

## RECOMMENDATION ITU-R SM.1537

**Automation and integration of spectrum monitoring systems  
with automated spectrum management**

(Question ITU-R 68/1)

(2001)

The ITU Radiocommunication Assembly,

*considering*

- a) that automated spectrum management systems are available to support administrative, licensing, engineering analysis, and monitoring control activities to simplify many of the responsibilities of administration of the radio spectrum;
- b) that modern computer networks allow an administration's automated spectrum management system and spectrum monitoring stations to be linked together so that a user at any operator workstation in the system can, with proper security authorization, access all of the resources of the general spectrum management and monitoring components, allowing very flexible integrated tasking and reporting;
- c) that integration of the monitoring stations with the management system allows such an integrated system to perform automatic violation detection – to identify frequencies on which there are transmitters which are not included in the licence database, and to identify transmitters which are not operating within their licensed parameters;
- d) that modern digital signal processing (DSP) techniques allow economical automation of monitoring stations, with measurements at a station performed by a small group of receivers and related electronics integrated with a computer, which reduces system cost relative to the cost of older systems which meet ITU Recommendations for minimum equipment for monitoring stations, lowers system size and weight, and may simplify maintenance and training;
- e) that the trend in technology is towards DSP-based measurement servers which are able to provide very broad instantaneous bandwidth along with a high dynamic range, so that such systems can scan very rapidly, and effectively acquire and measure intermittent, broadband and frequency agile signals;
- f) that modern computer graphical user interface (GUI) software allows powerful spectrum management and monitoring systems to be easy to use and easy to maintain;
- g) that many administrations already have computerized licence databases, from which information should be available to spectrum management and monitoring systems,

*noting*

- a) 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;

- b) that the analysis of data from an automated system requires trained and/or experienced operators who are able to perform such analysis;
- c) that automatically-acquired monitoring data should be validated by operators before entry in a central database,

*recommends*

**1** that administrations which intend to procure new spectrum management and monitoring systems should consider procuring an integrated, automated system using a common relational 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 is described and explained in more detail in Annex 1.

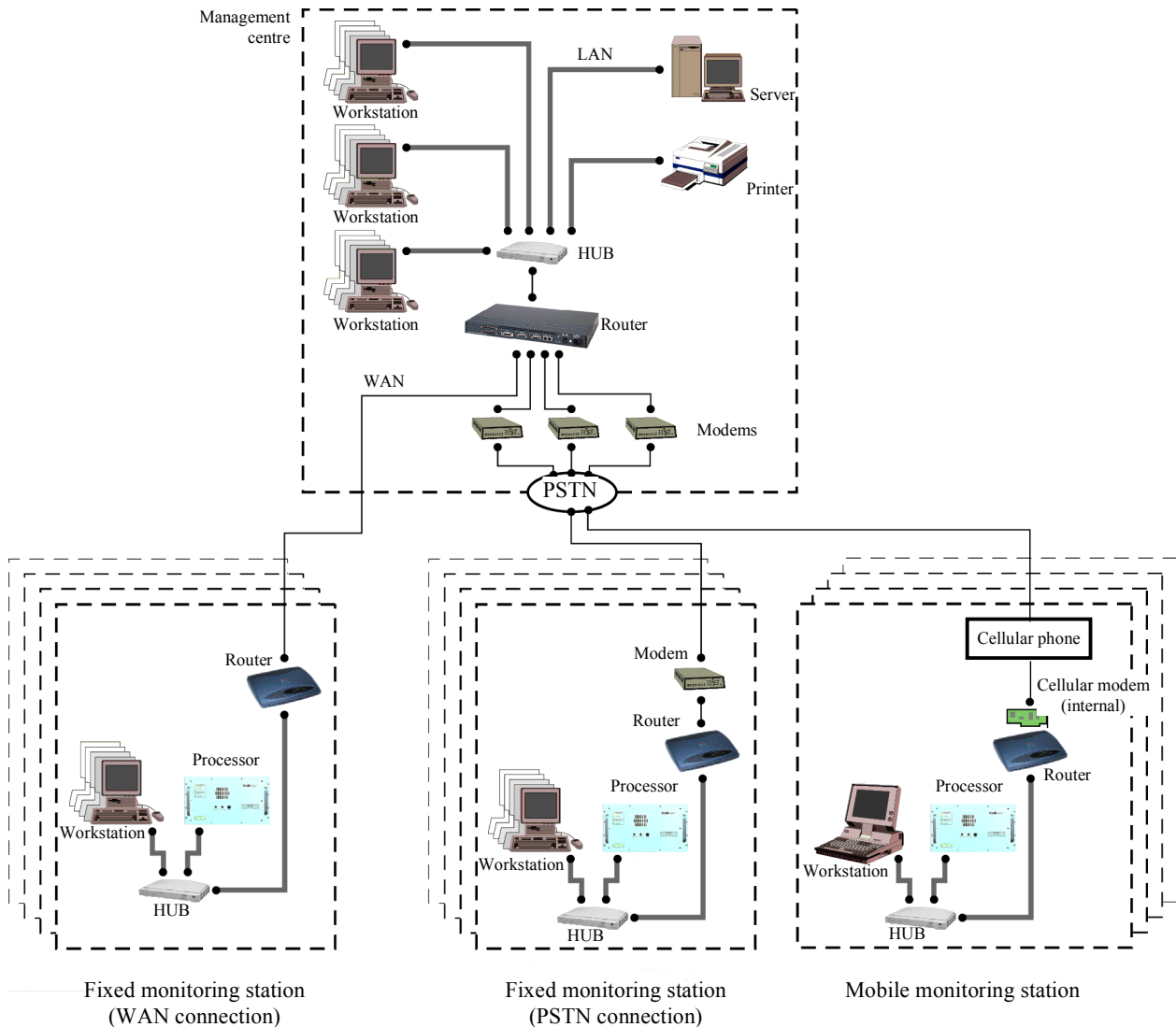
## ANNEX 1

### **Automation and integration of spectrum monitoring systems with automated spectrum management**

#### **1 Introduction**

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 measurement tasks rapidly and accurately, freeing service personnel for more demanding tasks. The use of databases and computer modelling streamlines spectrum management functions 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 unlicensed transmissions and other licensing violations. A typical integrated system is illustrated in Fig. 1. The configuration (number of workstations at each station, number of stations, etc.), methods of communication (transmission control protocol/Internet protocol (TCP/IP) or other protocol; use of the public switched telephone network (PSTN), radio or satellite) and other details will vary according to the application. An alternate system configuration includes the addition of a monitoring centre which is connected directly to the monitoring stations and in turn to the management centre.

FIGURE 1

**Typical integrated spectrum management and monitoring system**

LAN: local area network  
 WAN: wide area network

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Annex 1 addresses the benefits of automated spectrum monitoring and the integration of spectrum monitoring with automated spectrum management. Section 2 of this Annex notes those activities of an automated national spectrum management system that will benefit from integration with spectrum monitoring stations. The advantages of automating monitoring positions and entire monitoring stations are discussed in Section 3 of this Annex.

## 2 Computerized management and monitoring networks

### 2.1 Introduction

Spectrum management and monitoring includes a set of administrative and technical activities, which can be conveniently performed within the framework of a networked, integrated system.

*Spectrum management* activities ultimately result in the issuing of licences or authorizations. To perform these management tasks, a computer database is essential. This database, which incorporates such administrative and technical data as assigned frequencies, licence holders, equipment characteristics, etc., forms the core of the computerized automated spectrum management system.

*Spectrum monitoring* allows checking that these frequencies are used in accordance with the provisions of the authorization or licence and measures the spectrum occupancy by means of monitoring stations.

An important and indissoluble relationship exists between spectrum management and spectrum monitoring; close cooperation should be maintained between both, so that the spectrum monitoring tasks are very useful for spectrum management.

The main domains of interaction between spectrum management and spectrum monitoring are as follows:

- spectrum management establishes the official list of assigned frequencies for emission monitoring;
- spectrum management provides general instructions about bands to be scanned and specific tasks for monitoring;
- spectrum monitoring receives requests for specific tasks from the spectrum management: e.g. complaints of interference to be monitored to solve the problem, and measurement of occupancy on frequencies to be assigned;
- spectrum monitoring allows the measurement of technical parameters and checking for technical compliance of transmitters, identification of unlicensed or non-compliant transmitters and detection of specific problems.

Interaction between spectrum management and computerized spectrum monitoring systems allows operation to be optimized both for the efficiency of operation and cost of the system. The system is organized about a computerized database associated with the use of personal computers. The database is the core of all functions and associated applications: data updating, invoicing, frequency assignment, etc., as well as updating of technical parameters concerning frequencies and transmitters.

### 2.2 Integrated computerized national systems

A complete integrated computerized national spectrum management and monitoring system relies on one or more data servers with 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, as discussed below in Section 3. Each station

uses a modular architecture based on server and workstation computers interconnected via Ethernet LAN. All stations are linked over a WAN. This fully integrated network should provide rapid access by any operator position to any of the server functions available in the system. This system configuration is illustrated by the block diagram shown in Fig. 1.

The main server contains a relational database which is loaded with administrative and technical data of the region or national network, with a data content as recommended by the ITU-R Handbook – Computer-aided techniques for spectrum management, and Recommendation ITU-R SM.1370. The server generally is a structured query language (SQL) based system, allowing the user with appropriate access to easily query the database. Modern databases provide redundant systems and data along with periodic backup. The database with a distributed computerized network allows implementation of a client/server architecture and a distributed computerized system:

- the database server centralizes data management thus facilitating security and preserving a high integrity level; it contains data on applications, licences, sites, equipment, invoicing, frequency assignment, etc.; portions of this database may optionally be copied to local or mobile servers for specific applications;
- management, supervisor and data entry workstations: personal computers which allow the database to be loaded with administrative and technical parameters and which are used by management and monitoring personnel for frequency management, technical monitoring, etc.

The database software should provide for electronic data input from an existing database, should one exist, either directly or through a specially-prepared data conversion program.

### 2.2.1 Automation of the national spectrum management system

The national spectrum management system should consist of software and hardware that allows for efficient management of the nation's radio spectrum. The system should be capable of performing those functions described in the ITU-R Handbook – National spectrum management, which lend themselves to automation, including:

- *Frequency assignment and licensing*: this function is implemented on a relational database management system that ensures the integrity and consistency of the administrative data and protects access to the database via security protection. It provides graphical user screens that perform all administrative tasks listed in the next subsection below.
- *Spectrum engineering support*: this function provides engineering analysis tools for assigning frequencies to users with minimum interference. It also provides the capability to calculate interference between a transmitter and a victim receiver under various conditions.
- *Spectrum control (enforcement and monitoring)*: this function provides the interface to spectrum monitoring stations, allowing remote tasking of and reporting from these stations including remote gathering of monitoring data to support complaint resolution.

The spectrum management system should contain information in support of these functions; this information includes ITU and national frequency allocation plans and national geographic and topographic map data.

### 2.2.2 Frequency assignment and licensing functional requirements

The operation of the spectrum management system should be designed around the steps involved in the manual administration of licences. It should support the following administrative functions:

- *Application processing*: this function supports the data entry of an application for radio licence. This can be an application for a new licence, for modification to an existing licence, or modification to a pending application.
- *Frequency assignment*: this function supports the processing and analyses required to approve a requested frequency. This function can also be used to investigate the availability of frequency channels.
- *Licence processing*: this function supports renewing an existing licence for which all conditions of renewal have been satisfied, increasing the fee for an existing licence, and querying the database to locate one or a group of licences.
- *Fee processing*: this function supports the management of financial tasks, such as billing (production of invoices), recording of fee payments, and production of financial statements in statistical or individual format. It should also allow the setting and changing of fee rates.
- *Report processing*: this function supports the query of the database and production of standard notices, invoices, correspondence, text format reports and graphic reports of both management and monitoring data. It also supports the production of reports required by the ITU and custom reports as specified by the operator. Graphical reports are often a preferred method of examining data, because they provide a view of data which summarizes the information and makes it easy to identify trends and exceptions. Through the use of colour, even more information is conveyed in a single graph. A modern system should offer the same automated report capability from all workstations in the management and monitoring system. The capability to remotely create a report based on data which is located at a different site is also part of typical system software.
- *Interference complaint processing*: this function supports the processing of interference complaints.
- *Utilities processing*: this function supports the review, update and printing of all tables used by the system. The authority can be limited to the director of spectrum management and the system administrator as the only people with authority to view or modify any table in the system.
- *Security processing*: this function restricts access to specific data records or to certain types of transactions to only those operators who have the proper security access level.
- *Transaction processing*: this function creates a record in the database, registering the data, time and identity of the operator who performs each transaction, such as administrative approval of a licence.

### 2.2.3 Engineering analysis functions

The management system should include a set of engineering analysis tools. These are computer programs to assist in the assignment of frequencies in accordance with ITU Recommendations, as well as national frequency plans, and the local policies established by the spectrum management authority. Analysis tools should include radio service analysis, HF analysis, VHF/UHF analysis, SHF/microwave analysis, intermodulation analysis and electromagnetic compatibility (EMC) analysis. They perform analyses using information on transmitter power, antenna patterns, propagation and other parameters which may be extracted from the database or input to the system.

### 2.2.4 Monitoring functions

In an integrated system, the management system should be interfaced to the monitoring stations through a WAN to allow remote as well as local tasking of and reporting from the monitoring stations. Tasking for the monitoring stations includes systematic measurements in conformity with ITU-R Recommendations, such as spectrum occupancy and signal parameter and direction finding measurements on a specific frequency that may follow a complaint. Measurement servers (described in § 3.3) at the stations receiving the tasking automatically execute the requested measurements. The system may perform automatic violation detection as described in § 2.2.6 to identify frequencies on which there are transmitters which are not included in the licence database, identify transmitters which are not operating within their licensed parameters, or determine that measured signals comply with their licences. This information is made available to supervisory personnel in alphanumeric or graphical reports. The monitoring reports may include results of measurements and geographical displays of a coverage area or region, with:

- locations of the monitoring stations;
- locations of known transmitters;
- results of the stations' direction finding (DF) bearings for transmitter location.

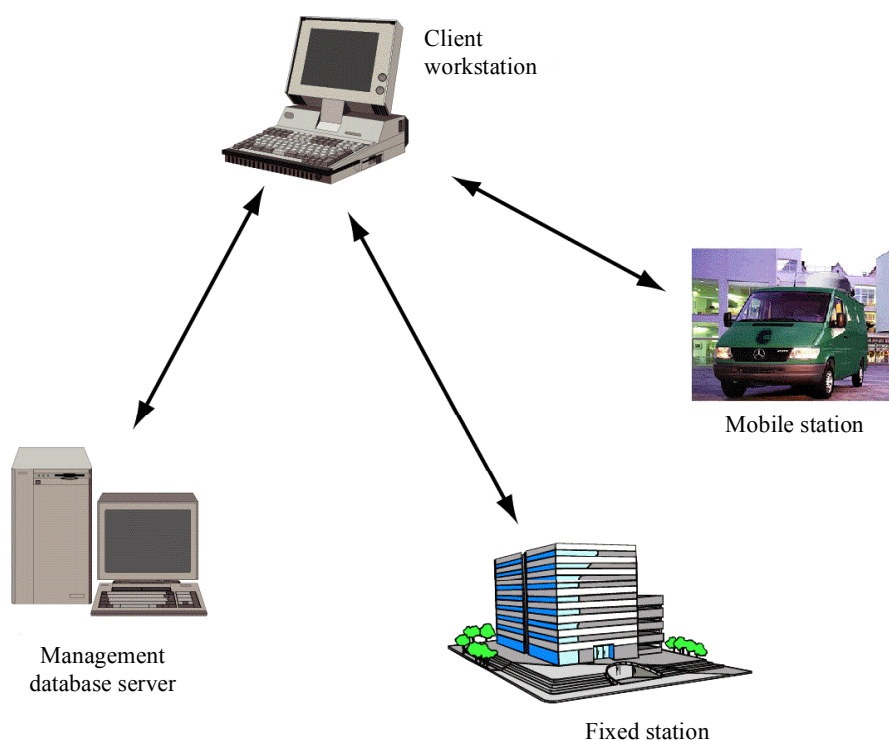
Monitoring stations may be fixed or mobile, and some of each are useful in a computerized national system. Fixed stations are appropriate for monitoring HF, where propagation is typically long range via sky-wave. Fixed stations near urban areas are also useful for monitoring VHF/UHF in those urban areas. Mobile and transportable stations are appropriate for monitoring VHF/UHF/SHF (and HF groundwave), since with shorter range propagation for these cases, the measurement system must generally be moved to the area of interest. They are also needed in many cases where illicit stations or sources of interference have to be localized precisely.

### 2.2.5 Remote access to system resources

Integrated, networked, multi-tasking systems with the client/server architecture typically allow an operator of a client at any station to access the resources of any or all of the measurement servers,

both those co-located with the client and those at other stations, as illustrated in Fig. 2. Thus all of the resources of a multi-station network are available to any given operator, provided he has the proper authorization to access all of those resources.

FIGURE 2  
Control of entire system from one workstation



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The monitoring stations may be controlled remotely from a workstation at a spectrum monitoring centre, the spectrum management centre, a local command centre, or locally at the station itself, and monitoring results may be reported back to that workstation. This remote control accommodates spectrum monitoring operators who may desire to work from a central location and not travel to distant monitoring sites, provided that the situation does not require an experienced monitoring operator at the site. Operators still need to analyse measured data and validate any data before entry into a central database.

Communication links only need be available between stations when a client is issuing tasking to remote servers, and later when the client is requesting results of his tasking; as long as communication links are available when the tasking is issued, if they then become unavailable, measurement results are not lost, but are retained on the measurement server until requested.

### 2.2.6 Automatic violation detection

Performing spectrum searches is necessary for detecting interference, looking for signals which are deviating from their licence parameters, and looking for unlicensed signals. An integrated spectrum management and monitoring system should include an automatic violation detection function to perform this task by allowing the operator to define a monitored range by specifying the start and stop



frequencies of the band(s) to be searched, and to specify search parameters including the time period over which the search may be done. A typical tasking window for automatic violation detection is shown in Fig. 3. The user should be able to identify any of the following for purposes of alarms:

- Important signal parameters or parameters measured by the system.
- Signals which are deviating from their licensed parameters.
- Unlicensed signals.

FIGURE 3  
Automatic violation detection control window

**Automatic Violation Detection**

Noise Riding: 20 dB

Duration: 2 mins

Storage Interval: 15 secs

Fixed Rate: ☐

Station Name: 004

**Schedule**

☒ Immediate  
☐ Delayed

Date:   
Time:

**License Information**

Last Time Imported: 17:21 04/28/2000

Import...  
Show Map...

**BAND LIST**

☐ All Single Channels

List	Start Freq (MHz)	Stop Freq (MHz)	Bandwidth	Identity
1	88.100000	107.500000	200 kHz	A1
2				
3				
4				
5				
6				
7				
8				

**Current Tasks**

327  
328

New  
Run

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The system performs a scan over the specified frequency range and for the specified time period. The system uses the measurements obtained from the scan and uses information in the licence database to determine which signals in the measured spectrum are not in the licence database, and automatically provides a list of frequencies which are being used which are not in the database. The system also checks signal parameters, such as bandwidth, over modulation and not being on licensed centre frequency, and issues alarms where violations are found. Alarms therefore alert the operator to unexpected or non-compliant signals based on the search parameters the operator has specified, and provide the basis for closer examination by the operator. Automatic violation detection results, including information on unlicensed or non-compliant emitters by frequency or by channel, are displayed on a results screen such as that shown in Fig. 4.

FIGURE 4  
Automatic violation detection results

**Automatic Violation Detection Results**

Station Name: 004

START		STOP		Status	
Task	Date	Time	Date		Time
327	05/15/00	14:28	05/15/00	14:30	Completed
328	05/15/00	14:28	05/15/00	14:30	Completed

AVD Results Task 328 004

	Ctr Freq	Chan	Result	Freq	Dev Hz	%Occp	BW kHz
9	91.1	130	Not Found	0.000	0	0	0.0
10	91.5	140	Not Found	0.000	0	0	0.0
11	92.3	160	Compliant	92.300	130	100	138.3
12	93.3	130	Compliant	93.299	249	100	108.3
13	94.1	140	Compliant	94.099	25	100	79.9
14	94.5	150	Non Compliant (Freq)	95.500	511	100	132.8
15	94.9	160	Non Compliant (Freq)	95.899	936	100	134.2
16	95.3	170	Non Compliant (Freq)	95.299	438	100	118.0
17	95.7	190	Not Found	0.000	0	0	0.0
18	96.1	200	Not Found	0.000	0	0	0.0
19	96.5		Unlicensed (High Usage)	96.499	642	100	130.9
20	97.3	230	Not Found	0.000	0	0	0.0
21	97.7	240	Compliant	98.699	84	100	114.4

Tolerances: Freq 350 Hz BW 200 kHz %Occp 0 Band# 1

Reports: Save Preview Print

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In order to facilitate the automatic violation detection process and assure it is operational even in the event of unavailability of communications among stations, each station, whether fixed or mobile, should maintain its own database of licensed stations in its area of operation. This database is obtained from the management system database. With the availability of this local database, each fixed and mobile station can continue to operate and perform automatic violation detection even if communications are unavailable.

### 3 Automation of monitoring operations

All routine monitoring measurements are repetitive tasks which lend themselves easily to automation:

- Occupancy measurements: fine-resolution scanning of the frequency bands with computer-generated displays and storage capacity of channel occupancy over several days is well suited to automation.
- Frequency measurements: these can be made automatically when the signal-to-noise ( $S/N$ ) ratio is sufficient and for transmissions with carrier frequency. At HF, channels are usually very closely spaced, and a sharp frequency selectivity must be provided in the case where several frequencies are present in the same channel.

- Level and, if applicable, field strength measurements.
- Bandwidth measurements.
- Modulation parameter measurements: advancements in digital signal processing hardware and algorithms have led to the development of modulation recognition systems which identify modulation types in real-time. These systems may be implemented in stand-alone instruments, computer add-in cards and associated software, or may be integrated into other instruments (such as receivers or analysers). These systems can be used to recognize various modulation formats (both digital and analogue), measure common technical parameters, and demodulate or decode the signals.
- Signal analysis: nevertheless, not all aspects of signal analysis can be done fully automatically.
- Radio direction-finding.
- Station identification: through location, or automatic signal analysis (code recognition, number of elements, transmission rate).

All of these measurements can generally be made automatically, but some measurements, such as bandwidth and modulation, require signals with good  $S/N$  to achieve sufficient accuracies. These measurement tasks yield technical measurement data that can be compared to the technical parameters recorded in spectrum management databases or to data desired therefrom. The technical parameters recorded for a transmitter in such a database include:

- assigned frequency;
- calculated field-strength;
- emission class;
- assigned bandwidth;
- emission bandwidth;
- call-sign.

Each monitoring station usually has a list of transmitters and the operators match the listed transmitter parameters against the observations recorded by the automated equipment. Integrated automated systems may perform the comparison in addition to the collection of data, in other words, the automatic violation detection discussed in § 2.2.6. Either way, the comparison must be made using tolerances in measured parameters which are consistent with ITU-recommended measurement accuracies, to minimize false alarm rate. The goal is to confirm the compliance with established procedures and with the technical data listed in their database file. When discrepancies or anomalies are detected, they typically include:

- illegal or unlicensed transmitters or frequencies;
- unauthorized operating periods or locations;
- illegal emission classes or poor modulation quality;
- excessive frequency offset;
- no call-sign or incomplete call-sign;
- excessive bandwidths;
- excessive power (excessive field-strength).

### 3.1 Levels of automation

Automation can occur at many levels within monitoring operations. A single workstation may conduct an automated occupancy survey using pre-programmed parameters. Several workstations at a site may be tied into a single set of measurement equipment to share those measurement resources. An entire station, or network of stations, may be automated, possibly because of their remote location, and the results of their monitoring may be re-transmitted to a more centralized station. Individual positions at several sites may be linked together in such a manner that one position automatically tunes positions at other sites to obtain multiple simultaneous measurements on signals of interest. Automation can help reduce the time to locate and identify a signal, reduce the personnel needed to operate stations and make these personnel available for other functions such as data analysis, and increase the portion of the radio-frequency spectrum that a service can effectively monitor. On the other hand, the absence of an operator or technician at a remote site may result in long equipment down times should there be an equipment failure. Also, automated equipment may not give the sensitivity for tuning difficult to receive signals that an operator can achieve through manual tuning, which may often be the case in the HF environment. In any case, when automating a position, a service should incorporate the option to revert the position to manual operation, either locally or remotely.

### 3.2 Position automation

When a monitoring position is automated, a computer with a multi-tasking operating system is used to control measurement equipment including antennas, RF distribution and receivers. Automation of older equipment will usually need a separate computer, and in some cases, the older equipment may need to be replaced. As an example of automation, a computer-controlled receiver can be programmed to monitor fixed frequencies or scan prescribed bands. It can be programmed to look for certain characteristics of a group of known licensed transmitters and record all of the signal that match the programmed parameters. The computer can be programmed to notify an operator when it finds a match, or to notify an operator when it finds a signal that does not match. The latter approach is a useful, automated way to recognize unlicensed or illegal transmitters, and is an example of automatic violation detection. This task is carried out in the same way as normal monitoring, but on frequencies not listed by the system. If the operator wants to separate this search from systematic monitoring of known stations, he starts a monitoring sequence (in a frequency band or on a list of discrete frequencies) with instructions to record the measurements on signals not corresponding to a known transmitter.

Such a position or group of positions allows the operator to concentrate on higher priority tasks, such as assisting a mobile station in direction-finding operations. Positions may be configured to allow manual operation as well, and several may be linked into a single measurement suite. The positions can also be designed to generate technical reports noting signal characteristics detected and possible locations and users. If the station uses a LAN, the automated equipment can forward a

technical report to an operator's computer so he can include in the report other information that identifies the user. In cases where follow-up is required, automated systems can flag database files for recurring tasking so that the service can determine if the interference has been eliminated.

### 3.3 Station automation

Modern DSP techniques allow economical automation of entire stations. An automated station consists of:

- a measurement server, consisting of a small group of sophisticated measurement equipment modules including digital receivers operated by a computer whose software can be easily augmented to accommodate new technologies and new services; and
- operator workstations, or clients, which are used for operator interface and which contain computer software which make the system easy to use and maintain.

The station can be operated either locally, or it can be remotely controlled from a more convenient location. The links between the measurement stations and control stations can be radio or terrestrial. Essentially, the station becomes a node on a WAN administered at the control station.

A fully automated station typically has the architecture illustrated in Fig. 5. This station consists of antennas, a measurement server which is a modular, high speed bus unit including processors, receivers and other compact electronics, one or more low-cost commercial workstation clients, and various peripheral equipment including printers, phones, and modems. An alternate but related station architecture includes separate but highly integrated units including digital receivers, direction finders and processors; in this case, the portion of Fig. 5 containing the open architecture high-speed data bus with various modules is replaced by separate units, including a digital receiver, a digital direction finder and a processor.

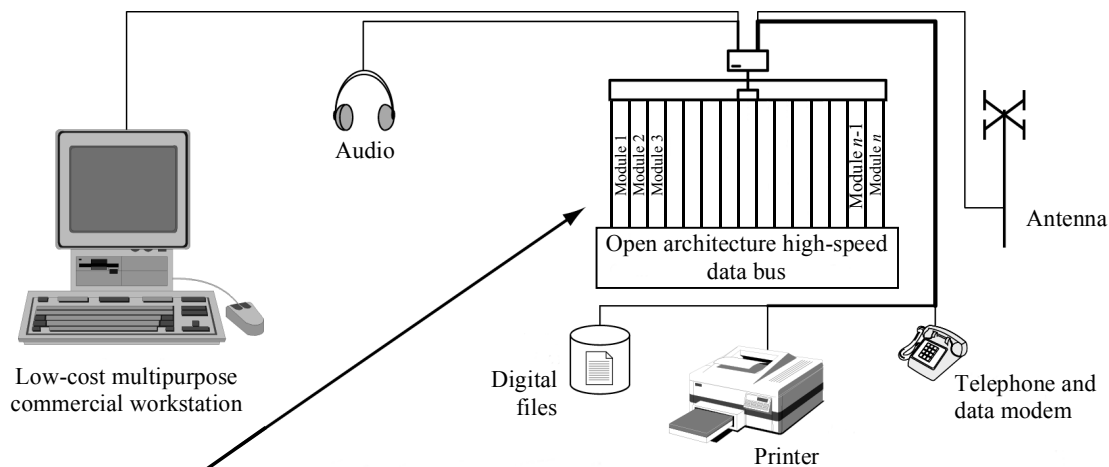
The functions of an automated monitoring station include:

- monitoring, demodulation and decoding;
- audio recording;
- technical measurement and analysis including frequency and frequency offset, level/field strength, modulation parameters including AM modulation depth and FM frequency deviation, bandwidth, and spectrum analysis;
- spectrum occupancy;
- direction finding;
- automatic real time comparison with licence parameters;
- automatic alert generation on abnormal or unknown transmissions.

Automated monitoring stations typically have three modes of operation which are used to perform these tasks:

- interactive mode;
- automatic or scheduled mode;
- background mode.

FIGURE 5  
Typical modern integrated radio spectrum monitoring station



Functions performed by hardware and computer software modules:

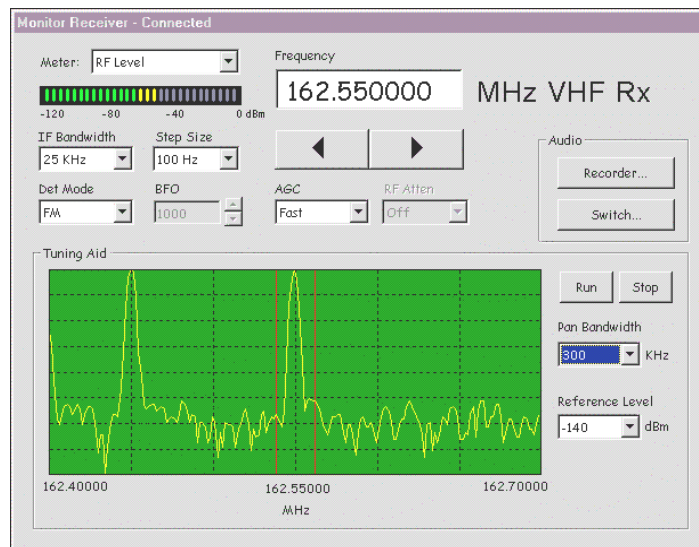
- |  |                              |
|--|------------------------------|
| - DF processing                              | - Workstation interface      |
| - Fast analogue/digital conversion           | - Spectrum displays          |
| - Digital signal processing and demodulation | - Oscilloscope-type displays |
| - Receiver 1                                 | - Spectral activity displays |
| - Receiver 2                                 | - Audio matrix               |
| - Receiver $n$                               | - RF matrix                  |
| - Digital audio                              | - Communications interface   |
| - Multimedia card                            | - Emitter database           |
| - Global positioning system (GPS) receiver   | - Expansion slots            |

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Interactive mode allows direct interaction with various functions that provide instantaneous feedback such as monitor receiver tuning, demodulation selection and pan-display selection. These functions are controlled from virtual control panels on the client workstation, using screens as illustrated in Fig. 6. Synthetic panoramic and spectrum displays are created on the operator workstation, and include waterfall displays (three dimensional displays of signal amplitude, versus frequency, versus time) and spectrogram displays (two dimensional displays of signal frequency versus time, with signal amplitude indicated by colour).

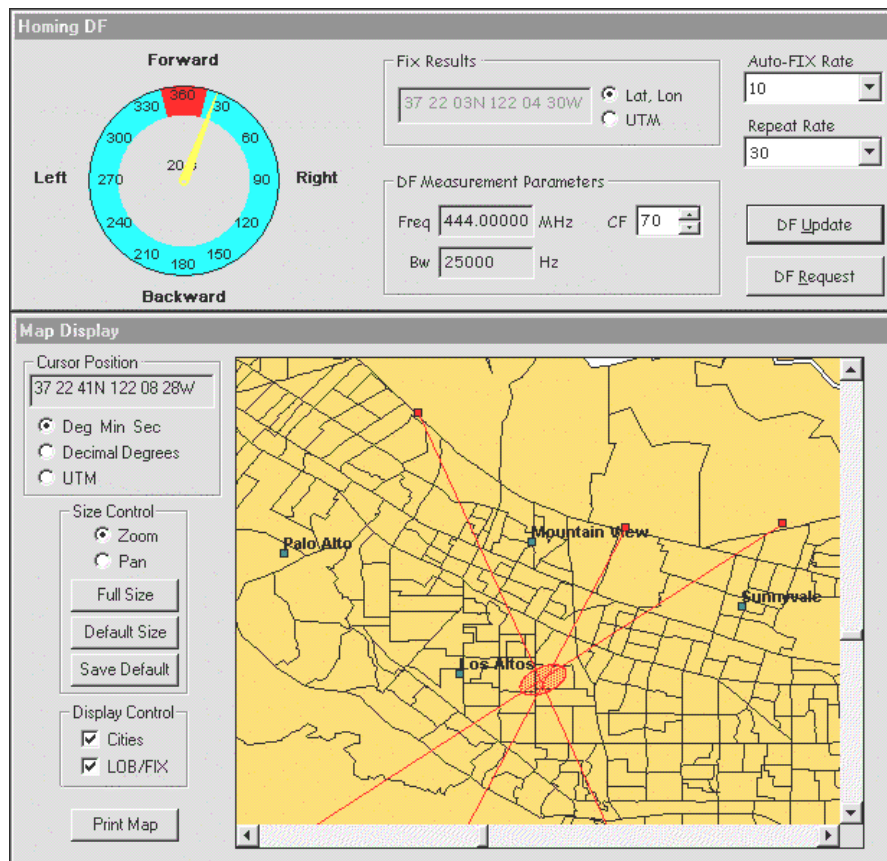
DF homing is an important example of interactive operation. DF may be commanded in a mobile unit as the unit is in motion. DF results are presented with respect to the front of the vehicle, as illustrated in Fig. 7, and allow the driver to decide which direction to drive to approach the desired signal transmitter. DF results from different locations are also displayed on a geographic map, allowing automatic triangulation by the system to locate the signal transmitter. The exact location of the mobile unit is continuously updated by a high precision GPS receiver, and the orientation of the vehicle with respect to North is measured by an electronic compass.

FIGURE 6  
Virtual control panel for monitor receiver



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FIGURE 7  
DF homing display and geographic map



1537-07



Automatic or scheduled mode may schedule tasks to be executed immediately or to be executed at specified times in the future. Functions which are performed under the scheduled mode include technical measurement and analysis, and direction finding. Measurement parameters, such as measurement and averaging method, and measurement time (or times, in the case of measurements which are to be repeated) may be specified, or default values provided by the system may be used. The operator may use a screen containing a calendar such as illustrated in Fig. 8 to schedule these functions. The client requests time slots for the desired measurements from the measurement server. The time slot assignment approach allows multiple clients to connect to a single server. In order to handle scheduling attempts of multiple measurements in the same time slot, the server should support a convenient mode of scheduling. When the requested time slot is already reserved, the client's request for a server time slot is moved to the first available time slot. The server can look for the available time slot within a specified time window that is typically  $\pm 5$  min. The measurement server performs the requested measurements, using appropriate scheduling and priority algorithms to resolve any scheduling conflicts, and retains the measured results until the client requests them.

FIGURE 8  
Automatic or scheduled mode tasking screen

The screenshot displays the 'Automatic or scheduled mode tasking screen'. It features a 'Task Calendar' on the left with a list of time slots from 10:20 PM to 11:40 PM. The 10:20 PM slot is selected and highlighted in green, with a small icon and the text 'K149' next to it. To the right is a calendar for June 1999, with the 18th highlighted in blue. Below these is a configuration panel with tabs for 'Measurement', 'Bandwidth', 'Modulation', 'Field Strength', 'Frequency', 'Direction', and 'Tasking Options'. The 'Tasking Options' tab is active, showing 'Tasking Selection' with 'Immediate' selected, 'Delayed Scheduling Options' with 'Convenient' selected, and 'Repeat Options' with 'Repeat' checked and 'Task Count' set to 1.

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Background mode is used for performing spectrum occupancy and automatic violation detection – tasks where it is desirable to collect data over long periods of time. Wideband scanning for occupancy, or DF combined with occupancy (termed “DF scan”), may be specified, and the system may be scheduled to perform an automatic scan over particular frequencies or ranges of frequencies, and upon detecting a signal, initiate operator specified activity, such as DF or technical measurement. Background mode operates on a lower priority than scheduled mode, so specific scheduled measurements will interrupt the background mode to use the measurement server. After the scheduled measurements are completed, control returns to any background mode measurements which were in process.



When the client requests the results of measurements, he may see them displayed in convenient formats. Much of the information is displayed graphically, in the form of occupancy histograms, field strength versus frequency plots (see Fig. 9), geographic map displays showing location results (see Fig. 7), and other graphical displays. These systems can perform DF on many frequencies simultaneously and provide azimuth versus frequency plots (see Fig. 10) which are useful for intercepting and processing modern digital modulations; DF results on such a display at the same azimuth from many different frequencies are a clear sign of the presence of a frequency hopping signal.

Sophisticated client/server systems can be designed to be easier to use than systems with separate or stand-alone units of equipment such as receivers and spectrum analysers. With task icons and toolbars on the computer screen which the operator can access via pointing and clicking on a computer mouse, these systems can be very intuitive and easy to learn. For administrations with difficulty in obtaining qualified operators, simplicity of operation of a monitoring system is an important consideration.

Modern DSP-based measurement servers are able to provide a very broad instantaneous bandwidth, such as several MHz of instantaneous bandwidth, along with a high dynamic range so that strong signals within this bandwidth do not prevent very weak signals in the bandwidth from being received and processed. Systems with very broad instantaneous bandwidths are able to scan the spectrum at very fast scan rates and are able to effectively acquire and measure intermittent, broadband and frequency agile signals. Operators can view a very broad panoramic display, improving their ability to locate interferors and identify the kinds of signals and interference being monitored.

FIGURE 9  
Field strength vs. frequency display

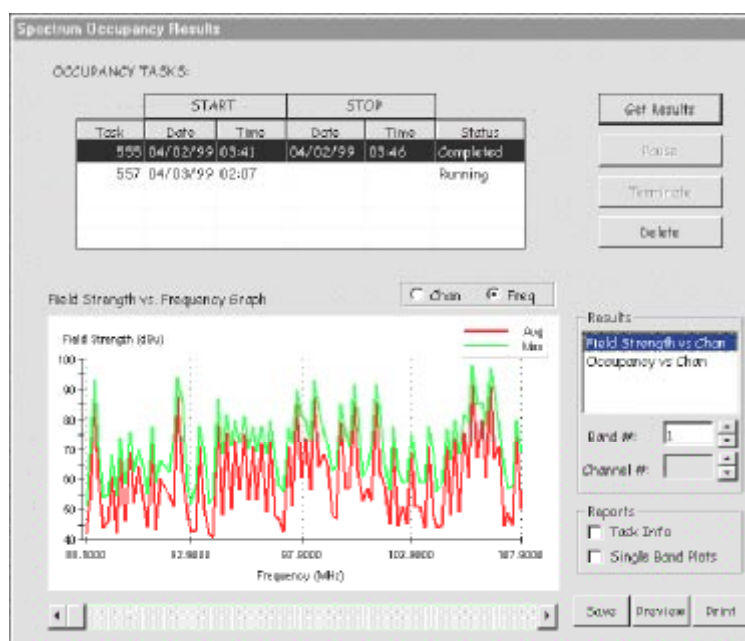


FIGURE 10  
DF scan results display

