International Telecommunication Union

ITU-R

Radiocommunication Sector of ITU

Recommendation ITU-R SM.2039
(08/2013)

Spectrum monitoring evolution

SM Series
Spectrum management

International Telecommunication Union

Foreword

The role of the Radiocommunication Sector is to ensure the rational, equitable, efficient and economical use of the radio-frequency spectrum by all radiocommunication services, including satellite services, and carry out studies without limit of frequency range on the basis of which Recommendations are adopted.

The regulatory and policy functions of the Radiocommunication Sector are performed by World and Regional Radiocommunication Conferences and Radiocommunication Assemblies supported by Study Groups.

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Series of ITU-R Recommendations

(Also available online at http://www.itu.int/publ/R-REC/en)

Series	Title
BO	Satellite delivery
BR	Recording for production, archival and play-out; film for television
BS	Broadcasting service (sound)
BT	Broadcasting service (television)
F	Fixed service
M	Mobile, radiodetermination, amateur and related satellite services
P	Radiowave propagation
RA	Radio astronomy
RS	Remote sensing systems
S	Fixed-satellite service
SA	Space applications and meteorology
SF	Frequency sharing and coordination between fixed-satellite and fixed service systems
SM	**Spectrum management**
SNG	Satellite news gathering
TF	Time signals and frequency standards emissions
V	Vocabulary and related subjects

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.2039

Spectrum monitoring evolution

(Question ITU-R 235/1)

(2013)

Scope

This Recommendation gives a brief introduction on the evolution of spectrum monitoring and recommends requirements and technologies to be considered to support the evolution of spectrum monitoring.

The ITU Radiocommunication Assembly,

considering

a) that spectrum monitoring is a key element of spectrum management;

b) that radiocommunication technologies and systems are in constant and rapid evolution;

c) that, among other technologies, the impact of software-defined radio and cognitive radio systems on spectrum monitoring needs to be studied;

d) that spectrum use in higher frequency bands continues to increase;

e) that the ITU-R Recommendations and Reports in the SM-series, as well as the ITU Handbook on spectrum monitoring (Edition 2011) provide extensive information on spectrum monitoring of existing radio communication technologies and systems;

f) that the existing spectrum monitoring systems and/or methods (including fixed, mobile and transportable stations) may need to be assessed with respect to their capability for monitoring new radiocommunication technologies and systems;

g) that the improvement in spectrum monitoring equipment enhances the efficiency and effectiveness of the spectrum management process;

h) that the increasing amount of collected spectrum measurement results may require adaptation of the organization and handling of the data and of the spectrum monitoring techniques used,

recognizing

a) that the use of co-frequency multiplexing, advanced spectrum sharing techniques and other methods could improve frequency occupancy and spectrum efficiency;

b) that wideband radio systems could enable faster communications, and the technology is developing very fast especially in future data networks;

c) that some spectrum monitoring systems have difficulty detecting and locating low power radio devices which use modern modulation techniques,

recommends

1 that the evolution of spectrum monitoring makes use of systems that can extend the monitoring coverage, perform various functions and include user-friendly operation which are described in Annex 1;

2 that the evolution of spectrum monitoring utilizes technologies, such as Detection of Weak signals, Co-frequency Signal Separation, and Multi-mode Location based on a combination of techniques, which are described in Annex 2.

Annex 1

Requirements of systems supporting the evolution of spectrum monitoring

1 Extending the monitoring coverage

With the continuous and rapid development of radio technologies, with higher frequencies and broader bandwidths, the more radio propagation distance decreases. It brings about a new challenge to spectrum management and monitoring. To strengthen the management and monitoring of radio spectrum, it is necessary to expand the coverage of spectrum monitoring or improve the sensitivity of the monitoring system to detect weak signals under low signal-to-noise ratio conditions. To detect weak signals, the following technologies would have to be used:

– Increase of the antenna gain (e.g. directional antenna, reconfigurable antenna).
– Decrease of the transmission loss (e.g. outdoor installation of equipment for minimizing RF cable loss).
– Reduction of the receiver noise figure.
– Reduction of the noise by signal processing (e.g. noise subtraction, correlation).

However, it is not enough to cope with the decrease of radio propagation distance. An increase in the number of monitoring stations should be considered but it is not always practical to deploy large fixed monitoring networks. When considering the practical conditions, the flexible operation and deployment with various types of monitoring systems should be needed:

– Monitoring systems with high performance (e.g. fixed monitoring system).
– Low-priced monitoring systems for special bands/signals (e.g. monitoring system for 2.4 GHz ISM band).
– Monitoring systems for specific purpose/region (e.g. airport monitoring system, transportable monitoring system for major events).
– Mobile and portable monitoring systems.

2 Performing the various functions

2.1 Multi-domains

The monitoring system should carry out various analyses in multi-domains as shown in Table 1. Analysis of multi-domains helps operators to identify signals and to extract parameters of the signals. Specifically, analysis of the known standard data communication protocol can provide more information including transmitter identification. The existing analysis such as time/spectrum domain and amplitude/phase domain is basic and necessary. As wider signal bandwidths and shorter signal durations are becoming more common, this analysis may be required for performing the multi-channel direction finding in addition to a general single-channel direction finding. Development of signal processing technology makes it possible to perform the simultaneous multi-channel direction finding which can enable obtaining the spatial information of each channel. Also, direction finding of short duration signals like hopping signals is possible and direction finding results of multi-channel systems can inform whether an unknown wideband signal is the same channel or not. Furthermore, if carrying out single-channel and multi-channel direction finding at the same time, it can be expected to produce more reliable direction finding results.

TABLE 1

Example of various analyses in multi-domains

Level vs. Time	**Level vs. Frequency**	**Frequency vs. Time**	**In vs. Quadrature-phase**	**Space vs. Frequency**
– Amplitude – Pulse – Eye-diagram	– Spectrum – Occupancy – Spurious – Spectrum mask – Noise	– Frequency deviation – Frequency offset – Frequency hopping	– Constellation-diagram – EVM – Phase offset	– Multi-channel direction finding

2.2 Multi-measurements

With high-performance measurement systems, it takes less time to measure by reducing processing overhead such as receiver setting time and signal processing time. As a result, the multi-measurements can be performed by time sharing as indicated in the following examples:

– Measurement of the channel occupancy and analysis of particular frequency by time-sharing simultaneously.

– When two users request the measurement and analysis of distinct frequency bands at the same time, the computation and transmission of results are possible by sharing time.

2.3 Multi-receivers

If using multi-receivers, the improvement of speed and performance by concurrent measurements can be expected and the following functions can be performed:

• Searching and listening by handover

  Operators can search and listen to the detected signals by handover.

• Direction finding and location

  The details on direction finding and location of transmitters are referred to in Chapter 4.7 of the ITU Handbook on spectrum monitoring (Edition 2011). In the case of using multi-stations for location, there are two methods which are the triangulation method using angle of arrival (AOA) of systems with multi-receivers and time difference of arrival (TDOA) method using time difference of each distributed system. Better location accuracy can be achieved through the combination of the two methods because of the complementing advantages and limitations of each method.

- Spatial diversity

  The signal is transmitted over several different propagation paths which cause phase shifts, time delays, attenuations, and distortions that can destructively interfere with one another at the aperture of the receiving antenna. The spatial diversity is usually performed by selecting the best signal-to-noise ratio (SNR) among received signals or/and by combining signals through direct or coherent addition and can improve the signal quality and reliability of a wireless link.

- Correlation detection

  The system with multi-receivers can use correlation methods. It can be possible to detect weak signals by reducing random noise sources like the white noise of receivers.

2.4 Multi-user

The connection methods used between stations and operators should be changed. When controlling monitoring stations at any terminal, the connection type would be shifted from one-to-one (1:1) to one-to-many (1:N) or many-to-many (N:N) in the same manner as the transformation of telecommunication networks from circuit-switching to packet-switching. When multiple users call for measurements from arbitrary stations simultaneously, the station analyses and schedules its own resources. Next, it conducts the measurement and transmission of results on schedule. In the case of using several stations (e.g. TDOA and Cross-correlation detection), the master station (or central controller) can schedule and control measurements.

3 User-friendly operation

As technology advances and various new signal types appear, the signal bandwidth is increasing and setting parameters are getting more complex for signal analysis purposes. The use of analogue modulated sounds and images has moved to digital data communications which usually use more complicated modulation methods and various coding techniques. For example, in the case of using analogue modulation, it is possible to analyse the signal by setting frequency, bandwidth and modulation type. However, when analysing digital modulation methods, analysis should include not only frequency, bandwidth and modulation methods but also standard parameters such as matched filter type, symbol rate, frame structure and various codes.

As a simple domain such as spectrum and level of signals is changed into multi-domains as shown in Table 1, operators may require a user-friendly control display (often called Graphical User Interface, or GUI) which enables automatic settings of parameters and graphics for effective and convenient analysis. The useful and user-friendly display for monitoring may be equipped with functions such as automatic parameter setting according to signal types and different digital communications standards. Also, it should contain gain control depending on the received signal level and convenient diagnosis of the network and hardware. When the monitoring and measurements are performed for a long time, large amounts of data are accumulated in database. Therefore, temporal and spatial changes of signals can be effectively estimated by comparing with the existing data through easy access to database.

Annex 2

Technologies supporting the evolution of spectrum monitoring

1 Detection of weak signals

The use of wideband devices and short range devices has been increasing rapidly in recent years, which causes difficulties for some monitoring systems without advanced processing, which have to deal with such low-power-density signals, especially to locate illegal transmitters or spurious emissions, etc. Deploying more monitoring systems will help to solve this problem, but this solution can be expensive.

In many cases, detection of weak signals can be improved by using a dynamic monitoring network, which may consist of mobile systems supporting and working to complement the fixed stations.

Future spectrum monitoring systems using technology for detection of weak signals will detect low-power-density signals without high cost. Typically, cross-correlation can improve sensitivity of spectrum monitoring systems 20-30 dB. Advanced technologies, such as locked-in amplifier, sampled integration, auto-correlation, cross-correlation and adaptive noise cancelling, may be used to detect low-power-density weak signals.

2 Co-frequency signal separation

In order to improve frequency occupancy and spectrum efficiency, radio frequencies are utilized in different domains, including frequency domain, time domain, amplitude domain, modulation domain, space domain, etc. Traditional monitoring devices can separate different FDMA signals easily, but it can be difficult to monitor co-frequency signals, for example, co-frequency interference, TDMA, CDMA and SDMA signals.

Future spectrum monitoring system using co-frequency signal separation technology can monitor signals working in different domains with ease. Just like a filter can separate signals working at non overlapping frequencies, beam-forming antenna can separate signals coming from different directions. Advanced technologies, such as strong-signal recovery, independent component analysis, spatial spectrum based beam-forming, and space-matched filtering may be used to separate signals working in different domains according to their different features.

3 Multi-mode location (based on a combination of location technologies)

Signals in different domains carry related location information. Correspondingly, such location information can be extracted by related technology or computer processing algorithms used in signal location. Digital signal processing (DSP) and networking capability is becoming more and more powerful. Devices based on DSP and networking are becoming more affordable. Spectrum monitoring systems based on DSP algorithms and network technology can make identification of transmitters with different characteristics working in different domains easier.

Future spectrum monitoring systems using the technology of multi-mode location based on DSP and networking will improve efficiency and accuracy when monitoring signals with different characteristics. TDOA is a good example of a system based on DSP processing and networking to locate emitters using the relative arrival times of a signal at multiple receivers. TDOA systems offer flexibility in antenna selection and placement as TDOA accuracy is minimally affected by nearby reflectors, and antennas and cables are generally not integral to TDOA receivers. Available advanced technologies, such as AOA (angle of arrival), TDOA, FDOA (frequency difference of arrival), POA (power of arrival), and identification data-aided techniques, may be used to locate emitters under different circumstances.