Radiocommunication Study Groups

INTERNATIONAL TELECOMMUNICATION UNION

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PROPOSAL TO REVISE RECOMMENDATION ITU-R SM.1880-0

Spectrum occupancy measurement

Introductory remarks

In its contribution Document 1C/83 of 12 February 2014, the Russian Federation proposed changes to the text of Recommendation ITU-R SM.1880, on spectrum occupancy measurement, in order to provide greater clarity in this rather complex area. The WP 1C meeting in June 2014, in anticipation of further contributions on this subject, decided to publish this material, on behalf of WP 1C, in Annex 1 to Document 1C/119 of 23 June 2014, with a view to returning to discussion of the subject at the next WP 1C meeting in June 2015.

During the discussion of Document 1C/83 at the WP 1C meeting in June 2014, it was suggested, *inter alia*, that the material presented was too long and detailed for the relatively short text of Recommendation ITU-R SM.1880. It was proposed to reflect on the possibility of splitting it into two parts, incorporating fundamental provisions in Recommendation ITU-R SM.1880 and placing the remaining explanations in Report ITU-R SM.2256, on spectrum occupancy measurements and evaluation.

To this end, if at its meeting in June 2015 WP 1C agrees to splitting the material in this way, this contribution sets out the part to be included in Recommendation ITU-R SM.1880. The part proposed for incorporation in Report ITU-R SM.2256 is set out in Document 1C/140.

Proposal

The proposed draft revision of Recommendation ITU-R SM.1880 is set out in the attachment.

ATTACHMENT

RECOMMENDATION ITU-R SM.1880-1

Spectrum occupancy measurement and evaluation

(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;

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

j) 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 both Report ITU-R SM.2256 and 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. An example of the procedure for such post-processing is presented in Report ITU-R SM.2256 (Annex 1). 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.

Integration time: Time interval for which an individual occupancy estimate is made. Normally 5 or 15 minutes.

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

No change

3.2 Site considerations

No change

3.3 Time related parameters

No change

3.4 Accuracy, ~~and~~ statistical confidence level and required number of samples

~~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.

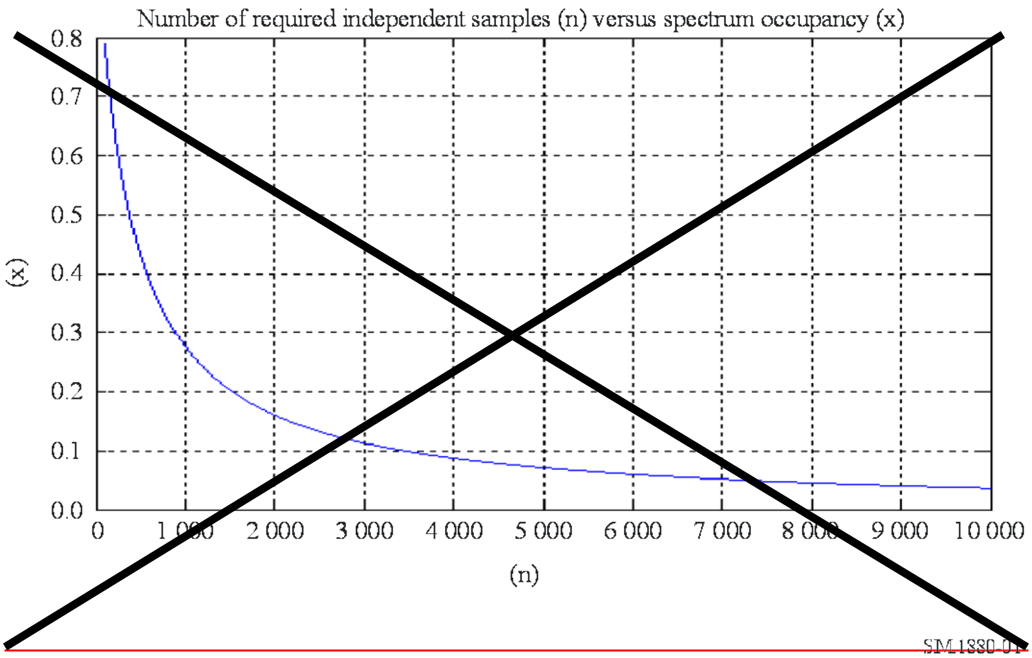
TABLE 1

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



In practice, the result of the collection and processing of data when conducting measurements of radio-channel (or frequency-band) occupancy is not in itself the true value of occupancy, abbreviated as *SO*, but an estimate – a random variable whose over different integration times may deviate significantly from *SO*. The quality of the measurements is thus characterized by the absolute accuracy Δ_{SO}, which determines the extent to which large deviations in the estimates from the true value *SO* are considered permissible, and by the confidence (confidence level) which indicates the minimum probability with which occupancy estimates must fall within the interval from $(SO - \Delta_{SO})$ to $(SO + \Delta_{SO})$, referred to as the confidence interval. It is sometimes more convenient to state the confidence interval limits in the form $SO \cdot (1 \pm \delta_{SO})$, where $\delta_{SO} = \Delta_{SO} / SO$ is the maximum permissible relative evaluation error.

Even in cases where, during the integration time, the monitoring equipment provides only a small number of data samples, calculation of the occupancy estimate will give a number of values characterizing the radio-channel occupancy to a greater or lesser degree. However, such values will correspond to the true value of occupancy (*SO*) only when averaged over a large number of integration times, while the individual evaluations may deviate considerably from *SO*.

On the other hand, if the monitoring equipment is capable, over the *integration time*, of providing a number of samples considerably exceeding what is actually necessary, the accuracy and confidence of the measurements will appear to be superfluously high under an excessive amount of computing resources. Measurements therefore need to be performed with a somewhat optimum number of samples used.

To ensure sufficiently accurate and confident measurements with economical use of computing resources, account needs to be taken of the following.

The accuracy and confidence of occupancy estimates are determined not only by the number of samples obtained over the *integration time*, but also by the nature of the signals observed in the radio channel. The most exacting requirements in regard to the number of accumulated samples and operating speed of the monitoring equipment come into play in the case of radio channels with predominantly pulsed signals having duration of less than one thousandth of the *integration time*. This type of analysed signal is also characteristic when it comes to the measurement of frequency-band occupancy. In the case of channels with pulsed signals, the number of samples required to produce accurate and confident measurements is determined, all other things being equal, by the actual level of channel occupancy, as can be seen from Table 1.

If, however, lengthy signals are observed in the radio channel, the required number of samples will depend primarily on the average number of signals observed during the integration time, and will generally be markedly lower than in the case of pulsed signals. Recommendations on occupancy evaluation for channels with lengthy signals may be found in Annex 1 to Report ITU-R SM.2256.

TABLE 1

Number of samples required to achieve a maximum 10% relative error δ_{SO} or a 1% absolute error Δ_{SO} with a 95% confidence level

Channel occupancy, %	**Required relative error δ_{SO} = 10%**		**Required absolute error Δ_{SO} = 1%**	
	Resulting magnitude of absolute error, %	**Required number of independent samples**	**Resulting magnitude of relative error, %**	**Required number of independent samples**
1	0.1	38 047	100.0	**380**
2	0.2	18 832	50.0	**753**
3	0.3	12 426	33.3	**1 118**
4	0.4	9 224	25.0	**1 476**
5	0.5	7 302	20.0	**1 826**
10	1.0	**3 461**	10.0	**3 461**
15	1.5	**2 117**	6.7	4 900
20	2.0	**1 535**	5.0	6 149
30	3.0	**849**	3.3	8 071
40	4.0	**573**	2.5	9 224
50	5.0	**381**	2.0	9 608
60	6.0	**253**	1.7	9 224
70	7.0	**162**	1.4	8 071
80	8.0	**96**	1.3	6 149
90	9.0	**43**	1.1	3 459

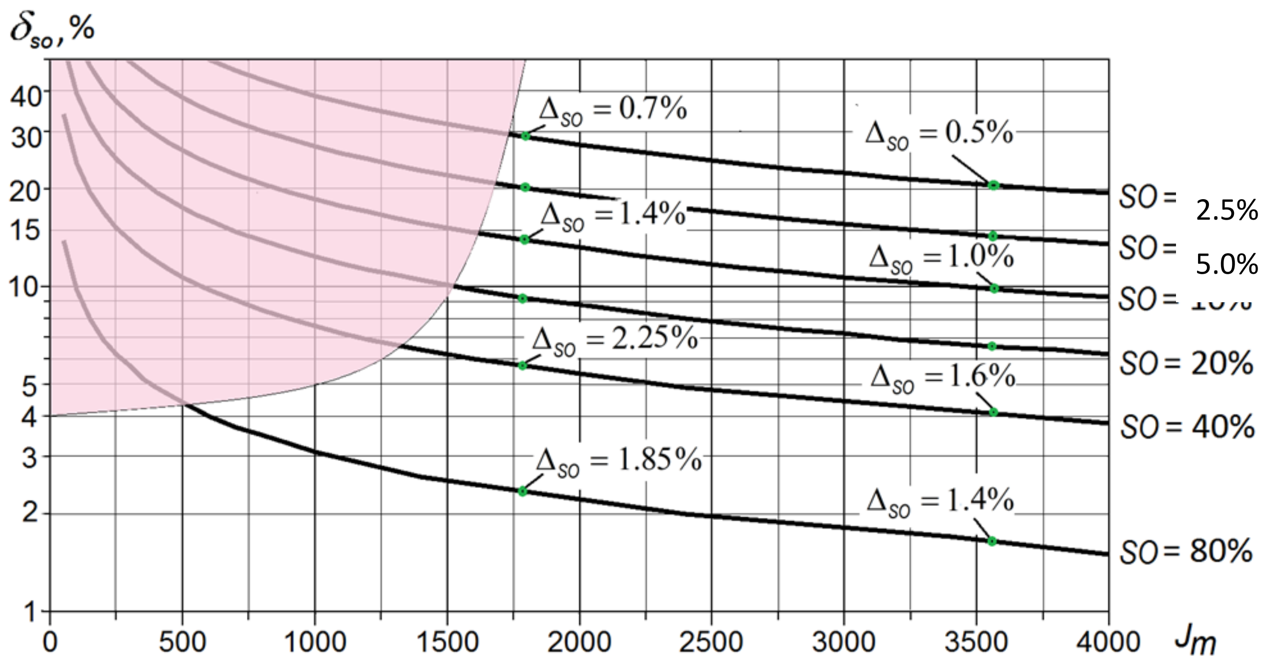
Measurement errors for different occupancy values and differing numbers of processed data samples can be estimated using the graph shown in Fig. 1. The upper left-hand part of the graph is a shaded inadvisable area, signifying that to estimate occupancy with such a small number of samples is not recommended owing to an unacceptable increase in error.

If the estimate is made while, for small occupancy values, limiting the permissible absolute error, and, for large occupancy values, limiting the permissible relative error, this significantly reduces the number of samples required to achieve the confidence level (see the values in bold type in Table 1). The associated increase in relative evaluation error for small occupancy values is entirely acceptable from the practical standpoint, since the absolute evaluation error will be small.

The advisability of using such an approach is clearly verified in cases where occupancy in the monitored radio channels varies significantly and the conventional requirement for limiting permissible relative error throughout the whole range of occupancy values entails using more than 10^4 samples for channels with an occupancy of less than 4% and accepting using less than 500 samples for channels with an occupancy of 50% or greater. In such cases, it is more practical to use a relatively large universal fixed number of samples. For example, when evaluating occupancy with 3 600 samples (corresponding to a sampling rate of 4 times per second over a period of 15 minutes), the measurement error will be lower than 10% of the relative error for channels with an occupancy exceeding 10%, and lower than 1% of the absolute error for channels with an occupancy of less than 10% (see Fig. 1). Where 1 800 samples are used instead of 3 600, the absolute estimation errors increase by a factor of $\sqrt{2} \approx 1.41$ yet still remain fairly low, and so occupancy measurement with 1 800 samples may also be considered acceptable for practical purposes for monitoring equipment that is not too fast. More detailed information may be found in Report ITU-R 2256-1[1].

FIGURE 1

Dependency of the relative error of occupancy estimates (δ_{SO}, %) on the number of accumulated samples (J_m) with a 95% confidence level for channels with pulsed signals



3.5 Considerations on occupancy measurements

No change

3.6 Presentation and analysis of collected data

No change

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[1] Amended as proposed in Document 1C/140.