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Radiocommunication Sector of ITU

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(08/2013)

Automation and integration of spectrum monitoring systems with automated spectrum management

SM Series

Spectrum management

International Telecommunication Union

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***Note**: This ITU-R Recommendation was approved in English under the procedure detailed in Resolution ITU-R 1.*

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RECOMMENDATION ITU-R SM.1537-1*

Automation and integration of spectrum monitoring systems with automated spectrum management

(2001-2013)

Scope

Current technology allows most spectrum monitoring functions, and indeed entire monitoring stations, to be highly automated, and allows spectrum monitoring systems to be highly integrated with automated spectrum management. Many activities of an automated national spectrum management system will benefit from integration with automated spectrum monitoring stations. This Recommendation describes recommended functionality of these systems.

Keywords

Spectrum monitoring automation, automated spectrum management, automated monitoring

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 licence 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;

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* Radiocommunication Study Group 1 made editorial amendments to this Recommendation in the years 2019 and 2023 in accordance with Resolution ITU-R 1.

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 to 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

that administrations which perform both spectrum management and spectrum monitoring should consider using an integrated, automated system with 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 addresses the benefits of automated spectrum monitoring and the integration of spectrum monitoring with automated spectrum management. Section 2 of Annex 1 notes those activities of an automated national spectrum management system that will benefit from integration with spectrum monitoring stations. The advantages of automating entire monitoring stations are discussed in § 3 of Annex 1.

Annex 1

Automation and integration of spectrum monitoring systems with automated spectrum management

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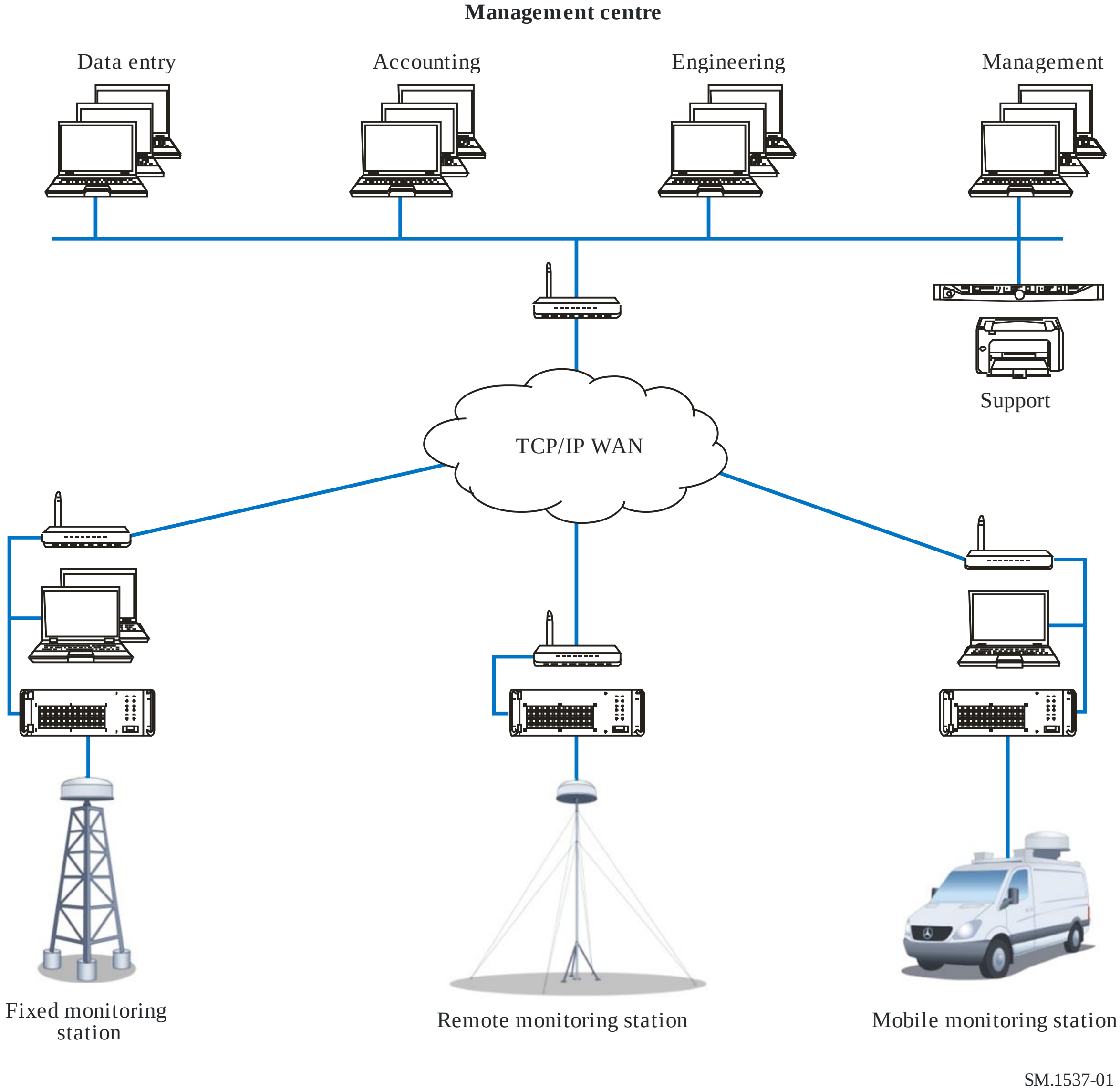
1 Introduction

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 and can help prevent interference. Coupling of spectrum management and spectrum monitoring makes possible an integrated system, which can automatically use measured data from the monitoring system and licence information from the management database to detect frequencies of apparent unlicensed transmissions and other licensing violations for closer examination by the operator. The integrated monitoring and management system may have a central management facility, in which overall management of radio monitoring system is performed and statistical analysis of stored measurement data in the monitoring system database are available. These analysed results are utilized for spectrum management planning (for example, frequency withdrawal and reassignment). A typical integrated system diagram is presented 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 a wide area network (WAN), the public switched telephone network (PSTN), radio or satellite) and other details will vary according to the application and available infrastructure. An alternate system configuration includes the addition of a monitoring centre that is connected directly to the monitoring stations and in turn to the management centre.

FIGURE 1

Typical integrated spectrum management and monitoring system



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 an integrated and networked 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 administrative and technical data such 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 concerning bands to be scanned and specific tasks for monitoring;

– spectrum monitoring receives requests for specific tasks from 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 around a computerized database and the use of personal computers. The database is the core for 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 database servers connected to a network so that workstations or clients throughout the system can access the database. Management systems may 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 § 3. Each station uses a modular architecture based on server and workstation computers interconnected via Ethernet LAN with all stations being 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 that is loaded with administrative and technical data of the region or national network, with additional data content as recommended by the ITU-R Handbook on Computer-aided techniques for spectrum management, and Recommendation ITU-R SM.1370. The server generally is a structured query language (SQL) based system, allowing users with appropriate access to easily query the database. Modern databases can be configured to provide redundant systems along with periodic backup. The database, with a distributed computerized network, allows for the 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.

When upgrading to a new management system, 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 on 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 interface (GUI) 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 issuing a new licence, 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, signal parameter and direction finding measurements on a specific frequency that may follow a complaint. Measurement servers (described in § 3.2) 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 licence 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 geographic 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, transportable or mobile, and it is useful in a computerized national system to have some of all types. Fixed stations are most appropriate for monitoring signals over long time periods, or for HF, where requirements for antenna space is important and propagation is typically long range via sky-wave. Fixed stations near urban areas are also useful for monitoring VHF/UHF in those urban areas. Transportable and mobile stations are appropriate for monitoring VHF/UHF/SHF (and HF groundwave), since with shorter range propagation in these cases, the measurement system must generally be moved to the area of interest. Transportable stations can monitor from building tops or countryside locations where mobile vehicles cannot reach. Mobile stations are needed in many cases where illicit stations or sources of interference have to be localized precisely.

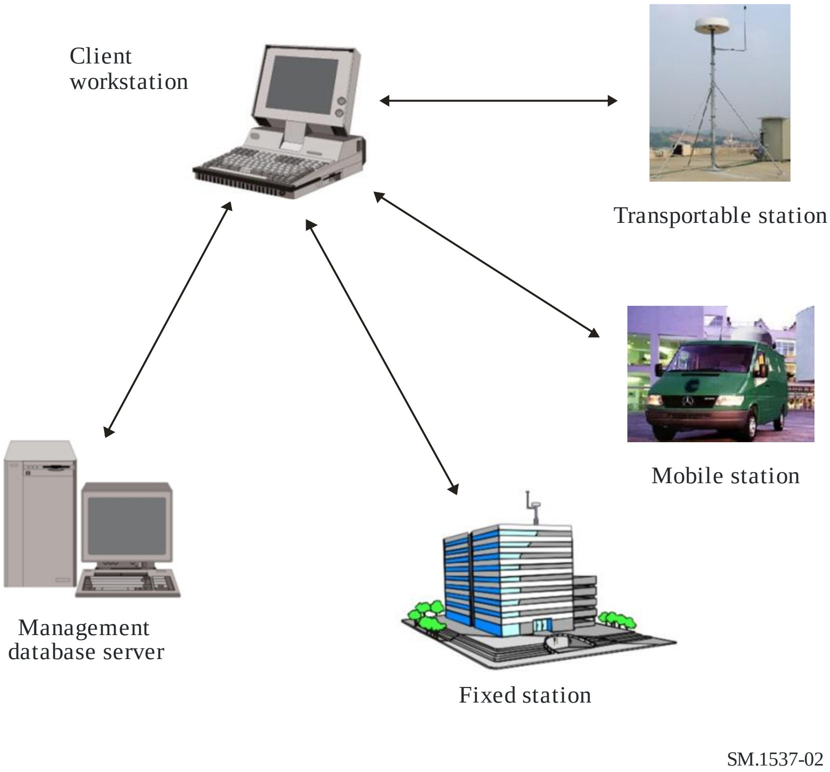
Some monitoring stations may include time difference of arrival (TDOA) location capability as discussed in Report ITU-R SM.2211 and Chapter 4.7.3.2 of the ITU Handbook on Spectrum Monitoring (Edition 2011), in addition to or in place of angle of arrival (AOA) capability. Emitter location using multiple networked stations can be done by triangulation from at least two AOA sites, or by a hybrid approach with at least two sites (at least one of which would have AOA capability and both of which would have TDOA capability). The hybrid approach can be designed to emphasize the advantages of both AOA and TDOA location technologies, while minimizing the disadvantages.

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 that the operator has the proper authorization to access all of those resources.

FIGURE 2

Control of entire system from one workstation



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 need 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. It is important to note that operators still need to analyse measured data and validate any data before entry into a central database.

Communication links only need to 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:

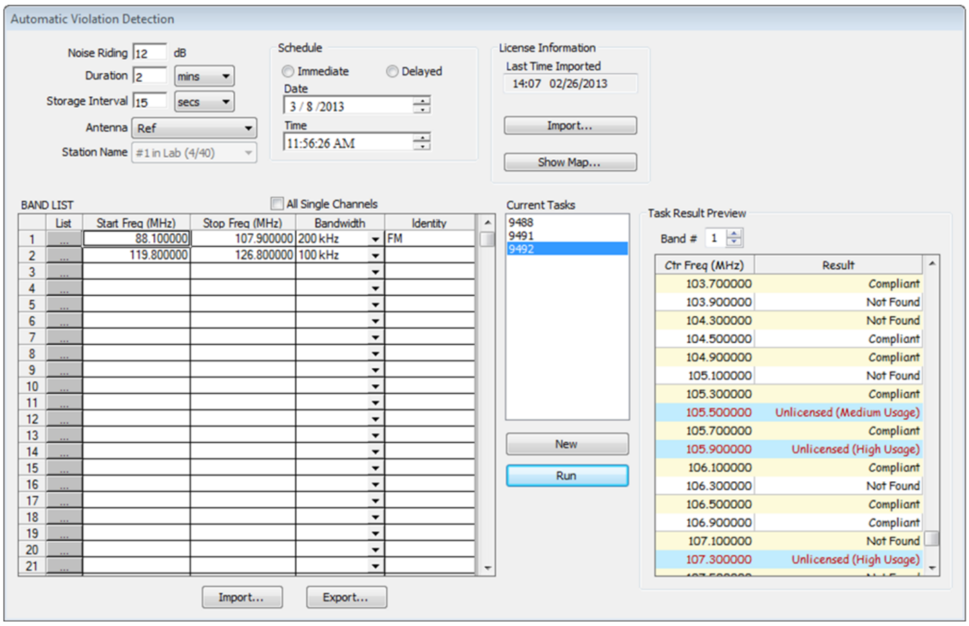
– Important signal parameters or parameters measured by the system.

– Signals which are deviating from their licence parameters.

– Unlicensed signals.

FIGURE 3

Automatic violation detection control window



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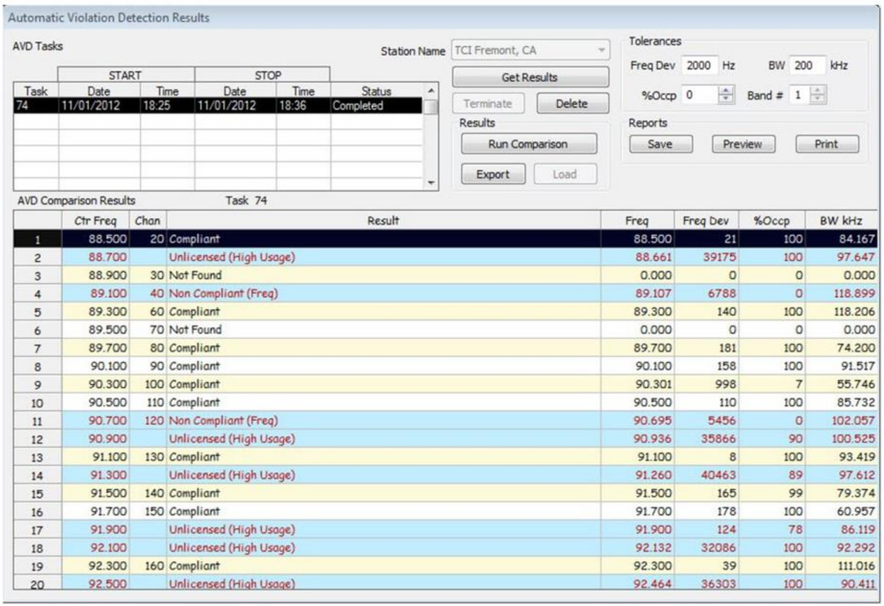
The system should be able to perform a scan over the specified frequency range and for the specified time period. The system uses the measurements obtained from the scan and then uses information in the licence database to determine which signals in the measured spectrum are not in the licence database, and thus automatically provides a list of frequencies which are being used that are not in the database. The system should also check signal parameters, such as bandwidth and deviation from licensed centre frequency, and issues alarms or reports where violations are found. Alarms or reports therefore alert the operator to unexpected or non-compliant signals based on either default criteria or criteria 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 transmitters by frequency or by channel, are displayed on a results screen such as that shown in Fig. 4.

FIGURE 4

Automatic violation detection results



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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 should be 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 that lend themselves easily to automation:

– Occupancy measurements: Fine-resolution scanning of a frequency band or of a number of 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 a carrier frequency. At HF, channels are usually very closely spaced, therefore 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 (DSP) 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 automatically.

– Radio direction-finding.
– Station identification: Through location, message content information, 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 automate this comparison task in addition to collection of data, which is an example of 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 the 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 to 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 retransmitted 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 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
– local or remotely located 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 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 from 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. Automatic built in test equipment (BITE) can provide the current status of all devices and can give alarm in case a device shows a fault.

The functions of an automated monitoring station include:

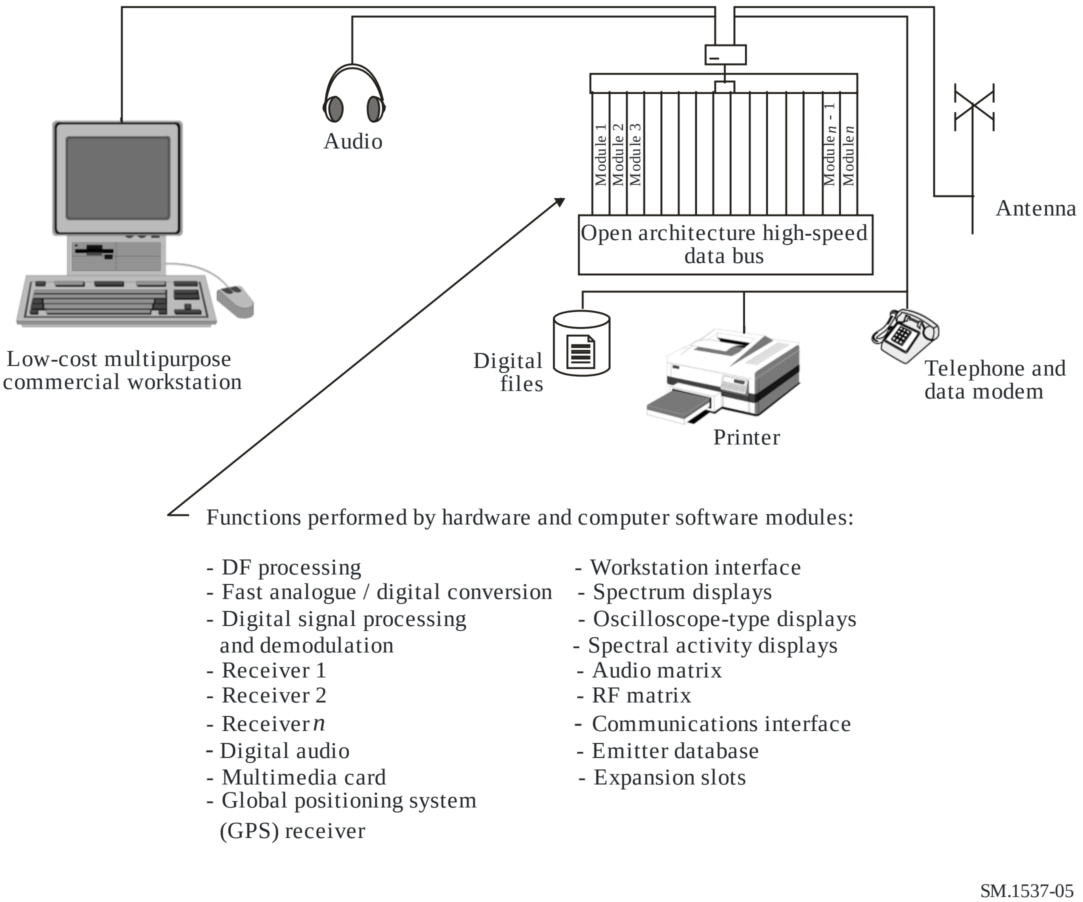
– monitoring, demodulation and decoding;
– recording, both of audio and of wideband digital (such as receiver IF output) data;
– technical measurement and analysis including frequency and frequency offset, level/field strength, modulation parameters including AM modulation depth and FM frequency deviation, 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 or real time operational mode;
– automatic or scheduled mode;
– background mode.

FIGURE 5

Typical modern integrated radio spectrum monitoring station



Interactive mode: Allows direct interaction with various functions that provide instantaneous feedback such as monitor receiver tuning, demodulation selection and pan-display selection. An interactive mode is necessary even in an automated system to allow operator intervention when necessary, so that equipment can be remotely controlled by operators as well as by the automated system software. Interactive functions are controlled from “virtual control panels” on the client workstation, using screens such as the one 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 both with respect to the front of the vehicle and on a map with respect to true north, as illustrated in Fig. 7, which allow the operator to decide which direction to drive to approach the desired signal transmitter. As the mobile unit moves from location to location over time, DF results from those different locations are displayed on a geographic map, allowing automatic triangulation by the system to self-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 a combination of GPS and electronic compass, depending on whether the mobile unit is in motion or is stationary.

FIGURE 6

Virtual control panel for monitoring receiver

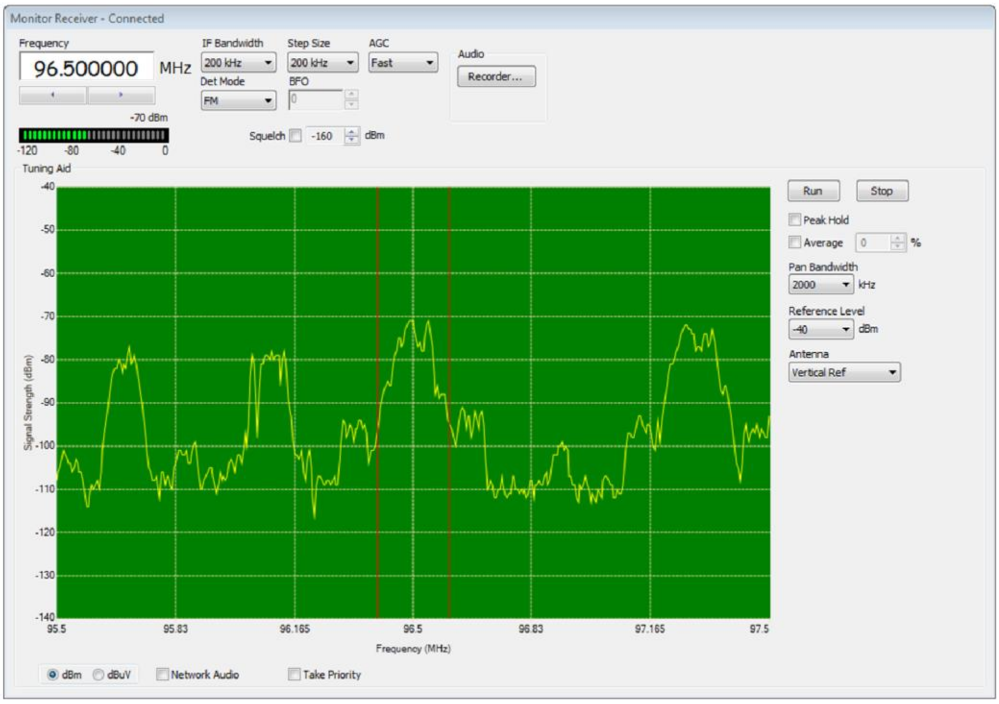


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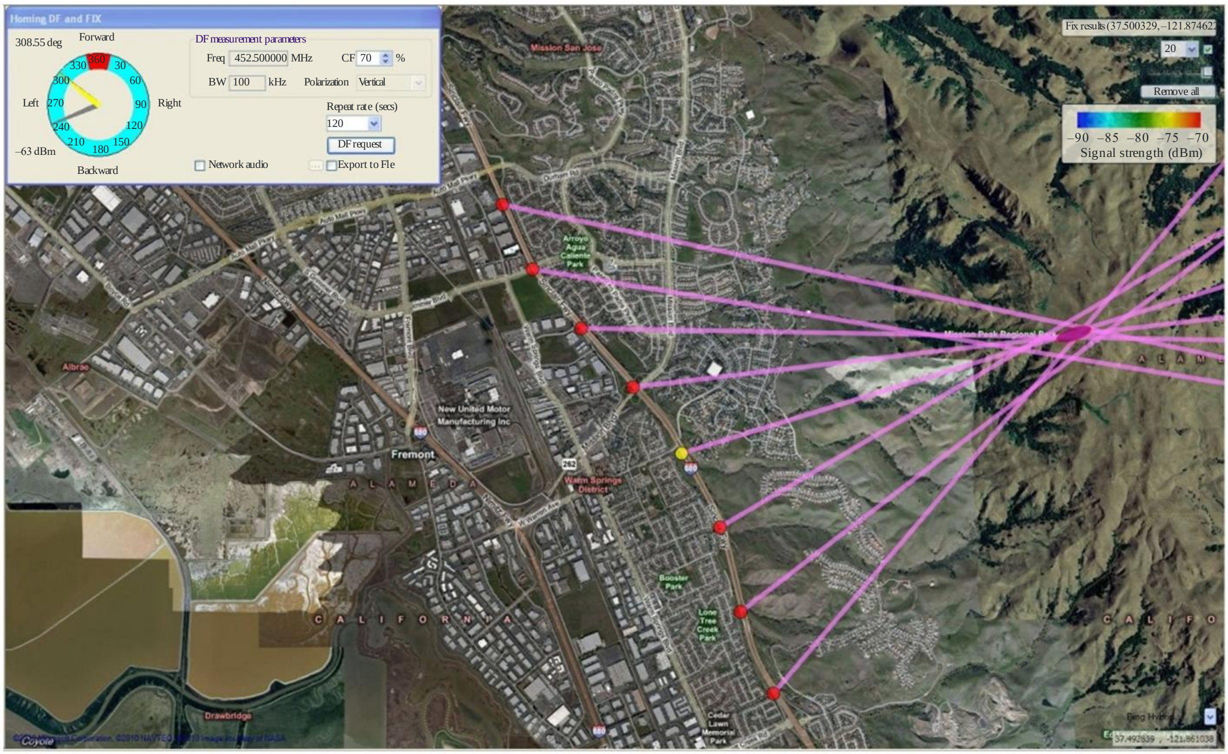
FIGURE 7

DF bearing display and geographic map showing field strength Line Of Bearing (LOB) and FIX measurements



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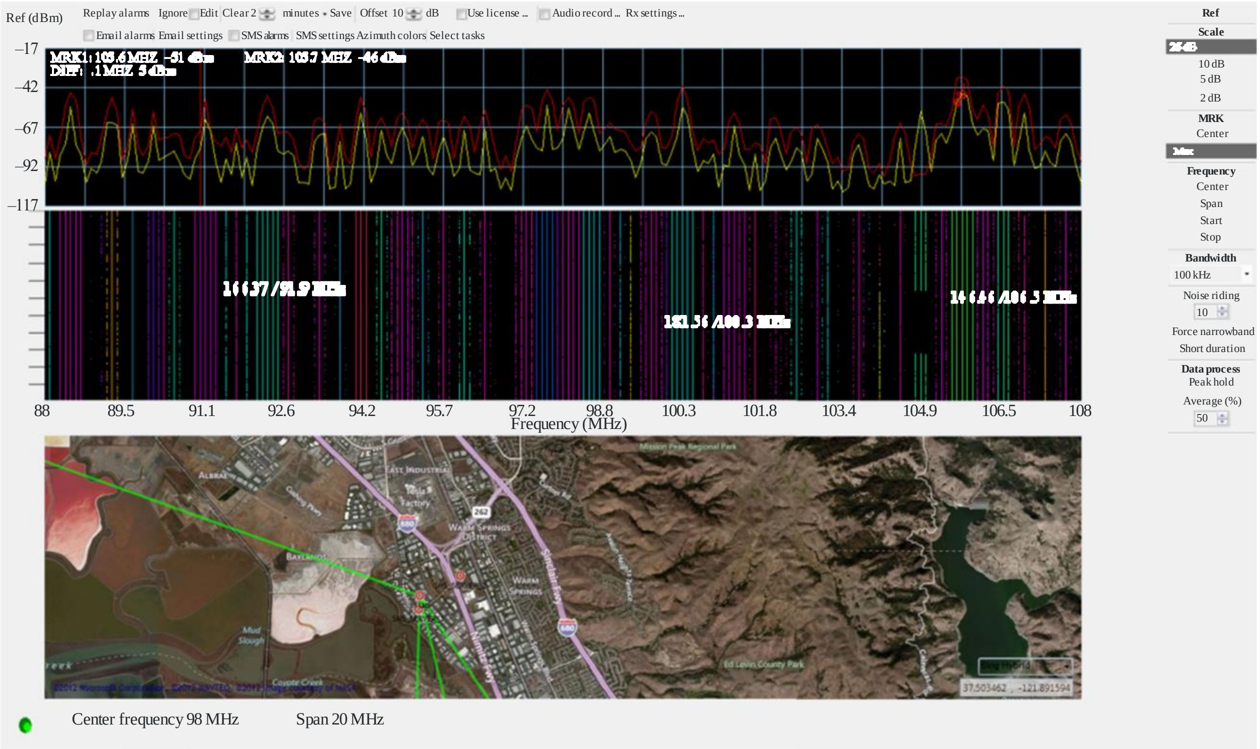
Modern wideband monitoring equipment provides the capability to perform measurements on many frequencies at the same time and generate an alarm if a signal crosses a present threshold. An example of this function can be seen in Fig. 8 where current signal levels can be seen in yellow with a threshold setting showing as a red line nominally 10 dB above. Direction finding results are shown as coloured lines on which the operator can click to see the bearing displayed on the geographic map.

FIGURE 8

Alarm display showing signal alarm threshold and selected DF results



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Automatic or scheduled mode: May schedule tasks to be executed immediately or to be executed at specified times in the future. Functions that 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. 9 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 ±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. A typical measurement results display is illustrated in Fig. 10.

FIGURE 9

Automatic or scheduled mode tasking screen

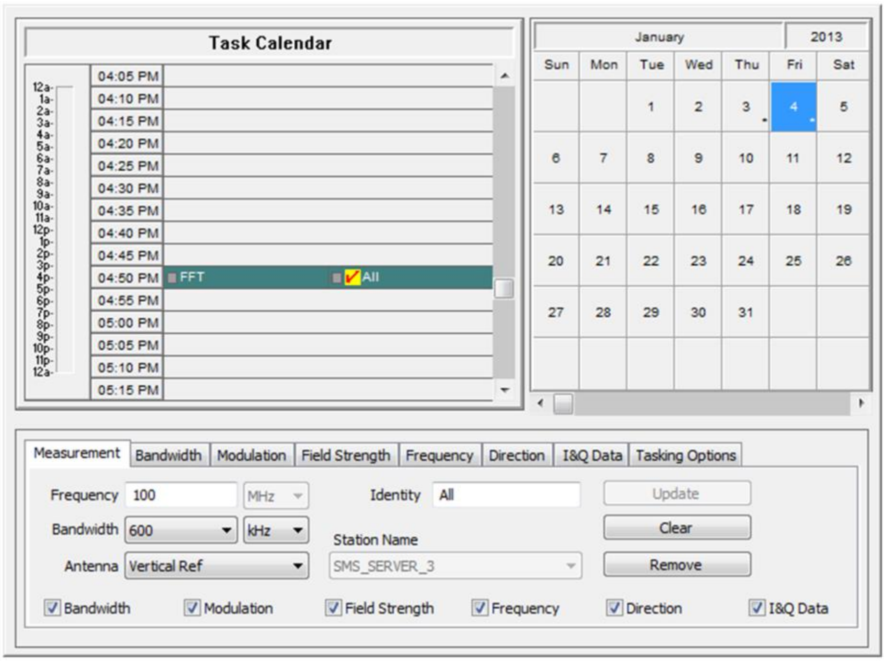

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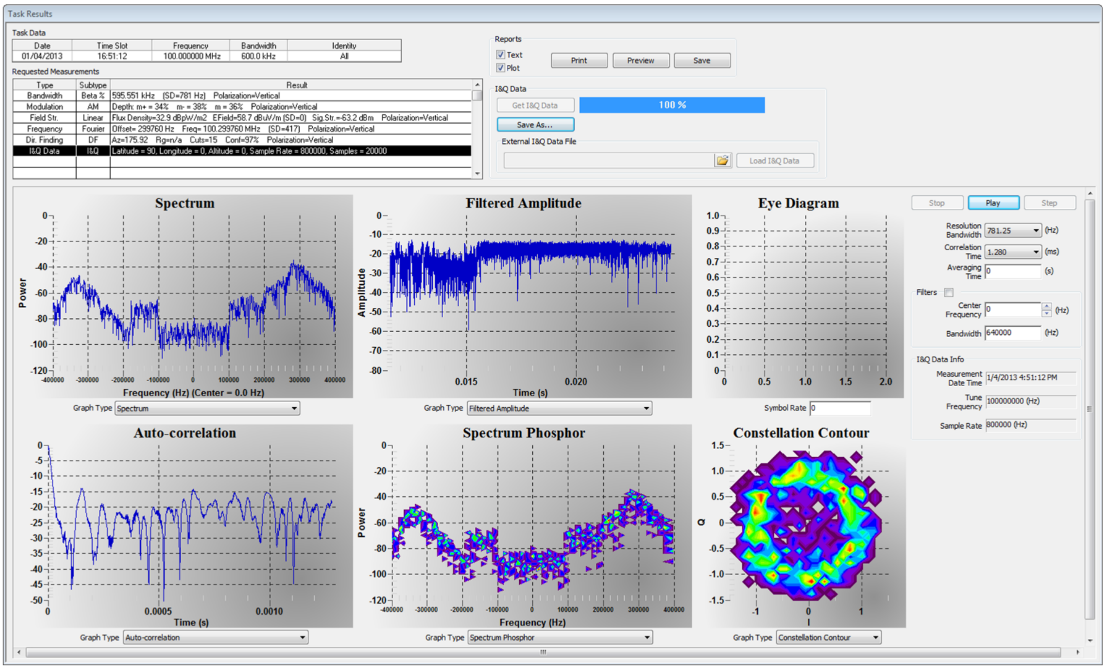
FIGURE 10

Example of scheduled modulation parameter measurement result display



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Background mode: Is used for performing tasks such as 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.

An important consideration for all monitoring locations, but especially when measurement equipment is located remotely from the operators is the ability of the measurement equipment to properly handle loss of electrical power to the station. Uninterruptible Power Supplies (UPS) and other means should be used to allow the measurement equipment to continue to operate during periods when main power is not available. However should these contingencies be exhausted and power is removed from the measurement equipment, both currently running tasks and tasks which are scheduled to run in the future should automatically resume, or start to run on schedule, after power to the equipment is returned.

When the client requests the results of measurements, the results should be displayed in convenient formats. Much of the information is displayed graphically, in the form of occupancy histograms, field strength versus frequency plots (see Fig. 11), geographic map displays showing location results (see Fig. 7), field strength by location (see Fig. 12), and other graphical displays. These systems can perform DF on many frequencies simultaneously and provide azimuth versus frequency plots (see Fig. 13) 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 good sign of the presence of a frequency hopping signal.

Sophisticated client/server systems can be designed to be significantly 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, with tens of MHz of instantaneous bandwidth (made possible by very wideband IF filters in the receivers) that can provide coverage of GHz of the spectrum (such as the entire VHF/UHF band). These systems employ components with high dynamic range so that strong signals within this wide bandwidth do not prevent very weak signals in the bandwidth from being received and processed. Automated 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 interferers and identify the kinds of signals and interference being monitored. Computer software can provide a very large variety of displays to aid the operator in understanding complex signal situations. Many examples of such displays are given in §§ 3.6.2.2.2 through 3.6.2.2.7 of the 2011 edition of the ITU Handbook on Spectrum Monitoring.

FIGURE 11

Field strength vs. Frequency display

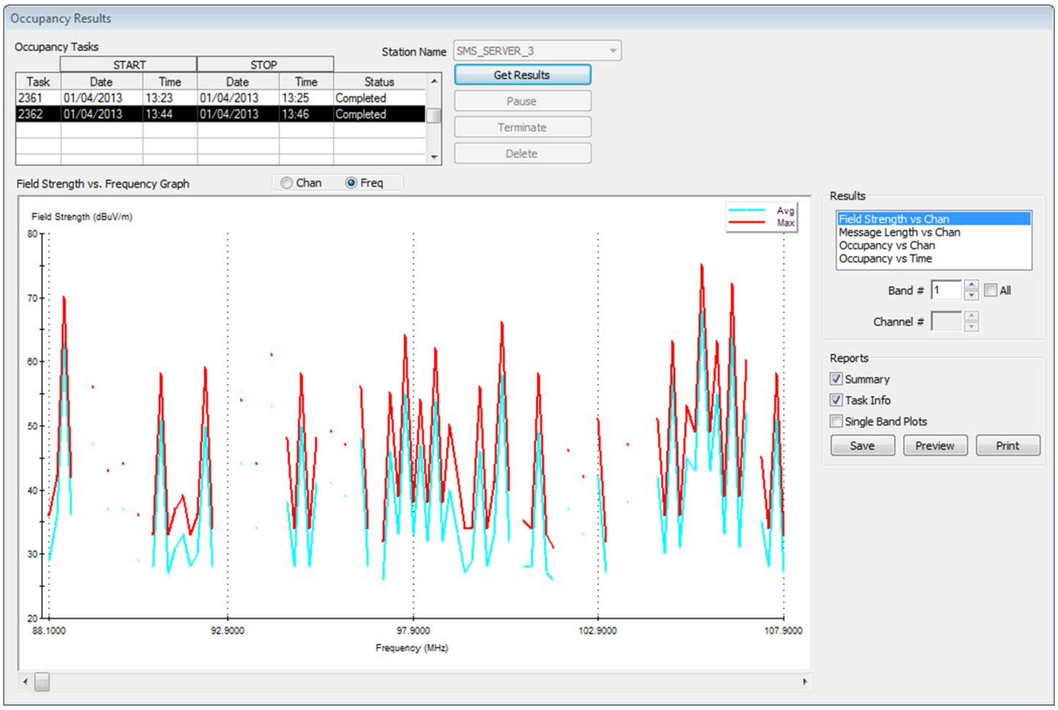

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FIGURE 12

Field strength mapping display showing field strength by frequency whilst mobile unit is moving

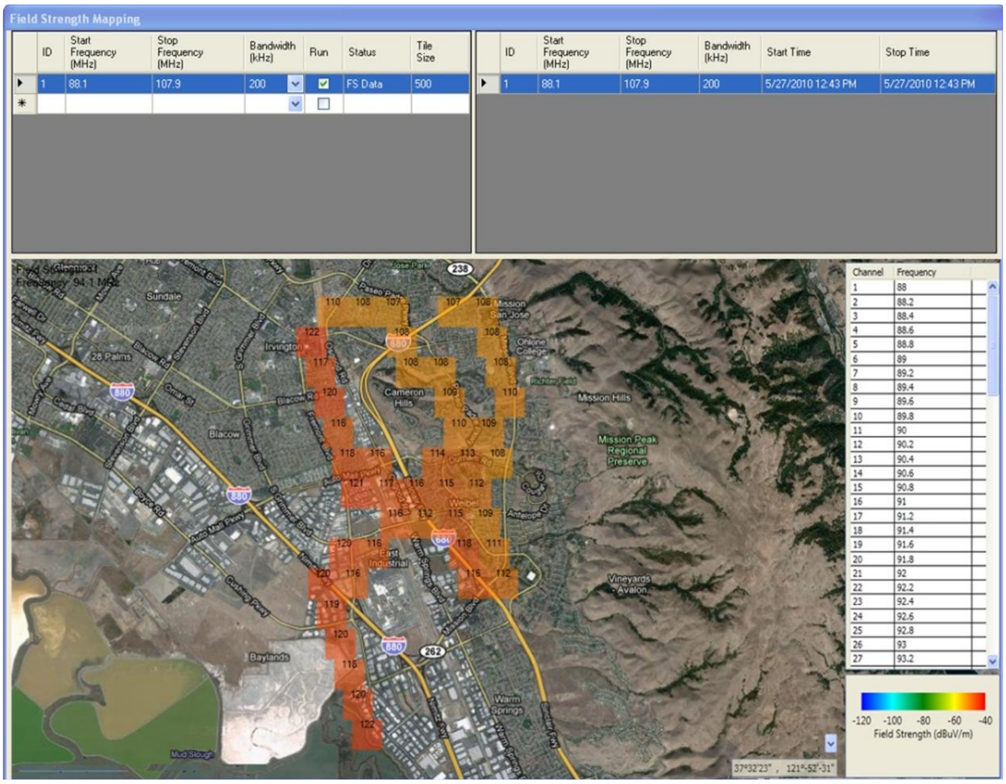

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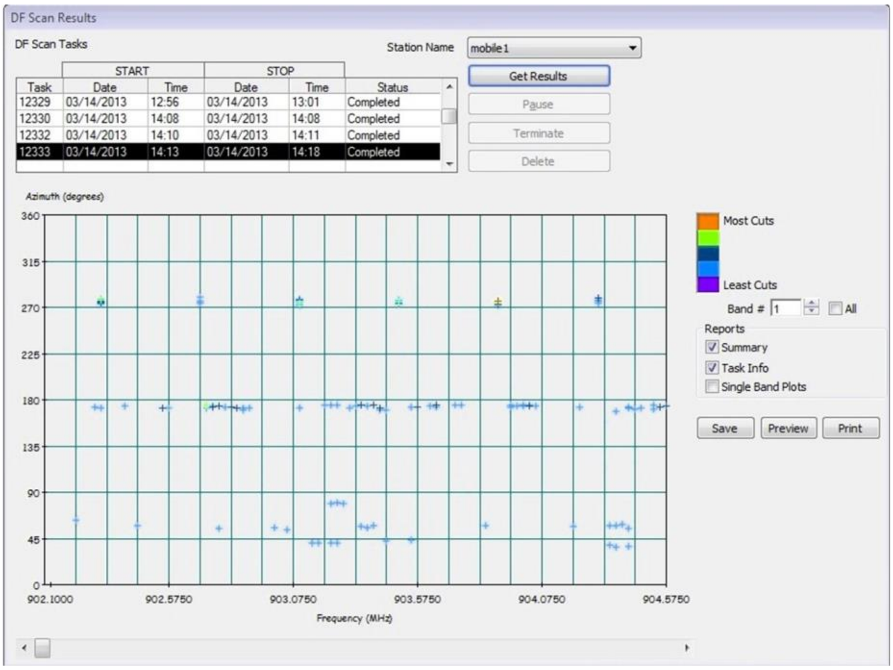
FIGURE 13

DF scan results display showing direction by frequency



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