INFRASTRUCTURE

# Guidelines for the preparation OF A TENDER TO SET UP OR UPDATE A SPECTRUM MONITORING NETWORK

Report

Telecommunication Development Sector

# Guidelines for the preparation of a tender to set up or update a spectrum monitoring network

**Acknowledgements**

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# Table of Contents

# List of tables, figures and boxes

**Figures**

# 1 Introduction

These guidelines are intended to provide a standard approach to set up a new or update an existing spectrum monitoring network. These guidelines do not include monitoring equipment tender documentation specifications. Such specifications will depend on the need and type of national monitoring and on the national laws and regulations.

These guidelines are based on the ITU Handbook on Spectrum Monitoring[1], which contains detailed information on monitoring system planning and tenders. Valuable information can also be found in the following ITU publications:

- National Spectrum Management[2]; and
- Computer-Aided-Techniques for Spectrum Management[3].

These three ITU handbooks have been developed by ITU-R Study Group 1[4] on spectrum management. ITU-R Working Party 1C[5] includes international experts on spectrum monitoring related studies, including the development of techniques for observing the use of the spectrum, measurement techniques, inspection of radio stations, identification of emissions, and location of interference sources.

Chapter 2 of this report provides a short introduction to the need for spectrum management, whilst Chapter 3 includes the role spectrum monitoring has in spectrum management. Chapters 4-13 further describe and discuss aspects to be considered and implemented when setting up a new spectrum monitoring network.

# 2 Spectrum management

The radio frequency spectrum, a natural limited and valuable resource, is used for all forms of wireless communications, including mobile telephony and broadband access, radio and television broadcasting, aeronautical and maritime communications, radiolocation and radionavigation, satellite communications (incl. tracking, tele-command, control), as well as for multiple science services (incl. for Earth observations and meteorology, sensing systems, space research, astronomy, etc.). The radio frequency spectrum (referred to simply as spectrum in these guidelines) is used to support a wide variety of commercial, public sector and governmental uses. Because the spectrum cannot support all of these uses simultaneously to an unlimited extent, its use must be managed or coordinated to prevent signal interference.

The growth in telecommunication services and radio technologies has led to an ever increasing demand for the use of spectrum among competing business, public sector and other users. Some established uses, such as broadcasting, microwave links, aeronautical and maritime radar, satellites, etc. continue to utilize significant amounts of spectrum. On top of this, the growth in mobile broadband communications has led to an increase in demand for mobile radio-based applications. This growth, against the background of maintained demand elsewhere, is placing increasing pressure on regulatory systems.

The task of strategic spectrum planning is becoming increasingly complicated. It must take into account the complex interaction between technical developments, market forces, economic development and social trends. It must also reflect international developments on regulations, harmonization and standardization, as radio waves do not stop at national frontiers and most major radio services are now developed for a global, or at least a regional market.

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1 ITU Handbook on Spectrum Monitoring 2011 (especially Annex 1): www.itu.int/pub/R-HDB-23
2 National Spectrum Management: www.itu.int/pub/R-HDB-21
3 Computer-Aided-Techniques for Spectrum Management: www.itu.int/pub/R-HDB-01
4 www.itu.int/en/ITU-R/study-groups/rsg1/Pages/default.aspx
5 www.itu.int/en/ITU-R/study-groups/rsg1/rwp1c/Pages/default.aspx

Thus, the efficient and effective management of the spectrum, while crucial to making the most of the opportunities that the spectrum resource represents, becomes more complex. Improved data handling capabilities and engineering analysis methods are key elements to accommodating the number and variety of users seeking access to the spectrum resource, including dynamic spectrum access. If the spectrum resource is to be used efficiently and effectively, the sharing of the available spectrum has to be coordinated among users in accordance with national regulations within national boundaries and in accordance with the Radio Regulations (RR) of the International Telecommunication Union (ITU) for international use and recognition. The ability of each Member State to take full advantage of the spectrum resource depends heavily on how spectrum managers facilitate the implementation of radio systems, and ensure their compatible operation. Furthermore, the imbalance between the demand for radio frequencies and the availability of spectrum keeps growing, especially in urban areas.

While the international framework for the utilization of the radio frequency spectrum is set out in the ITU Radio Regulations, there is considerable flexibility for the establishment of national policies within this framework. There are many ways to organise national spectrum management, as each country must develop its own system to meet political and legislative regimes and regional situations. ITU Recommendation ITU-R SM.1047[6] (national spectrum management) specifies the topics to be addressed for the development of national spectrum management programmes.

In this complicated task of national spectrum management, spectrum monitoring can assist in providing information on the actual use of the spectrum and to realise a usable spectrum that is as much as possible free of interference.

## 3 Role of spectrum monitoring in spectrum management

Monitoring can be defined as observing the use of the radio electric spectrum and reporting on it. This observing is done via measurements on single transmissions and via frequency band registrations.[7]

Spectrum monitoring serves as the eyes and ears of the spectrum management process. It is necessary in practice because in the real world, authorized use of the spectrum does not ensure that it is being used as intended. This may be due to the complexity of the equipment, interaction with other equipment, a malfunction of equipment, or deliberate misuse. This problem has been further exacerbated due to the accelerating proliferation of terrestrial wireless and satellite systems and of equipment that may cause interference, such as computers and other unintentional radiators. The monitoring system provides a method of verification and “closes the loop” on the spectrum management process.

Use of the spectrum occurs every hour, every day, every week of every year, whether locally, regionally, or globally. Likewise, spectrum monitoring should also be on a continuous basis if the purposes and goals of monitoring are to be appropriately fulfilled.

The purpose of spectrum monitoring is to support the spectrum management process in general, including frequency assignment and spectrum planning functions. Recommendation ITU-R SM.1050[8] (Tasks of a monitoring service) specifies the tasks to be assigned to a monitoring service. Goals of monitoring (not necessarily in order of priority) could be summarized as follows and are illustrated in Figure 1:

- Assist in the resolution of electromagnetic spectrum interference, whether on a local, regional or global scale, so that radio services and stations may coexist compatibly, reducing and minimizing

[6] www.itu.int/rec/R-REC-SM.1047

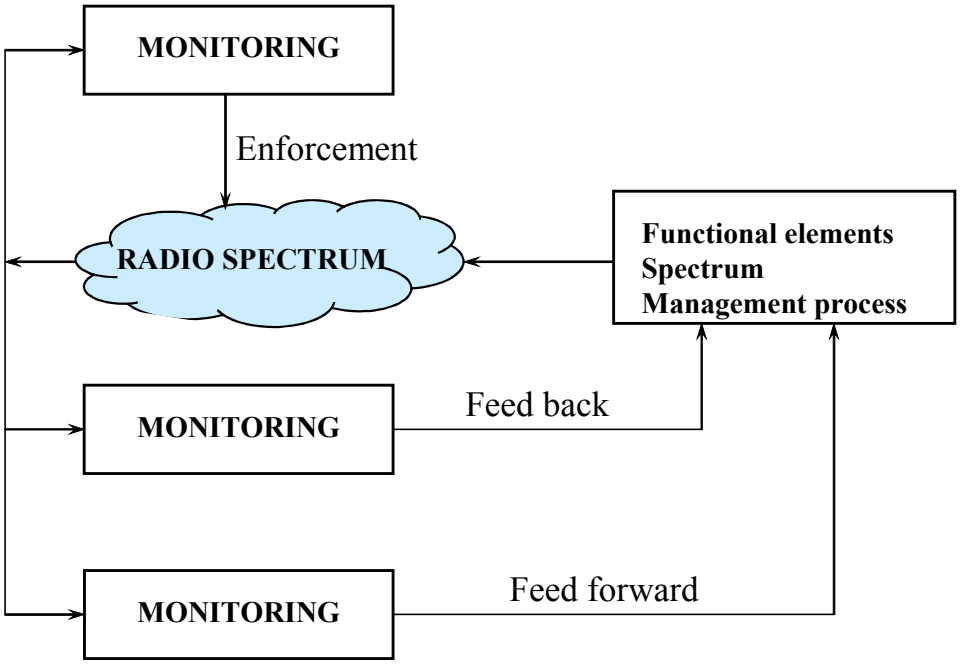
[7] Measurement is the process of assigning a value to an attribute or phenomenon. The result is, in principle, independent of the procedure used. Nevertheless, the accuracy of the measurement process is essential to obtain a reliable value.

[8] www.itu.int/rec/R-REC-SM.1050

resources associated with installing and operating these telecommunication services while providing economic benefit to a country's infrastructure through access to interference-free, accessible telecommunication services.

- Assist in ensuring an acceptable quality of radio and television reception by the general public.
- Provide valuable monitoring data to an administration's spectrum management process concerning the actual use of frequencies and bands (e.g., channel occupancy and band congestion), verification of proper technical and operational characteristics of transmitted signals, detection and identification of illegal transmitters, and the generation and verification of frequency records.
- Provide valuable monitoring information for programmes organized by the ITU Radiocommunication Bureau, for example in preparing reports to Radiocommunication Conferences, in seeking special assistance of administrations in eliminating harmful interference, in clearing out-of-band operations, or in assisting administrations in finding suitable frequencies.

Figure 1: The role of monitoring in the spectrum management process




Source: ITU

The role of monitoring in the spectrum management process:

1. The spectrum is used for all kinds of radio transmission. The spectrum management elements (e.g. frequency allocation, assignment, licensing, and enforcement) are important for efficient and effective use of the spectrum. National authorities set rules for the use of the spectrum via assignments, licence parameters, etc.
2. The monitoring service observes the radio spectrum. The monitoring operators compare whether the use of the radio spectrum matches the various spectrum management elements (feedback).
3. In observing the radio spectrum, monitoring provides spectrum management information on potentially unforeseen elements of the radio spectrum. When trials for a new service are being run before a policy (regulations on a new service) has been developed, spectrum management monitoring can observe and provide useful information on it (feed forward). Under this principle, monitoring can also assist spectrum re-farming by providing information on the frequency band to be re-farmed if the frequency band is 'ready' (no, or free of, previously assigned users) for the new use or services.
4. Monitoring can also address radio spectrum users directly in case of interference or technical infringements of national (or international) regulations. Operators can use monitoring to provide guidelines to users such as on how to avoid interference. This is referred to as an enforcement activity.

## Relation between monitoring and spectrum management

The functions of spectrum monitoring and spectrum management are closely related. Linking these functions through an integrated computer system can result in significantly increased effectiveness and cost-efficiency for both.

- It is critically important when implementing a spectrum management system to first develop a system structure that maintains the integrity of the process, and a database that contains all relevant information to support the process.
  - ITU Recommendation ITU-R SM.1370[9] provides design guidelines for developing automated spectrum management systems. In the case of an inadequate database, the combination of monitoring and enforcement techniques can be effectively used to obtain critical information and thereby, help improve the database and the overall spectrum management process.
  - ITU Recommendation ITU-R SM.1537[10] describes the automation and integration of spectrum monitoring systems with automated spectrum management.
- Monitoring is also closely associated with inspection and compliance in that it enables the identification and measurement of spectrum usage, interference sources, the verification of proper technical and operational characteristics of radiated signals, and detection and identification of illegal transmitters, producing data on the effectiveness of spectrum management policies.
- Monitoring further supports the overall spectrum management efforts by providing general measurements of channel and band usage, including channel availability statistics of a technical and operational nature, thereby giving a measure of spectrum occupancy.

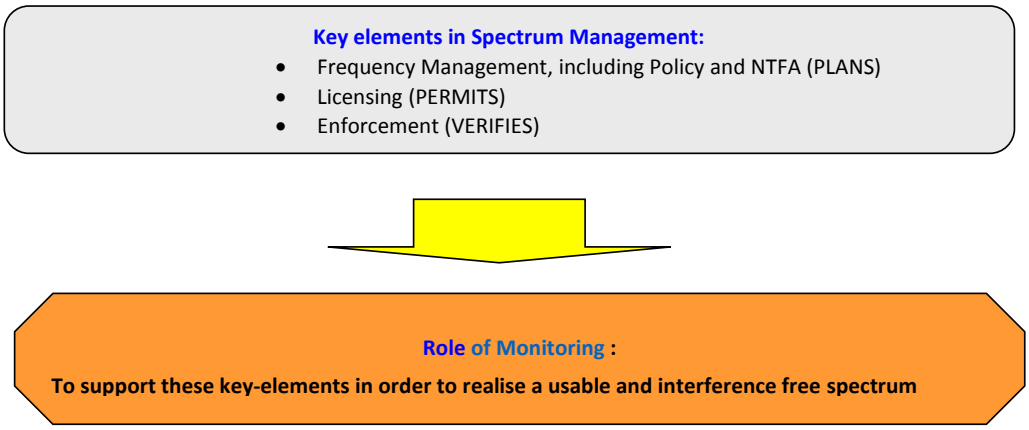
9 Design guidelines for developing automated spectrum management systems: www.itu.int/rec/R-REC-SM.1370

10 Automation and integration of spectrum monitoring systems with automated spectrum management: www.itu.int/rec/R-REC-SM.1537

- Monitoring is also useful for planning, in that it can assist spectrum managers in understanding the level of spectrum use as compared to the assignments that are registered on paper or in data files. A monitoring and measurement system can help in some instances where a solution to a problem requires more than knowledge of authorized or designed characteristics of radio systems. A monitoring and measuring system also obtains information on the operation of individual stations, for regulatory, enforcement, and compliance purposes, and can be used to establish the location and identity of stations causing interference.

In general terms, monitoring gives feedback to spectrum management on whether the practical use of the spectrum matches the national policy. Monitoring can also identify the need for future requirements for spectrum management officials. In this case monitoring gives feed-forward information to spectrum management.

Figure 2: Key elements in spectrum management




Source: ITU

# 4 Setting up or updating an existing monitoring network

Monitoring has to serve the whole spectrum management organisation and for this reason it is essential that before decisions are taken on what type of monitoring equipment is needed, a fundamental discussion must be held between the spectrum management organisation stakeholders to identify the need for monitoring support on a national level. Once this is agreed, a system design can be identified and the technical specifications can be developed.

## 4.1 Considerations leading to design

A monitoring network system design requires a number of monitoring issues to be considered based on:

- the responsibility of the spectrum management organisation (regulator);
- the functional elements of the spectrum management organisation;
- the future use of the spectrum;
- monitoring needs;
- practical considerations.

### Need for monitoring based on the responsibility of the spectrum management organisation (regulator)

Depending on the responsibility of the spectrum management organisation (i.e. regulator) for the national use of the spectrum, the need for monitoring support can be identified. In some countries the spectrum management organisation is responsible for all national spectrum use, including spectrum use by governmental organisations (e.g. military, police) as well as aeronautical and maritime use. In some other countries the spectrum management organisation is only responsible for the commercial use of the spectrum and other entities such as other governmental organisations and broadcasting have their own spectrum management responsibility. ITU report ITU-R SM.2093[11] on *Guidance on the regulatory framework for national spectrum management* provides guidance and includes possible approaches to management of national spectrum organizations. From this responsibility, it has to be decided which frequency range and geographical areas need twenty four hours a day, seven days a week monitoring support via fixed (remote) locations.

### Need for monitoring based on the functional elements of the spectrum management organisation

Frequency planning, including engineering, licensing and enforcement departments are setting the rules and regulations for the use of the spectrum based on the responsibility of the spectrum management organisation (i.e. regulator). These entities indicate the frequency ranges, user groups, type of measurements and geographical areas that need monitoring support and how frequently monitoring data needs to be collected.

As an example:

- Frequency planning will need to know the border area spectrum use, in addition to frequency band occupancy, in order to identify possible spill-over by neighbouring countries and to have a good understanding of the use of the various frequency bands.
- Licensing will need data on spectrum use in areas with high density via frequency channel occupancy measurements. The licensing department will use these measurement to decide if incumbent users should share the frequency with a new applicant(s) or if a new frequency should be assigned.
- Enforcement will need to organise monitoring campaigns to identify illegal use.

### Need for monitoring based on the future use of the spectrum

Monitoring equipment is expensive, so it is important that present and future spectrum use is taken into account, for example, it does not make sense to invest in monitoring capabilities for analogue broadcasting, but digital broadcasting is essential.

### Need for monitoring based on monitoring needs

Chapter 3 defines monitoring as *observing the use of the radio electric spectrum and reporting on it*. This definition includes collecting data, not only on request of the functional elements of the spectrum management process, but also on frequency bands where no information is requested. Monitoring collects information on these frequency bands in order to provide it to the functional elements whenever that information may be required.

### Need for monitoring based on practical considerations

Finding locations for fixed (remote) stations is often difficult, with many ideal locations already occupied by high powered broadcasting stations or by mobile operators, too close to high power lines, etc. or there are other infrastructure issues, such as access, electricity supply, or communication infrastructure. When a less than ideal location is used, this often means that more stations are needed to cover a specific geographical area.

[11] www.itu.int/pub/R-REP-SM.2093

## 4.2 Illustration with the planning and optimization of spectrum-monitoring networks in the VHF/UHF frequency range

The ITU *Procedures for planning and optimization of spectrum-monitoring networks in the VHF/UHF frequency range* (Report ITU-R SM.2356)[12] includes discussions on three different methods for planning and optimization of spectrum-monitoring networks (SMN) in the VHF/UHF frequency range. The first model combines angle of arrival (AOA) measurements from multiple sites using direction-finding antenna arrays to determine the emitter location. The second combines time difference of arrival (TDOA) measurements from a minimum of three sites (two pairs of TDOA measurements between the three sites are required for geolocation). The third method combines both AOA and TDOA measurements to perform geolocation processing (a minimum of two sites are needed: one with both AOA and TDOA capability, and one with TDOA capability only). Report ITU-R SM.2356 includes three annexes:

- Annex 1: Practical example on local AOA SMN planning at relatively plain terrain.
- Annex 2: AOA SMN planning in mountainous and hilly regions.
- Annex 3: Receiver performance and its impact on network coverage.

## 4.3 Type of equipment and type of stations (including numbers)

The needs discussed in the sections above will lead to a decision on the design of the new network. The design leads to the following questions:

- What are the monitoring principles?
- Based on the size, geographical location and topography of the country and/or its regions:
  - Where will the manned monitoring stations be located?
  - Where will the automated remote fixed monitoring stations be located?
- What are the frequency bands to be covered?
- What type of equipment is needed?
- How many mobile monitoring vehicles are needed?
- How many transportable stations are needed?

## 4.4 Where to locate monitoring stations

In most countries there exists only one manned monitoring station. This manned station controls the whole network via the fixed and/or wireless communication network.

However more than one manned station will be needed to avoid long travelling times for mobile monitoring in large countries, or where spectrum management is a regional responsibility. The design should therefore consider:

- the need for monitoring coverage for certain geographical areas;
- how many stations are needed to cover a predefined area, depending on the tasks to be carried out.

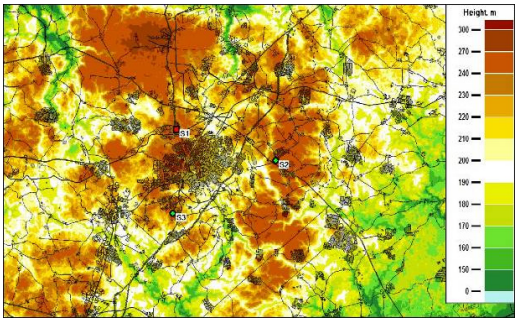
For listening purposes, one station needs a lower signal for measurements, whilst for direction finding a stronger input value is needed. The ITU Handbook on Spectrum Monitoring[13] (Chapter 6, section 6.8) includes information how to calculate the coverage of a monitoring station in a geographical area.

[12] www.itu.int/pub/R-REP-SM.2356
[13] www.itu.int/pub/R-HDB-23-2011

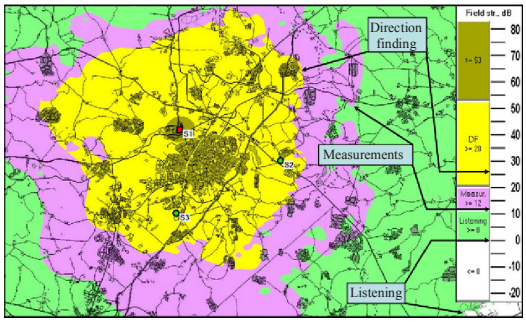
Figure 3: Monitoring coverage needs

Topography of the area in question

Monitoring coverage areas of station S1, showing the external boundaries of the listening, measurement and direction-finding coverage zones




Spectrum-6.8-02




Spectrum-6.8-03

Source: ITU

The right side graph in Figure 3 indicates that the coverage for listening needs a lower value signal than necessary for measurement purposes. To take correct direction finding (DF) measurements an even stronger signal is required.

Therefore, for coverage of a large city, where also DF is required for speedy interference resolution, the coverage is determined by the coverage by DF, which in the graph on the right is the yellow area.

### Which frequency bands are to be monitored?

The choice of frequency bands to be covered is decided during the design of the network. In the past, monitoring was tasked to cover the high frequency (HF) range, whilst nowadays focus is on even higher frequencies, VHF/UHF, and due to the increasing implementation of broadband wireless access (BWA) systems, even the SHF (super high frequency) bands are becoming more important to cover by monitoring.

Depending on the responsibility of the spectrum management organisation (i.e. regulator), it might be necessary to equip one mobile monitoring station with HF direction finding capabilities and the (remote) fixed stations with an HF receiver.

In general terms, the following frequency ranges can be used:

- For fixed (remote) and transportable stations 20 – 3000 MHz for measurements and direction finding.
- Sometimes it is argued that for the fixed (remote) and transportable stations the upper range should be 6000 MHz, however the use of the spectrum above 3000 MHz is in most cases for small areas only and as such it does not make sense to equip these stations above 3000 MHz as they are too far away from those very small user areas.
- For mobile monitoring stations 20 – 6000 MHz, and depending on the use of BWA above 6 GHz the range for monitoring will be 20 MHz – 8 GHz.
- For portable operations a handheld receiver is needed in the frequency range 20 – 6000 MHz.
- For monitoring the frequency ranges used by fixed links, equipment is needed up to 40 GHz upgradable to 50 GHz. For this monitoring a portable spectrum analyser may be used.

Both the portable receiver and spectrum analyser are installed in the mobile monitoring station to be able to continue with monitoring on places where the mobile station cannot go.

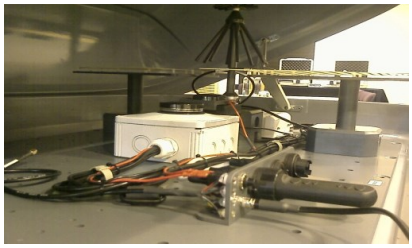
## Which type of stations are needed?

A number of types of station are known: fixed (remote) monitoring stations, mobile monitoring stations, including portable equipment, and transportable stations.

- Fixed (remote) monitoring stations are used for all types of monitoring tasks and cover a certain geographical area.
- Mobile monitoring stations, including portable equipment are used for all types of monitoring tasks and are able to cover those areas that cannot be covered via the fixed stations. Interference handling, including location identification, is an especially important task for the mobile stations.
- Transportable stations are used for all types of monitoring tasks. These stations are equipped in the same way as fixed stations. The purpose of transportable stations is for monitoring at locations where there is no complete coverage by fixed locations. Using transportable stations for a specific time gives a good impression of spectrum use in the monitored area before being moved and installed at other locations.

To collect data for the use above 3 GHz, it is not possible to do this via traditional (remote) fixed stations. A possible solution might be to collect data on the use of the spectrum using mobile data collection. In this case, a car can be equipped with a receiver and positioned near to the transmitter. This will provide a good overview of the spectrum use (even on street level).

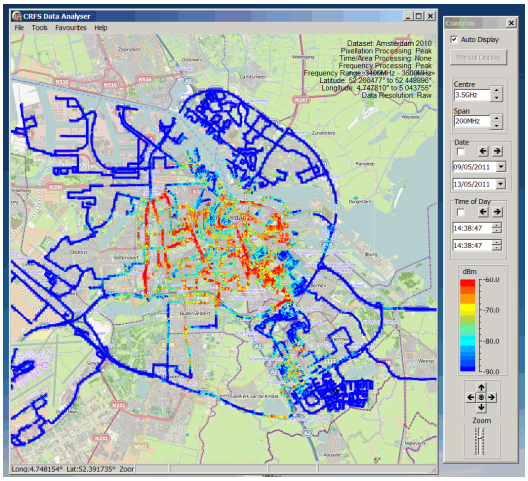
Figure 4: Car equipped with a receiver

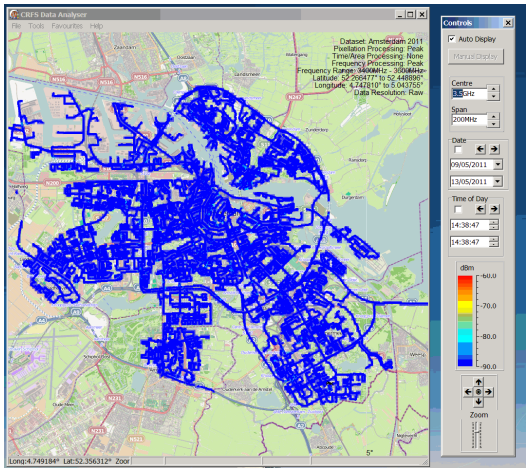


Source: ITU

Figure 5: WiMAX in the 3.5 GHz range in the city of Amsterdam (mobile data collection)

2010 2011




Source: ITU

An example of such mobile data collection is given in the graphs in Figure 5, where the use of WiMAX in the 3.5 GHz range in the city of Amsterdam, the Netherlands was collected. In the 2010 graph, there is clearly WiMAX observed (in red, blue is noise). In the 2011 graph, the same programme was carried out and it clearly shows that there is no WiMAX being used.

In fact, the available budget will decide what type of stations can be procured. If the budget is very low and there is no external funding, the best is to start with a mobile monitoring station only. This mobile station can be equipped to cover all possible tasks that are assigned to monitoring. The moment additional budget is available a phased set up for a network is advised:

- First phase: Install the manned station, where the main control centre and a mobile monitoring station are located.
- Second phase: The most important areas need to be covered via (remote) fixed stations and other mobile monitoring stations.
- Third phase: The stations for the less important areas can be installed, including transportable stations.

For interference resolution, it is advised to use the facilities at the (remote) fixed locations, or to go directly with a mobile station to the location from where the interference is reported, which may be more efficient because trying to identify possible interference using the frequency planning, licensing, and interference databases etc. can be very time consuming.

For this, the following principle is applicable:

***What can be done using the equipment and facilities of the (remote) fixed monitoring stations should not be done by mobile monitoring stations.***

The consequence is that in remote areas, there is a need for more direction finding equipment for triangulation reasons. If the design of the new network with the desired quality cannot be covered by the available budget, the following steps are considered:

- Consider the most important areas to be covered: The various stakeholders shall need to set priorities because the required levels of quality cannot be ensured through the use of fixed monitoring stations everywhere.
- Consider the number of transportable stations: These stations can carry out the measurement tasks for which initially a fixed monitoring station was foreseen.
- Consider the number of mobile stations: If a considerable reduction of (remote) fixed stations is needed, one or two additional mobile stations may perform the monitoring tasks in areas that should be covered initially by fixed monitoring stations.

### Quality of the equipment

The quality of the equipment is of major importance as the equipment must respond to the demand for monitoring with the required quality. The following aspects are to be taken into account:

- Antenna system- What type of antennas are needed?
- Receiver- What is the quality of the receiver?
- Measurements- What type of measurements are to be done?
- Processing results- How does the results look like? They should be user friendly?
- Communication- How is the network configuration connected?

#### *Antenna system*

The following is to be considered:

| Task | Type of antenna per required frequency range |
|---|---|
| Measurements | Omni directional antennas |
| Interference handling | Directional antennas, direction finding |
| Illegal use of the spectrum | Vertical and if possible horizontal polarisation |

### *Receivers*

To assist customers in setting the quality of the receiver, a number of ITU-R SG1 WP1C Recommendations have been developed that include a measurement protocol to allow customers to compare the values as provided by the manufacturers. It is underlined that the relevant sections of the Handbook are intended to be seen as background information and do not have the same status as the mentioned Recommendations.

**Monitoring equipment test measurement procedures**

| | |
|---|---|
| Selectivity of monitoring receivers | Recommendation ITU-R SM.1836<br>Report ITU-R SM.2125 |
| IP3 of monitoring receivers | Recommendation ITU-R SM.1837<br>Report ITU-R SM.2125 |
| Noise figure of monitoring receivers | Recommendation ITU-R SM.1838<br>Report ITU-R SM.2125 |
| Scanning speed of monitoring receivers | Recommendation ITU-R SM.1839<br>Report ITU-R SM.2125 |
| Sensitivity of monitoring receivers | Recommendation ITU-R SM.1840<br>Report ITU-R SM.2125 |
| Direction finder accuracy | Recommendation ITU-R SM.2060 |
| Direction finder immunity against multi-path propagation | Recommendation ITU-R SM.2061 |
| Other parameters | Report ITU-R SM.2125 |

### *Measurements to be performed*

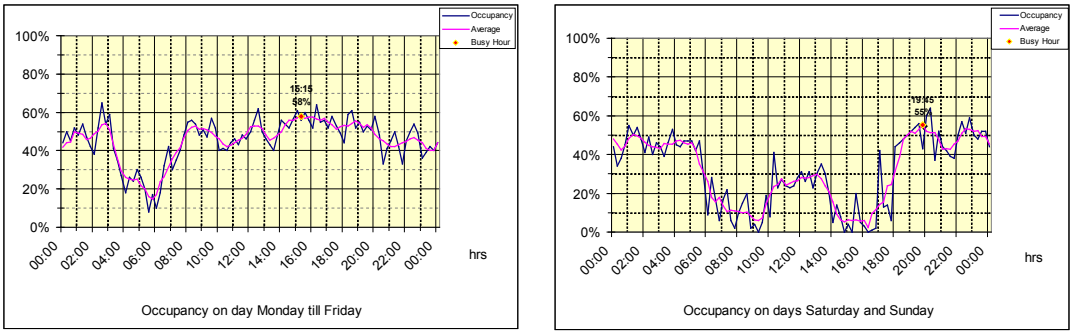
| Signal Parameter measurements | |
|---|---|
| Frequency | Recommendation ITU-R SM.377, ITU Spectrum Monitoring Handbook, 2011, Section 4.2 |
| Field strength (see also Radio Regulations Art. 21 | Recommendation ITU-R P.845<br>Recommendation ITU-R SM.378<br>Recommendation ITU-R SM.1447<br>Recommendation ITU-R SM.1708<br>ITU Spectrum Monitoring Handbook, 2011, section 4.10 |
| Modulation | Recommendation ITU-R SM. 1268<br>ITU Spectrum Monitoring Handbook, 2011, Sections 4.6 and 4.8 |

| Signal Parameter measurements | |
|---|---|
| Bandwidth | Recommendation ITU-R SM.443<br>ITU Spectrum Monitoring Handbook, 2011, Section 4.5 |
| Identification | Recommendation ITU-R SM.1600<br>ITU Spectrum Monitoring Handbook, 2011, Section 4.8 |
| Signal analysis | ITU Spectrum Monitoring Handbook, 2011, Section 4.8 |
| Measurements related to the inspection of radio installations | Report ITU-R SM.2130<br>Report ITU-R SM.2156 |

### *Processing results*

The monitoring system is collecting an enormous amount of data that needs to be processed in a user friendly format for further handling. The graphs in Figure 6 represent the channel occupancy on a frequency channel used by a taxi company. The difference between week and weekend days can be clearly seen. It is important that the licence department can analyse the results of such measurements to decide how a new licence should be issued, either with incumbent users on the same frequency or that a new frequency needs to be assigned.

Figure 6: Channel occupancy of a frequency channel used by a taxi company




Source: ITU

There are various types of results for the various measurements presented by the manufacturers. In discussion with the stakeholders the form of presentation should be decided and included in the specifications of the technical document of the tender.

### *Communication infrastructure for the network*

Based on the design, the various stations are to be connected to a control room for:

- direct control;
- uploading measurements tasks;
- downloading results.

Questions to be answered:

- Is there a need for remote control via Internet?
- Is a fixed communication network available?
- How to connect the mobile monitoring stations to the control room?

# 5 Financing the system

The following possibilities are available for financing the system:

- national resources;
- financial institutions/development partners (e.g. the World Bank);
- through spectrum licence fees (individual licences need to mention that contribution is needed for developing monitoring systems);
- other funding.

If funding is through national resources, the customer is able to set its own criteria for making a choice of the manufacturer for awarding the project. If the funding is by financial institutions/development partners, the rules for evaluation and awarding are set by the procedures of the financial institutions/development partners[14].

# 6 Development of a tender document: Request for proposals

After having decided on the design, type and number of stations with the required quality, the next step is to develop the various parts of the request for proposals (RFP); interested manufacturers are asked to send in a proposal based on the requirements of this tender document. The following documents should be included in the RFP:

- Master document.
- Technical and service specifications document.
- Commercial and legal conditions document.
- Compliancy matrix.

## 6.1 Master document

The master document should contain at least the following parts:

1. Introduction: Information on the customer its mission and objectives.
2. Structure of the RFP: This should include how the RFP is organised, including type of documents and a description of the type of compliance.
3. RFP process: In this process, a description is given on the purpose of the RFP, the time line, questions and answers regarding the RFP, the RFP evaluation criteria, and the date when the valuation outcome is expected.
4. Response instructions: This should include the RFP structure of the requirements, format of the response, sections format, and information on the compliancy matrix, how and where the documents should be delivered, response costs, and delivery address.
5. Overview of the design of the system: Information is included on the design, type and number of stations, the frequency range, and where they will be installed. Furthermore information is included on the overview of service required and the timeline of the delivery of the new system.
6. Statement of requirements: Information is given on general requirements, conditions, and future proofing.

[14] Additional details on the economic aspects of spectrum management can be found in ITU report on Economic aspects of spectrum management (ITU R SM.2012): www.itu.int/pub/R-REP-SM.2012

## 6.2 Technical specifications document and service document

In the technical specifications and services document the following is included:

1. Introduction: Type of documents.
2. Terminology: As used in the RFP document.
3. Overview of the design: Details on the stations such as architecture, requirements of hardware, software, interfaces, operational support, and if applicable, a breakdown in case the system is delivered in phases.
4. Statement of technical requirements: In the statement of the technical requirements all information is included on the type, frequency range, type of measurements, quality of the equipment according to ITU-R Recommendations, power supplies, requirements on lightning, safety of the vehicles etc. Furthermore, a detailed description of the software requirements to control the system should be included, including software licences, management information system, principles and features of the remote control of the stations, communication within the system, display formats, calibration and self-testing, reports to be produced, interface with a spectrum management system (such as ITU SMS4DC) if applicable, and analysis of the measurement results.
5. Statement of services requirements: In the service requirements, information is included on standards such as ISO 9001, project management, logistics management; installation, project lifecycle, ancillary technical deliverables, language support, training, testing and commissioning, soft and hardware maintenance; hard and software warranty, and maintenance and repair outside the warranty period, including local support.

## 6.3 Commercial and legal conditions document

In the commercial and legal conditions document the following is included:

- Bidding structure: In this part, the bidder includes details of the company, and if applicable the partners in the joint venture. This part has to be signed by the bidder.
- Terms and conditions including, e.g. conditions for financial proposal: These terms and conditions include information on the validity of the proposal (e.g. 120 days after submission), conflict of interest, proposals format, proposals options (e.g. one proposal only or in combination with other firms), proposal sections format, technical evaluation and weighting criteria, financial proposal, acceptance or rejection of proposals, bidders legal responsibility, permits and licences, disclaimer, confidentiality, new releases, proposals costs, bidders responsibility, pre-proposal communication, disclosure of proposals contents, examination of the RFP documents, payments and taxes, documents data and proprietary information, suspension and working credentials.
- Project administration: This includes information on project management during the project, project manager on behalf of the bidder, etc.

## 6.4 Compliancy matrix

In addition to relevant sections of the master document, the compliancy matrix document includes:

- Response information on compliancy, the bidder shall respond as follows:
  - The supplier shall fill each tab with the requirements contained in each respective RFP document listed in the *contents tab*.
  - The supplier shall fill in the requirements in order they appear in the RFP document and with no breaks in between requirements belonging to different sections of an RFP document.

  - The supplier shall respond to each requirement based on the 'compliancy type' described in the relevant section of the master document.
  - The supplier shall provide references, where necessary, to a particular response by clearly providing a reference ID in the remark column; no document shall be embedded in this spreadsheet (also see relevant section of the master document).
- The type of compliance can be included as C (for compliant), NC (for non-compliant) or PC (for partly compliant).
- Compliancy to the master document.
- Compliancy to the technical and services document.
- For the master, and technical and services documents the format to be used is as follows:

| Requirement ID | | | Description of requirement | Compliancy | Supplier remarks, ref. |
|---|---|---|---|---|---|
| Doc. ID | Section ref. | Req. No. | | | |

## 7 Release of the tender

Depending on the type of tender and national regulations, the tender documents can be published[15], and once the tender documents are released:

1 *manufacturers* must indicate their willingness to send in a proposal to the RFP (normally within one week), and to send any questions they have regarding the RFP documents;

2 the *tendering organisation* must respond to these questions within one week and forward those responses to all bidders, before organising a site survey to allow bidders to see the local situation.

## 8 Evaluation of the bids

For the evaluation of bids, the following documentation is to be provided and are to be seen as an integral part of the bid of each manufacturer:

- the description of the proposed system;
- the response via the compliancy matrix;
- the relevant datasheets to proof the statements as included in the description and compliancy matrix documents.

All proposals received within the deadline for sending in proposals, will be evaluated based on:

- criteria as set and included in the commercial and legal document;
- for every technical requirement the compliance type result will be included;
- at the end of the technical evaluation, the total score will be determined;
- only those bids having a score above a predefined percentage will be taken into account for the financial offer;

[15] The documents in some countries are made public via the state journal or in case of a limited tender (if it is decided that only a limited number of manufacturers will be invited), directly forwarded to the specific manufacturers.

- the technical and financial score will lead to the winning bidder;
- the intention is to award the project to this bidder and contract discussions will follow.

### Evaluation criteria

In the commercial and legal document, weighting criteria must be included, for example:

- 70 per cent for the technical requirements;
- 30 per cent for the financial proposal.

The 70 per cent for the technical requirements is to be split up into:

- 70 per cent for the technical requirements;
- 20 per cent for the service requirements;
- 10 per cent for training.

In most countries, the technical evaluation is first carried out before the financial proposals are taken into account so that the price (as proposed) would not influence the technical evaluation. In some countries, openness and transparency is mandatory by law, making the information available to all.

## 9 Award of the project

After the evaluation, the winning bidder is informed by the tender organisation via a letter of intent, and invited for contract discussions. These discussions are necessary to find solutions for:

- the bidder, if not fully in compliance with the requirements;
- a start date for implementation;
- any other item for discussion.

After having concluded and agreed on all aspects of the project, the project documents and contract may be signed.

## 10 Implementation of the new network

During the implementation phase, special attention should be made to:

- the detailed design review as a result of the modifications agreed during the contract discussions;
- the design in accordance with the required design;
- all elements are described properly;
- project plan milestones;
- project management;
- civil work, if needed;
- importation of goods into the country;
- the deadline for the complete system to be delivered.

## 11 Training

The winning manufacturer will ensure proper training before the system is handed over, in order to allow the staff to control the systems with all features. Training will include:

- monitoring fundamentals;
- equipment features;
- system control;
- how to handle the output of the system.

Further training is required for staff to carry out the necessary system maintenance. The service document includes the number of staff to be trained and, in most cases, the training venue.

## 12 Testing

During the implementation phase, it is necessary to have a few pre-defined testing phases to be sure that the new network will perform as required. For this reason the manufacturer will organise:

- Factory acceptance test (FAT) at the venue of the manufacturer:
  - on pre-agreed testing parameters for the system;
  - witnessed by representatives of the customer;
  - on all sub-parts of the system, including vehicles and equipment that are not necessarily made by the chosen manufacturer e.g. spectrum analysers, portable receivers, etc.
- Site acceptance test (SAT) after installation, a total *in situ* system test with pre-agreed parameters:
  - remote control of the system;
  - performing required measurements;
  - interconnection of the system.

Based on the results of the tests, the manufacturer will ensure that any malfunction during the tests will be repaired before handing over the system to the customer.

## 13 New system into use

Once the new system is tested, and in accordance with the specifications of the tender documents, the handing over protocol is signed and from that moment the new system is under the full responsibility of the customer. The maintenance contract includes all relevant aspects of maintenance, such as response dates, and any support to the customer by the manufacturer, etc.

## Abbreviations[16]

| | |
|---|---|
| BWA | Broadband Wireless Access |
| C | Compliant |
| DF | Direction Finding |
| FAT | Factory Acceptance Test |
| GHz | Gigahertz |
| HF | High Frequency |
| ID | Identification |
| IP3 | Third order intercept point |
| ISO | 9001 International Standard on the quality of management systems |
| ITU | International Telecommunication Union |
| ITU-R | ITU Radiocommunication Sector |
| kHz | kilohertz |
| LoI | Letter of Intent |
| MHz | Megahertz |
| NTFA | National Table of Frequency Allocations |
| NC | Non-Compliant |
| PC | Partly-Compliant |
| RFP | Request For Proposal |
| SAT | Site Acceptance Test |
| SHF | Super High Frequency |
| SMS4DC | ITU Spectrum Management System for Developing Countries |
| UHF | Ultra High Frequency |
| VHF | Very High Frequency |
| WiMAX | Worldwide Interoperability for Microwave Access |

[16] For a detailed database of terms and definitions, see: www.itu.int/online/termite/index.html

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