International Telecommunication Union

ITU-R

Radiocommunication Sector of ITU

Recommendation ITU-R SM.1880

(02/2011)

Spectrum occupancy measurement

SM Series

Spectrum management

Foreword

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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

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Series	Title
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BR	Recording for production, archival and play-out; film for television
BS	Broadcasting service (sound)
BT	Broadcasting service (television)
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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.1880

Spectrum occupancy measurement

(2011)

Scope

Although automatic occupancy measurement will not completely replace manual observations, it is still well suited for most cases. Frequency channel occupancy as well as frequency band occupancy should have a certain level of accuracy, in order to be compared or merged if necessary. By using the technique and proper method a more efficient use of existing equipment is possible.

The ITU Radiocommunication Assembly,

considering

a) that the increasing demand of radiocommunication services requires the most efficient use of the radio-frequency spectrum;

b) that good spectrum management can only satisfactorily proceed if the spectrum managers are adequately informed on the current usage of the spectrum and the trends in its demand;

c) that results of spectrum occupancy measurements would provide important inputs into:

– frequency allotments and assignments;

– verification of complaints concerning channel blocking;

– establishment of the degree of efficiency of spectrum usage;

d) that information obtained from frequency assignment databases does not reveal the degree of loading on each frequency channel;

e) that some administrations assign the same frequency to more than one user for shared use;

f) that it is desirable to compare measurement results from different countries in border areas or for instance in the aeronautical or maritime mobile services bands;

g) that automatic monitoring equipment is now in use by administrations, including methods for the analysis of records, and a number of parameters can be evaluated which are of considerable value in enabling more efficient utilization of the spectrum;

h) that in designing an automated system to gather occupancy data for use in spectrum management, one must determine what parameters are to be measured, the relationship among these parameters and how often measurements have to be taken to ensure the data are statistically significant;

j) that measurement procedures and techniques should be harmonized to facilitate the exchange of measurement results between various countries;

k) that successful merging or combining monitoring data not only depends on the data format in which the data is stored but also on the environmental and technical conditions under which the data is gathered,

recognizing

a) that various principles and methods of spectrum occupancy measurements are in use in the different countries;

b) that one particular method exists to get the high-accuracy frequency channel occupancy data and that such data usually is the basic to form the frequency band occupancy,

recommends

1 that the measurement procedures and techniques specified in Annex 1 should be used for spectrum occupancy measurements;

2 that the ITU Handbook on Spectrum Monitoring in force should be used as guidance for the spectrum occupancy measurement and the equipment should satisfy the requirement mentioned in that Handbook;

3 that a common data format, that is a line-based ASCII file derived from the radio monitoring data format (RMDF), should be used following Recommendation ITU-R SM.1809.

Annex 1

1 Introduction

This Annex describes frequency channel occupancy measurements performed with a receiver or spectrum analyzer. The signal strength of each frequency step is stored. By means of post-processing the percentage of time that the signal is above a certain threshold level is determined. Different users of a channel often produce different field-strength values at the receiver. This makes it possible to calculate and present the occupancy caused by different users.

2 Definitions

Frequency channel occupancy measurements: Measurements of channels, not necessarily separated by the same channel distance, and possibly spread over several different frequency bands to determine whether the channel is occupied or not. The goal is to measure as many channels as possible in a time as short as possible.

Revisit time: The time taken to visit all the channels to be measured (whether or not occupied) and return to the first channel.

Observation time: The time needed by the system to perform the necessary measurements on one channel. This includes any processing overheads such as storing the results to memory/disk.

Maximum number of channels: The maximum number of channels which can be visited in the revisit time.

Transmission length: The average length of individual radio transmission duration.

Duration of monitoring: The total time during which the occupancy measurements are carried out.

Preset threshold level for measurement: If a signal is received above the threshold level, the channel is considered to be occupied.

Busy hour: The highest level of occupancy of a channel in a 60-min period.

3 Requirements

3.1 Equipment

A suitable system capable of making frequency channel occupancy measurements by using frequency band registrations will consist of a radio receiver or spectrum analyzer, appropriate antenna, cable, a PC/controller, with interface adaptor, suitable acquisition and post-processing software.

Other features may include GPS, for mobile/nomadic operation of the station, communications modem, for remote control and data exchange, system calibration for traceable field strength measurements, antenna switches, filters and attenuators, for multiple band and/or strong EMF exposure environments.

3.2 Site considerations

Site should be chosen such as that the expected signal strength for the emissions of interest is above the expected threshold level. The relation between these two parameters will define an area within which the measurement performed is of relevance to any station operating above a certain effective radiated power (e.r.p.) level or effective isotropic radiated power (e.i.r.p.) level.

The expected signal strength can be evaluated considering the licensed stations at the region, their emission profile and using simulation software. The threshold can be estimated considering the system sensitivity (noise floor) or previous measurements performed under similar conditions with the same equipment and configuration.

If no preliminary information is available, a site survey using portable equipment could be performed. This is especially important if the equipment placement is of definitive nature and future relocations may not be easily performed.

Measurement results should ideally be accompanied by a report of analysis performed to select the site, indicating the area and the emitters that are expected to be considered.

3.3 Time related parameters

There is a relationship between observation time, number of channels, average transmission length and the duration of monitoring.

The *revisit time* is directly dependent on the observation time and the number of channels. Also the *processing time* (data transfer between receiver and controller) influences the revisit time and should be kept as short as possible.

Revisit time = (Observation time × Number of channels of identical bandwidth) + Processing time

The *observation time per channel* is limited by the scanning speed of the monitoring equipment. In order to maintain a reasonably short revisit time with relatively slow equipment, the number of channels to be measured must be reduced.

Whenever applying the above equation to spectrum analyzers, when the RBW is set equal to the channel bandwidth, the *Number of channels* can be considered as the number of bins[1] per sweep and the observation time as the dwell time per bin.

On FFT analysers the principle still applies, especially if the number of channels to be scanned is greater than the FFT size and some sweep still being performed. On this case however, the number of scanned channels should be divided by the number of channels evaluated on each single FFT.

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[1] Bins in statistics refer to groups (or categories or classes) of data that fall within a certain range of values.

The monitoring system needs to scan at an acceptable speed in order to detect individual short transmissions.

There are principally two different approaches to obtain channel occupancy figures:

a) Capturing every transmission in the band under observation. This approach requires a maximum revisit time that is half the minimum on or off time of any transmission in the band, whichever is shorter. This method delivers an accuracy that is independent of the occupancy result and may allow shorter monitoring duration.

b) Statistical approach: Especially when considering bursts of digital systems, the minimum transmission time might be too small for the practical application of the above principle. However, if the monitoring time is long enough to provide enough samples, the occupancy result will be correct even with far longer revisit times, because the statistical probability of catching a transmission vs. the probability of missing it is the same as the duty cycle of the transmission. The accuracy of the statistical approach, however, depends on the value of occupancy as described below.

The *duration of monitoring* is a combination of the revisit time, typical transmission lengths expected, number of channels to be scanned and the wanted accuracy of the results.

The duration of monitoring should be long enough to allow the monitoring of all relevant emissions. If no time distribution pattern is known, initial evaluations should consider at least 24 h or multiples of 24 h. One week of monitoring gives the difference in occupancy over the various days of the week and occupancy during the week end. Seven periods of 24 h spread of a longer period of time (e.g. one year) gives more reliable occupancy information.

3.4 Accuracy and statistical confidence level

There is no linear relationship between accuracy and revisit time. In the case of measuring 100 channels with a revisit time of 1 s, which is a practical value, the number of channels can be increased to 1 000 with a revisit time of 10 s without affecting the confidence level/accuracy too much.

There is a linear relationship between the occupancy and the number of samples required to achieve a desired confidence level. The lower the occupancy, the more samples will be needed.

Table 1 compares independent sampling that is the simplest case using central limit theorem and dependent sampling using a first order Markov-chain differ little from many more complicated mathematical models.

Number of required independent samples versus spectrum occupancy at 10% relative accuracy and a 95% confidence level shown as Fig. 1.

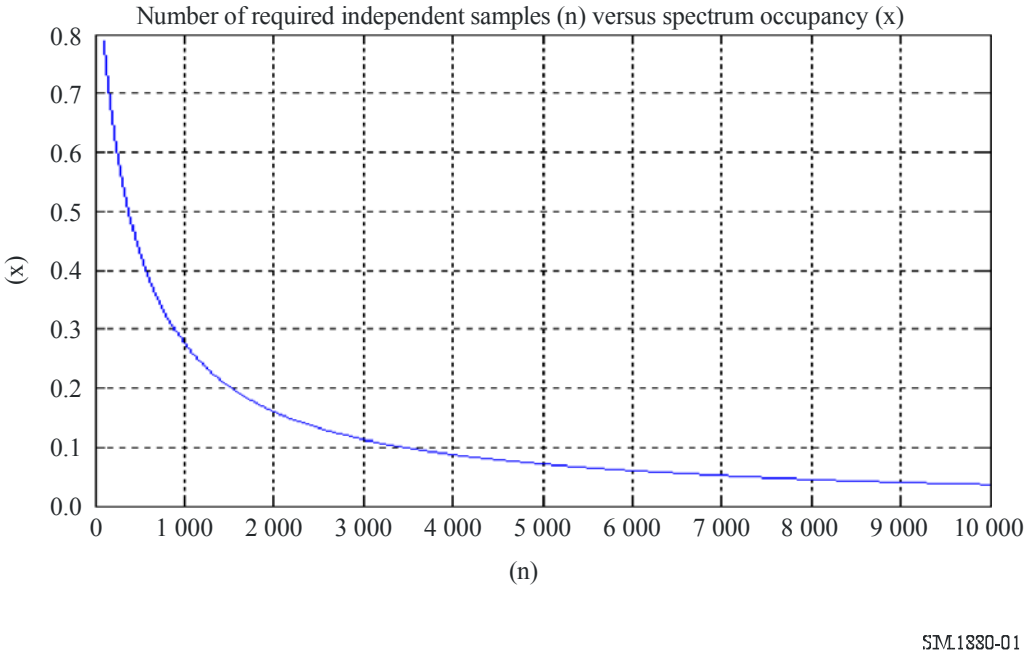
TABLE 1

Number of dependent and independent samples required to achieve 10% relative accuracy and a 95% confidence level at various occupancy percentages (assumes a 4 s sampling period)

Occupancy (%)	Number of required independent samples	Number of required dependent samples	Required hours of dependent sampling
6.67	5 368	16 641	18.5
10	3 461	10 730	12
15	2 117	6 563	7.3
20	1 535	4 759	5.3
30	849	2 632	2.9
40	573	1 777	2.0
50	381	1 182	1.3
60	253	785	0.9
70	162	166	0.2

FIGURE 1

Number of required independent samples versus spectrum occupancy at 10% relative accuracy and a 95% confidence level



3.5 Considerations on occupancy measurements

3.5.1 Emission identification

Simply recording the level does not allow discrimination between wanted and unwanted emissions or more than one user operating on a single frequency within the coverage area of the monitoring system. All emissions, if they are above the chosen threshold value, are usually treated as occupied channels.

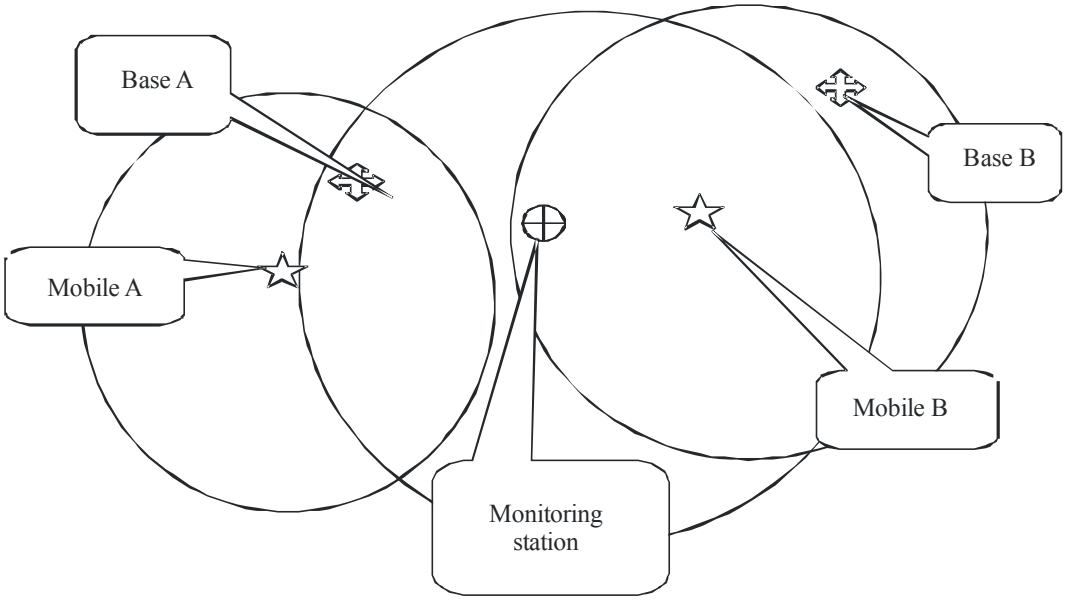
Using modern real time and post-processing software may enable discrimination between different users taking into consideration information such as field-strength or direction of arrival at the receiver, selective code information, modulation characteristics.

3.5.2 Monitoring mobile transmissions

It is possible that a wanted mobile unit (Mobile A) will be located significantly further from the monitoring site than the user's own base site (Base A). Therefore the received signal strength may be less than the monitoring threshold value set, although strong enough at the intended base site to be useable (see Fig. 2).

FIGURE 2

Monitoring mobile transmissions



Conversely, a mobile unit from an out-of-area co-channel user (Mobile B) may be received at the monitoring site but not heard at the main user's base site.

Either of the above situations might lead to misleading results since the occupancy results might not be representative for the entire mobile network, but only of the region covered by the monitoring site.

3.5.3 Propagation

Propagation conditions should also be considered when setting receiver threshold levels and propagation should be monitored during the measurement period.

3.6 Presentation and analysis of collected data

The results can be stored every 5, 15, 30 or 60 min as required. From this data it is possible to generate presentations based on tables, textual graphs, line/bar graphs and maps. After the desired information is extracted, these raw sampled data can be discarded.

The presentation system should, as a minimum, contain the location of the monitoring site, date and period of measurement, frequency, type of user(s), threshold level used, occupancy in the busy hour and revisit period.

3.6.1 Representative example of field strength used to discriminate between different users

If field strength is recorded, additional information can be extracted from the measurement.

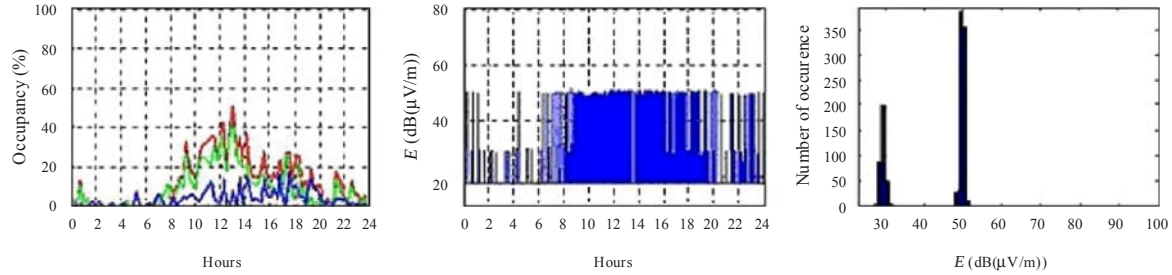
The left plot in Fig. 3 is a commonly used way to present the occupancy with a resolution of 15 min, normally with only one curve. The red curve in the left plot represents the total occupancy caused by all users on that channel. The green curve is the occupancy caused by the station received with about 49 dB(μV/m) (see right side plot) and the blue curve is the occupancy caused by all the other users, in this case the second user received with about 29 dB(μV/m).

The plot in the middle represents the received levels over time. Only received levels above the threshold level (here: 20 dB(μV/m)) are evaluated.

The right plot shows the statistical distribution of the received field strength levels. In this example 49 dB(μV/m) has been measured about 380 times in a 24-hour period, 50 dB(μV/m) about 350 times etc.

FIGURE 3

Enhanced processing of occupancy data



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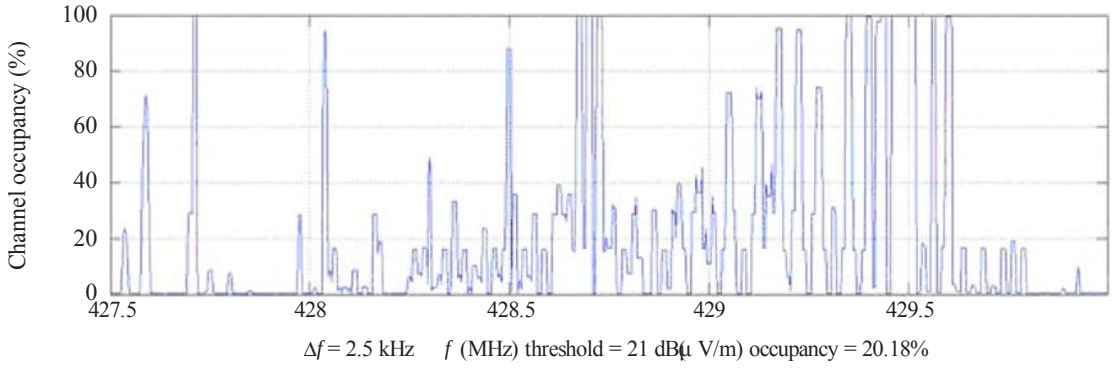
3.6.2 Representation of frequency band occupancy by percentage

Instead of presenting only the occupancy from every single channel, the occupancy of the whole measured frequency band should also be presented.

Figure 4 shows the average occupancy over 24 h from every single frequency step.

FIGURE 4

Average occupancy over 24 h



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As an example, assuming that a frequency band can be scanned in 1 000 steps in 10 s. From every step, 8 640 field-strength values are available in a period of 24 h. If, in this case, 4 320 times the threshold level on a channel/step is exceeded the occupancy will show 50%. In the resulting plot, as above presented, there is no time information left and there is no indication when this 50% occupancy was observed. This limitation should be considered when using this type of presentation.

3.6.3 Representation of frequency band occupancy by colours

To get a quick overview the occupancy can also be expressed by presenting a colour per channel per chosen resolution in time (normally 15 minutes). An example is given in Fig. 5.

In this presentation the time information is still available (96 values/24 h). The colour bar is presenting the occupancy (and not the field strength). The left Y-axis gives time, not in hours but in 96 periods of 15 min.

FIGURE 5

Frequency band occupancy using colours (spectrogram)