties, shrinking budgets and competition. As a result, there is increasing pressure on all governments, and on the ITU, to use better the existing resources. The proposed information system will contribute to that aim mainly through a better harmonization and integration of the existing resources, national and international.

New partners

Non-governmental multinational consortia, service providers, equipment manufacturers, consultants and other entities are the new partners in radio frequency spectrum management issues. With liberalization and privatization of the telecommunication sector in many countries, the role of these partners is increasing. We witness continuing development of trans-national exchange of goods and services, increasing regional cooperation and blurring border between national and regional spectrum management.

The existing spectrum management structures were created when State monopoly was prevailing, and a limited role has been foreseen for non-governmental entities. While this approach was justified in the past, it has not been adapted to the new environment. The new partners require more transparency in the radio frequency spectrum management and decision taking processes, vital for their activities. The future system will offer them an easy access to exact information on the current usage and management of radio frequencies, including data, and models.

Efficiency

In the absence of an automated system, the manual treatment of required examination and the follow-up actions in the International Frequency Registration Board (IFRB) were time-consuming operations, which delayed other activities of the Board. This was criticized on several occasions. In 1959, for instance, the following comments were made:

> "...***when an analysis is made of the work carried out by the IFRB over the last ten years, it must be admitted that the Board was in a position to carry out only one duty more or less satisfactorily. ...With regard to registration procedure itself, ...technical examination is exceedingly theoretical and is far removed from actual conditions. ...Moreover, ...if a technical examination is carried out, the registration of frequencies is unjustifiably delayed....***" ④

Many attempts were undertaken in the past to improve that situation. Organizational changes, application of computers at the ITU headquarters, provision of data on magnetic tapes, diskettes and CD-ROMs, and recent attempts to simplify the ITU Radio Regulations, are examples. Almost all possibilities have been explored, but all these efforts did not seem to meet the expectations of ITU Members.

④ *See Doc. No. 153, Plenipotentiary Conference (Geneva, 1959).*

Recently, APP-92 decided to merge the IFRB and the International Radio Consultative Committee (CCIR) Secretariats into the Radiocommunication Bureau (BR), and we have to wait to see whether or not this merging will meet the expectations. There is also another possibility for improvements, not fully explored until now: harmonization and integration of the existing spectrum management information systems and automatic exchange of data. It is the view of this author that the CCIR-IFRB merging per se cannot produce any practical effect, as long as the existing working arrangements among the national spectrum managers and with the ITU remain unchanged. The key element is the data exchange. Substantial improvements in the way the data are exchanged among administrations (and with the ITU headquarters) are necessary. The aim of the proposed system is to improve that exchange.

Complexity

Radio frequency spectrum management on the international scale is based on negotiations, coordination, and the consensus principle. In the early stages of radiocommunications, bilateral negotiations were practical, as an administration was generally required to coordinate with one administration only. Later, the increased number of radiocommunication systems resulted in a necessity to coordinate among three and more administrations. The negotiations with one may lead to modifying the characteristics of the network. This, in turn, may necessitate renegotiations with the other, and even the involvement of a third party, new in the processing, may be required.

Such iterative coordination and search-for-agreement process, especially for satellite systems, absorb much effort and time. A key element is to identify the parties with which coordination is required. In the proposed system, all parties that have to be involved in the negotiation process will be identified automatically, taking into account technical issues. This will allow to limit the coordination meetings to those parties that are involved due to technical reasons only. By applying the system software and data with respect to contemplated frequency assignments, it will be possible to investigate effects of varying system design parameters and select the alternative that involves minimum negotiations. This may decrease the total number of bilateral and multilateral coordination conferences.

Fragmentation

The approach to computerization of spectrum management has been different in various countries. National spectrum management has historically been tailored to the specific needs and conditions of the country and was developed separately in each country. As a consequence, in many countries, domestic regulations, frequency allocations, radio wave propagation models, interference criteria, etc. do not necessarily coincide with one another and with the internationally agreed compromise standards. This creates additional barriers to exchange of goods and services across the borders.

All parties concerned agreed on the need to maintain and follow certain common standards to facilitate interchangeability of data, but the direct interworking of the national systems within the ITU has not been foreseen. As a consequence, the data elements required for the bilateral and multilateral coordination have to be extracted from the domestic databases, re-formatted, printed out, and re-entered again into computer in a new format. Repetition of work and multiple verifications to eliminate human errors are unavoidable.

This resembles the early days of telegraph, when a message was sent out and transmitted by wire up to the border of the country. Here, it had to be printed out and carried across the border by a special messenger. On the other side of the border, the message had to be re-entered again into the wire system because interworking of national telegraph networks was impossible. Although all parties agree that

interchangeability of data between different countries will facilitate their tasks, and some studies have already been undertaken in the Radiocommunication Sector, still much has to be done in that area.

Many thousands of man-years have been spent to develop specialized computer programs for spectrum management. About a hundred of them have been offered for free use within the ITU. These programs, however, are not portable and most of them are mutually incompatible.

As the number and complexity of radiocommunication systems grow, spectrum managers must not only employ a larger number of diverse computer tools but they must also work in teams to accomplish their task and communication and integration issues are becoming key elements. Desktop and portable computers, telephones, facsimile machines, and other devices can all be connected globally by wire and fibre optic cables and radio waves, but to interwork seamless they must "speak the same language". The proposed system addresses that issue through harmonization, automation and greater integration of the existing systems.

Technology gap

With the introduction of computers to spectrum management, a technology gap appeared and is increasing between the developed and developing countries. This is a serious problem for the whole radiocommunication community, not only for developing countries as the radio frequency spectrum is shared by all nations. If a portion of the spectrum is wasted or used wrongly by a country, it is damaging for another country. It is like on a street: pedestrians, cyclists and lorry drivers, all are involved and have to move in a coordinated way to avoid accidents. The issue is addressed in the proposed system by offering the administrations of developing countries the same access to common computer resources as to anybody else.

Data reliability

We witness continuing development of radiocommunications. New radio stations are being put into operation, others continue with modified characteristics, and still others cease. In many countries, the national databases follow these changes fast, but it may take a long time to submit the modifications to the ITU central registers. As a result, there is a difference between the data on spectrum usage stored in the international (ITU) and national databases.

The ITU register, with about one million entries, contains a rather unknown proportion of records that are invalid. The need for its maintenance is, therefore, questionable. The proposed system addresses that issue by an automatic relationship between the system database and the national databases. This will guarantee that international and national data are consistent and equally reliable.

3. System concept

Integration

Information exchange is an integral part of the ITU's mission. The future information system for the radio spectrum management will integrate within one computer network the existing resources available in administrations, ITU and other organizations. It will be a network of national and regional computer networks used for the spectrum management purposes. Video communication and other auxiliary equipment will be added to facilitate further spectrum management tasks.

The system will evolve following the changing requirements, technological developments and available budget. It will allow for the incorporation of new users, new data, new services and new tools, as required. The system will be maintained by the ITU and will serve as a framework for spectrum management in a national, regional and worldwide scale.

Functioning

The functioning of the proposed system will resemble the well-known air-ticket reservation network, where a client can consult flight schedules, select connections and carriers, reserve a seat and buy a ticket at his local travel agent's office. In our case, it will be the frequency and/or orbital positions instead of airplane seats, but the concept is the same.

Automatic examination

The technical examinations defined in the Radio Regulations will be automated. Additional automatic analyses will be possible, as well as trial analyses to investigate effects of varying system design parameters. The results and complete documentation will be available at the user's desk within seconds.

Automatic warning

If a potential conflict is detected, the victim parties can automatically be identified. The system will determine who, where, when and how is threatened, and the complete documentation of the interference analyses performed by the system will be available. The necessary coordination/ negotiation between the involved parties could begin without delay. Or the characteristics of station can be modified and the examination process repeated with the new data. The victim parties can be warned automatically as soon as the threat is discovered.

Automatic notification

If the results of the examination are positive, and there are no interference threats to third parties, the data of the station can automatically be submitted for the international notification and registrations in accordance with the agreed rules. There will be no need for any further re-examination.

System organization

The system resources will be structured into territorial (sub-national), national, regional, and world centres, to limit data transfer and system reaction time. They will be logically integrated and physically distributed, and will serve as a worldwide extension to the existing (or planned) national and regional radio frequency spectrum management centres. The maintenance of the system will be centralized at ITU headquarters. The source data will be entered and maintained directly by the source organizations. It could also be done at ITU field offices, or headquarters, if so required.

System resources

The proposed system will allow for use of distant computers and databases connected to the network. These will contain administrative information and statistical, geographic and technical data and engineering models and tools. The existing resources will serve as the kernel of the system and new data, models and tools will be added as required. Table 1 shows possible content of the system databases.

Table 1. Sample of data accessible within the information system

International agreements
Final Acts of Radio Conferences, ITU Convention, Constitution, etc. ITU Radio Regulations and Rules of Procedure Lists of coast stations, ship stations, call signs, etc. Recommendations of ITU and other organizations relevant to radiocommunications Records of the frequency and satellite orbit assignments World and Regional Frequency Allocation Plans World and Regional Frequency Assignment Plans
Administrative data
Addresses of national spectrum management authorities Frequency allocation plans (national) Frequency assignment plans (national) Monitoring stations data National Radio Regulations and relevant legal documents Other data
Spectrum engineering models and data
Electromagnetic compatibility (EMC) criteria Frequency planning and frequency assignment tools Frequency sharing analysis models Propagation models for various regions, applications and frequency bands Radio equipment data (including antenna characteristics)
Geographical data
Ground conductivity maps Maps of administrative (political) borders Maps of ionospheric characteristics Maps of radio climate Population density maps Radio noise distribution maps Road map Topographic (terrain elevation) maps

Users

The system is intended to be used by all authorized parties according to the terms and conditions established by the competent body. This embraces the national spectrum managers, international organizations, governmental contractors, service providers, equipment manufacturers, scientific organizations, universities and training centres, private consultants, ITU staff (at headquarters and field offices).

Access

The system will offer an equitable access to the system resources and will guarantee data security. The access to the resources will be under control. The domestic, or "private", data and the data intended for a common use will be separated. Each authorized user of the system will have the "read-only" access to the shared data. To guarantee the sovereign rights of each country, only the national spectrum manager will be authorized to enter, modify, or delete its national data. He also will decide which data are to be "private" and which to be "public".

Data exchange

An automatic exchange of technical and operational data, including graphics and computer programs, is required for the spectrum management. The exchange will be possible among various users within a country, between neighbouring countries and among countries, worldwide. The information will be available directly from the system databases, through the communication network, 24 hours a day, or on CDROM and computer printouts.

Function separation

Technical examinations, and all tasks that are performed repetitively following the agreed criteria, rules and algorithms, will be separated from the management and decision-taking functions. The repetitive functions will be done automatically without human intervention. In this way, once the criteria, rules and algorithms are agreed, the results will be free of human errors and human intervention. The proposed system will thus offer a full transparency.

International coordination

The technical coordination of radio stations will be simplified and more effective. The direct cooperation of the parties involved will be facilitated and regional cooperation will be enhanced. The entering of the notification data will be done by each national spectrum manager, and technical examinations will be automated. The workload imposed on the BR will change. The weekly circulars and associated correspondence will be superfluous. The ITU staff will focus on the maintenance and further development of the system and on users' assistance and training, taking into account special needs of developing countries.

Domestic

In some countries, radio frequency spectrum management tools and data will require modifications to harmonize them with others. Each authorized entity will have the equitable "read-only" access to the common resources. The existing technology gap in spectrum management will disappear. Administrative barriers and restrictions imposed on non-governmental entities will disappear.

4. Remarks on implementation

Creation of a network of interworking computer networks devoted to convey strategic information on radiocommunications as proposed in this article is not an easy task. Several barriers may be expected and some are listed below. In addressing the interworking question, it is not surprising that many non-technical questions are more difficult to solve than purely technical problems.

Table 2. Possible implementation scenario

phase 1	read-only access to the existing ITU data bases
phase 2	standard data structures for selected services agreed read-and-write access to the existing ITU data bases for selected services automatic submission of notifications for selected services automatic submission of modifications to selected frequency plans
phase 3	standard structure of electronic maps agreed electronic maps for selected regions created
phase 4	standard models and criteria for selected services agreed automatic trial examinations allowed with the existing ITU data bases
next phases	harmonization and integration of national data bases new system data bases created automatic exchange of data and updating of the system data bases further development of the system

Step-by-step

The proposed information system will probably be implemented in an evolutionary way, step-by-step, in close collaboration with all potential users. One may expect that the initial costs of the system will be limited to the costs of the necessary modifications of the existing software and data banks and of implementation of the relevant standards recommended by the Radiocommunication Study Groups and developed further accordingly. The cost of the hardware may be disregarded because, in any case, the existing hardware has to be re-placed by a new one every few years or so, due to technological progress. Table 2 shows a possible scenario of implementation. The read-only access to the existing ITU databases is the easiest phase. Other phases may be more difficult.

The partial automation in phase 2 will probably be limited to the satellite and short wave services, and majority of the frequency plans. The implementation of the proposed system can also be initiated in an individual country or region, where conditions are favourable and specific problems need to be solved without delay. European countries may wish to interconnect directly their national systems, as they are well developed and have much in common. The South American countries may prefer to begin with the electronic maps of the region, as they need them urgently. In any case, it is extremely important to avoid the further fragmentation as discussed in section 2.

Electronic maps

The creation of new computer tools and databases, especially for terrain elevation data, is an-other issue. To automate technical coordination and planning of radio stations, terrain data and other geographic data must be available in a computer-readable form of electronic maps. Such maps have already been in use in almost all developed countries, and in some international organizations, such as, for example the Food and Agriculture Organization of the United Nations (FAO).[⑤] Although this technique is more and more popular and electronic maps of some regions are available on compact disks

[⑤] *See Geographic Information Systems in FA 0, United Nations Food and Agriculture Organization (Rome, 1988).*

(CD-ROM),[6] many countries do not have access to such maps and cannot benefit from automation. It will be a great opportunity and challenge for the ITU to follow FAO's example and create a framework within which electronic maps of individual countries and regions could be created and used for the benefit of each Member.

Alternatives

Organizations that have more money than manpower often find more practical to purchase a turnkey system with an out-of-house support staff that provides all the services a system user might desire. Such a solution has many benefits but the purchase of a commercial software often initiates a long-term dependence on the software vendor. Organizations that have significant talent but less purchasing power prefer a public-domain option instead of a single software vendor. In this approach, the system is developed by the self-supporting user community exchanging ideas and software. The results of such common efforts are available to the public, nominally without charge. In our case, a combination of both approaches might be the best solution.

Previous attempts

There were proposals in the past to allow for an external access to the ITU (formerly the IFRB) data files, but they were premature and have never been realized. The pectrum management issues have always been separated into national and international, and data security and national sovereignty problems have been raised. Today, the situation is different. In the meantime, not only the view on the role of government has changed,[7] but also dramatic progress has been made in computer networking and data security and data compression.

The necessary infrastructure has been created in many countries and in the ITU. Practical experience has been gained with the ITU Telecom Information Exchange Services (TIES). TIES provides a set of computer-based information services to about 700 external users from 83 countries and to 300 ITU staff.[8] The services are accessible through the public telecommunication networks and Internet (with no charge for the use of most TIES services if accessed via Internet). There are thousands of computers used for the national radio frequency spectrum management purposes, worldwide. More than 50% of them are interconnected in local and national networks. The proposed system will take the full advantages of that infrastructure and experience gained till now.

Proprietary barriers

Almost each organization has its own set of application software and data banks and might not want to abandon them for that provided by another organization. Such arguments as "not invented here" or "not under my control" might hamper any attempt to create a common spectrum management information

[6] *See Struzak R. G.: Microcomputer modelling, analysis and planning in terrestrial television broadcasting, Telecommunication Journal, Vol. 59, No. X, pp. 459-492. 7 See The changing role of government in an era of telecom deregulation, ITU, 1993*

[7] *See The changing role of government in an era of telecom deregulation, ITU, 1993*

[8] *The users are: representatives of the ITU Member States (ministries, embassies, missions, ITU Council Members, national administrations' staff); officials of international organizations involved in telecommunications (e.g. the International Telecommunications Satellite Organization (INTELSAT), standardization (e.g. the European Telecommunications Standards Institute-ETSI and the International Organization for Standardization-ISO), development (e.g. the United Nations Development Programme-UNDP) and finances (e.g. World Bank); representatives of telecommunication operating agencies (e.g. AT&T), industrial organizations (e.g. SIEMENS), research organizations (e.g. the Centre national d'e'tudes des telecommunications-CNET), libraries and training institutes; field project officers, telecommunication planners and other ITU staff. See: What is TIES?, ITU TS SG2, Inf. Doc. 4, Geneva, 1-11 June 1993.*

system. Some software and data are proprietary, and intellectual property issues may create additional obstacles. There might be a lack of willingness to give access to the "monopolized" data. A computer network might be seen as a mean to import and export computer resources without physically moving the equipment across the borders. In some countries, it might fall under the regulations restricting the export of technological "know-how".

Technological barriers

Each country has its own list of priorities and in many countries, the radio frequency spectrum issues are not at the top of that list. Some developing countries might be unprepared to take immediately full advantage of the proposed system. Unreliable telecommunication networks and lack of qualified human resources may be the obstacles. Many countries will have to start to organize their databases, which needs time and money. Joining efforts, combining resources from several similar projects and, finally, special programs can be envisaged to overcome these difficulties.

Standardization barriers

The proposed system, like any other network, requires some common standards to be applied by all parties. Unfortunately, there are many standards, and not all them work together. The system should provide applications and data portability, but portability can be achieved now only across a limited set of platforms and often after significant conversion efforts. The available spectrum management software has not been designed with the portability and reuse in mind.[9] Their harmonization, or provision of appropriate interface software, is needed.

5. Conclusions

Development of radiocommunication services creates new requirements for radio frequency spectrum management. Trends towards liberalization, privatization and exchange of goods and services across the borders add new dimension to the problem. An improved management is needed to satisfy the increasing demand for new frequencies and to make a better use of the frequency resources, and the proposed information system is the key element. Spectrum managers and radio services planners will be allowed to analyse, store, update, model, display and exchange data they need quickly and easily.

Data files can be developed for various frequency bands and for large or small geographic regions at any scale desired within the limits of original source documents and the storage capacity of the hardware. Time savings due to automation are additional advantages. It will be a major project, which will change dramatically the way ITU Members solve the radio frequency management problems. In this article, we have attempted to outline the system concept and to point out some issues that must be addressed before the proposed system can be implemented. It is quite evident that the path to network interconnection of national systems is difficult, and that the main obstacles are not technical or economic, but political.

To fulfil its task, the proposed system must be well understood and accepted by all those involved in its creation and use. Its concept, or “vision”, has to be agreed upon as soon as possible, to avoid further problems in the management of the spectrum resources. We hope that this article will contribute to acceptance of such a common vision, that practical solution to the problems mentioned can be found within a not so far future and that ITU will play here the “catalytic role”, postulated by the High Level Commission.[10]

Original language: English

[9] *See: Struzak RG and Olms K: Software for radio spectrum management, Telecommunication Journal, Vol. 59, No IV, pp. 168-174*

[10] *See Tomorrow’s ITU: the challenges of change, Geneva 1991.*

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