Radiocommunication Study Groups

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PROPOSED DRAFT REVISION OF RECOMMENDATION ITU-R SM.443-4

Bandwidth measurement at monitoring stations

Background

The latest version of Report ITU-R SM.2048-1, on use of the x dB bandwidth criterion for determination of spectral properties of a transmitter in the out-of-band domain, adopted in 2023, serves to supplement the provisions of Recommendation ITU-R SM.443-4, on bandwidth measurement at monitoring stations, in terms of expanding the scope of application for monitoring of the x dB bandwidth. In particular, this concerns measurements of the bandwidth for assessment at the universal -30 dB for the vast majority of emission classes in use and measurement of out-of-band emissions at −40, −50 and −60 dB.

Proposal

It is proposed to expand the title of Recommendation ITU-R SM.443-4 with a reference to out-of-band emissions and include two new sections in the body of Recommendation ITU-R SM.443-4 concerning bandwidth for assessment and out-of-band emission measurement.

Attachment: Proposed draft revision of Recommendation ITU-R SM.443-4, on bandwidth measurement at monitoring stations

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Attachment: 1

ATTACHMENT

RECOMMENDATION ITU-R SM.443-4*5

Bandwidth and out-of-band emission measurement at monitoring stations

(1966-1978-1995-2005-2007-....)

Scope

This Recommendation recommends methods for determining occupied bandwidth and out-of-band emissions of radio transmitters at monitoring stations for different classes of emission.

Keywords

Bandwidth measurements, β% method, x dB method, out-of-band emission measurement, monitoring stations

The ITU Radiocommunication Assembly,

considering

a) the need for the measurement of bandwidths of emissions and, when the interference situation allows, of out-of-band emissions at monitoring stations to promote efficient use of the radio-frequency spectrum;

b) the need for uniform, easy-to-perform and reliable results of bandwidth measurement at monitoring stations, to enable a comparison of the results obtained by different monitoring stations and with normalized values for this parameter;

c) the definitions of different bandwidths in the Radio Regulations (RR) and Recommendation ITU-R SM.328, especially the definitions of occupied bandwidth and *x* dB bandwidth;

d) the provisions of Report ITU-R SM.2048 demonstrating that the *x* dB bandwidth criterion is the single metrological basis for measurement of both the bandwidth of the emissions of a transmitter and of its out-of-band emissions; bandwidth can be determined for the vast majority of classes of emission at the universal −30 dB, and out-of-band emissions at −40, −50 and −60 dB, when the interference situation allows;

~~d~~e) the increasing availability of equipment able to directly measure the occupied bandwidth, including equipment employing digital signal processing and fast Fourier transform (FFT) techniques;

~~e~~f) Chapter 4.5, on bandwidth measurement, of the ITU-R Handbook on Spectrum Monitoring, (Edition 2011),

recommends

1 that the direct "β% method" specified in Annex 1 should be used at monitoring stations when measuring the occupied bandwidth;

~~* Radiocommunication Study Group 1 made editorial amendments to this Recommendation in the years 2018 and 2019 in accordance with Resolution ITU-R 1.~~

2 that the "*x* dB method" specified in Annex 2 should be used at monitoring stations when measuring the *x* dB bandwidth;

3 that the occupied bandwidth can be estimated from the *x* dB bandwidth using the procedure described in Annex 3 when the conditions for accurate measurement of occupied bandwidth are not met, or in the absence of equipments capable of performing β% measurement.; and

4 that the method set out in Annex 4 be used for out-of-band emission measurement.

Annex 1

Measurement method of occupied bandwidth (β% method)

1 Introduction

RR No. 1.153 and Recommendation ITU-R SM.328 define the term occupied bandwidth as follows:

> "*Occupied bandwidth:* The width of a frequency band such that, below the lower and above the upper frequency limits, the *mean powers* emitted are each equal to a specified percentage β/2 of the total *mean power* of a given *emission*.
>
> Unless otherwise specified in an ITU-R Recommendation for the appropriate *class of emission*, the value of β/2 should be taken as 0.5%."

In line with § 2 of Recommendation ITU-R SM.328 on an emission of a transmitter, the optimum from the standpoint of spectrum efficiency is reached when the occupied bandwidth is equal to the necessary bandwidth of the relevant class of emission, given by Recommendation ITU-R SM.1138, which is incorporated into the RR by reference.

According to the definition above, the occupied bandwidth can be measured using either digital swept spectrum analysers or digital monitoring receiver allowing to store the recorded traces in memory for later graphical processing, or with analysers employing FFT techniques.

2 General conditions for bandwidth measurement

General conditions for bandwidth measurement are the following:

– The line-of-sight (LoS) with Fresnel curve between the transmitting and receiving antenna must be secured to ensure the high degree of discrimination of source of emission.

– A directional antenna with high directivity and high front-back ratio should be used to minimize the influence on multipath fading effects.

– Any suitable sufficiently sophisticated spectrum analyser or digital monitoring receiver can must be used. If the spectrum analyser or monitoring receiver has significant non-linearity, the inter-beating of spectrum components of the transmitted signal within the required bandwidth may create intermodulation products falling into the out-of-band domain, thereby adding some power to the out-of-band emissions generated by the transmitter itself and thus extending the measured value of the occupied bandwidth.

– Impulse interferences should not occur (for example, interference from an ignition source).

3 Measurement procedure

The spectrum analyser or digital monitoring receiver is adjusted with the following settings:

– Frequency: estimated centre frequency of the emission
– Span: 1.5 to 2 times the estimated bandwidth of the emission
– Resolution bandwidth (RBW): less than 3% of the span
– Video bandwidth (VBW): 3 times RBW or more
– Level/Attenuation: adjusted so that the *S*/*N* ratio is more than 30 dB
– Detector: peak or sample
– Sweep time or acquisition time: auto (for pulsed emissions long enough so that one pulse is recorded for every pixel on the screen)
– Trace: MaxHold (for analogue modulation), ClearWrite (for digital modulation).

In most digital systems, the occupied bandwidth is constant over time, because normally a data stream is transmitted with a constant symbol rate. In these cases, the momentary value of the calculated bandwidth will be relatively constant for each recorded trace. To smooth the results of different subsequent measurements, a longer sweep time can be set. This will make the reading of the result easier.

In analogue systems, especially when audio signals are transmitted (F3E, A3E, J3E), the momentary occupied bandwidth changes rapidly with the modulation. In these cases, monitoring stations are only interested in the maximum occupied bandwidth within a certain observation time (e.g. one hour). To get this result, the “MaxHold” function has to be applied.

After the trace has been recorded, the displayed spectrum is mathematically analysed to calculate the occupied bandwidth as follows:

The spectral power (or level) of each frequency line of the stored trace is added throughout the adjusted span to give the 100% reference power. In a second calculation, starting from the lowest frequency recorded, the spectral power of each frequency line is again added up until the sum reaches 0.5% of the predetermined total power. At this point, a marker is set. The same calculation is then performed starting from the highest frequency recorded (the right edge of the display) until again 0.5% of the total power is reached and a second marker is set. The occupied bandwidth is the frequency difference between the two markers.

4 Measurement conditions and accuracy

The relative accuracy depends on:

– *The spectral shape of the signal*

  When the signal raises and falls steeply towards the edges of the used channel, the accuracy is higher.

– *The resolution bandwidth*

  Smaller RBW result in higher accuracy, because the bandwidth calculation is based on the graphical shape of the displayed trace which is always widened by the measurement filter.

– *The frequency span*

  If the frequency span is too wide, more and more noise will be included in the calculation process which results in less accuracy. However, the span has to be wide enough to include at least some spectral components below the 0.5% (or −26 dB) points.

– *The noise and interference level*

Since noise and interference outside the used channel is included in the calculation process, a high difference between useful signal and interference will increase the accuracy. Therefore a minimum adjacent channel power ratio (ACPR) or minimum difference of the peak level and level of outmost frequencies of 30 dB is recommended to ensure a measurement error of less than 10% (see Fig. 1 and Fig. 2).

– *Measurement trials*

The fluctuation of digital signal due to the non-constant modulation signal can lead uncertainty on the measurement result. Therefore the measurement trials of at least 400 times are recommended to obtain the average occupied bandwidth.

Care should be taken that no interfering signal can be seen inside the recorded span because this would be treated as part of the wanted signal which may result in a high measurement error.

FIGURE 1

Difference between peak level and level of outmost frequencies

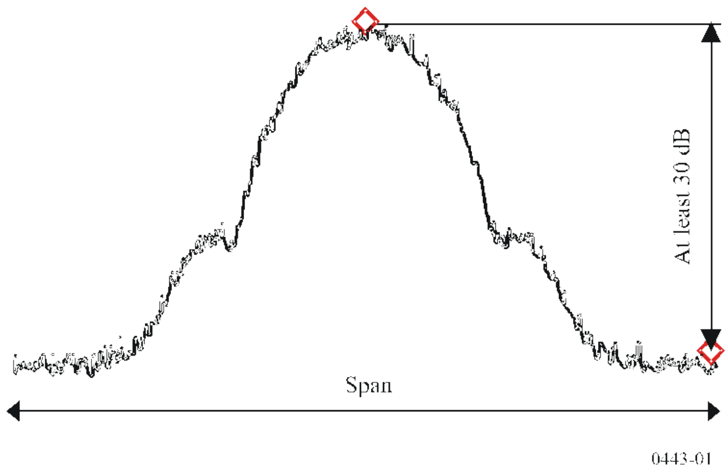
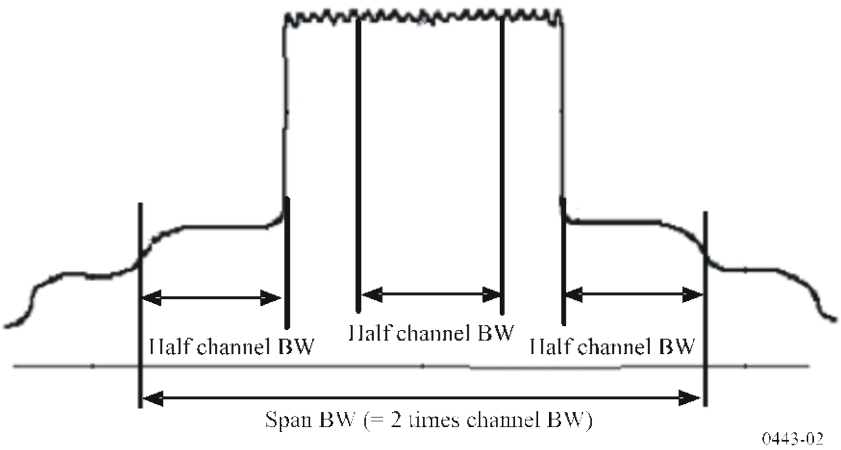


FIGURE 2

ACPR using half channel bandwidth



Annex 2

Measurement method of *x* dB bandwidth (*x* dB method)

1 Introduction

The "*x* dB bandwidth" (Recommendation ITU-R SM.328 (§ 1.8)) is defined as the width of a frequency band such that beyond its lower and upper limits any discrete spectrum component or continuous spectral power density is at least *x* dB lower than a predetermined 0 dB reference level.

In cases where it is specifically needed, for example to determine the border to the out-of-band domain of radar emissions, the *x* dB bandwidth can be measured using any spectrum analyser or digital monitoring receiver.

Moreover in line with the requirements of item 2 of Recommendation ITU-R SM.328 on an emission of a transmitter, optimum from the standpoint of spectrum efficiency, *x* dB bandwidth can be also related to the necessary bandwidth of the relevant class of emission given by Recommendation ITU-R SM.1138, which is incorporated into the RR by reference.

2 Measurement procedure

First, the 0 dB reference level has to be determined. This is usually the level of the highest spectral line when the spectrum is recorded with a narrow RBW on the analyser. Under the assumption that, during the recording time, the transmitter power returns to the carrier at least once, this level is equal to the total emitted power. However, in digitally modulated signals, this assumption cannot be made. Although the 0 dB reference is still set to the level of the highest spectral line, it is not the total emitted power, which is the reason that the *x* values, to gain comparable results, are different for analogue and digital emissions.

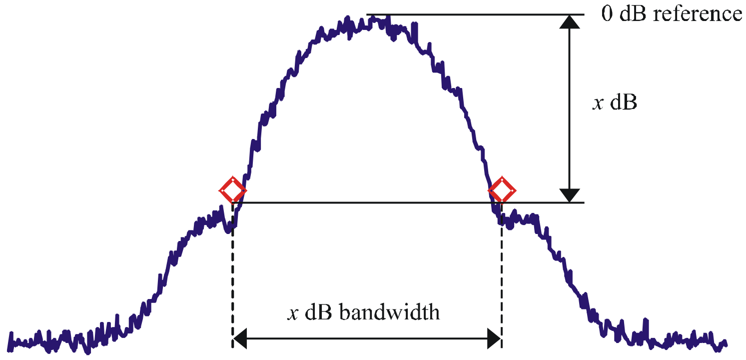
The spectrum analyser/digital receiver should be adjusted as follows:

– Centre frequency: f_0 (carrier frequency or estimated centre frequency of the emission)
– Span: 1.5 times the estimated bandwidth of the emission
– RBW: less than 3% of the span
– VBW: 3 times RBW or more
– Detector: peak
– Trace: MaxHold.

When the trace has built up, the peak level is searched. The value *x* dB bandwidth is read on the equipment screen as the width of a frequency band such that beyond its lower and upper limits any discrete spectrum component is at least *x* dB lower than a predetermined 0 dB reference level. If more than two spectral lines have this level, the outmost frequencies are taken. The frequency difference between the two markers is the *x* dB bandwidth.

FIGURE 3

***x* dB bandwidth**



3 Measurement conditions and accuracy

The accuracy of the *x* dB method depends on:

– *The spectral shape of the signal*

When the signal raises and falls steeply towards the edges of the used channel, the accuracy is higher.

– *The resolution bandwidth*

Smaller RBW result in higher accuracy, because the displayed shape of the signal is always widened by the measurement filter.

– *The frequency span*

If the frequency span is too wide, less display lines are available to show the signal and set the markers. Less resolution increases the measurement uncertainty.

– *The noise and interference level*

The signal-to-noise ratio must be sufficient according to the analysed emission. A minimum of *x* + 5 dB is recommended to ensure a measurement error of less than 10%. One of the best ways, when the dynamic of the signal is not sufficient in the monitoring station, is to make the measurement with a mobile station which can go near the transmitter.

A number of the provisions set out in Annex 1, § 3, in particular the conditions for the application of the "MaxHold" function of the spectrum analyser, are suitable for *x* dB bandwidth measurement. The same applies to the measurement methodology set out under § 5 of Report ITU-R SM.2048. Although the latter concerns measurements using test signals under conditions that do not change over time, a number of its provisions, in particular those concerning the setting of zero levels, are entirely suitable for cases of monitoring.

Interfering signals inside the displayed span can be tolerated and will not influence the result of a manual *x* dB measurement, if it is narrow compared to the bandwidth of the wanted signal, and if the interference frequency does not fall on one of the *x* dB points.

4 Measurement of *x* dB bandwidths in conditions of influence of interferences

In some cases values of *x* dB bandwidth can be measured or, at least, estimated in the presence of interferences whose levels exceed value of a measuring level *x* dB. As it is shown in Fig. 4, in the case when borders of *x* dB bandwidth from each edge of a spectrum of an emission under consideration are not masked by interferences (spectra 1 and 2), the bandwidth of this particular spectrum is measured, not taking into account spectra of interferences. In other words, in the case shown in Fig. 4, the *x* dB bandwidth B_{ox} is equal to B_m and not B_Σ.

In case of doubts whether spectra 1 and 2 belong to interferences, the interfering transmitters can be determined using a two-channel correlometer by a small value of mutual correlation factor between the signal corresponding to a spectrum of the emission under consideration and the signal of potential interference (§§ 4.4.5.4, 4.8.5.5, 4.8.5.6) of the ITU Spectrum Monitoring Handbook (Edition 2011).

Even in case of masking of one *x* dB bandwidth border by an interfering spectrum as shown in Fig. 5 (spectrum 3), if the spectrum of wanted signal is symmetrical, like most cases, the estimation of the bandwidth value can be carried out on the basis of half of spectrum width, i.e. $B_{ox} = 2\ B_k$.

It is natural that measurements in conditions of influence of interferences are burdened by greater errors, than measurements in the absence of interferences. However, estimations obtained in some cases are quite suitable for practical applications.

FIGURE 4

Bandwidth measurement in presence of interferences

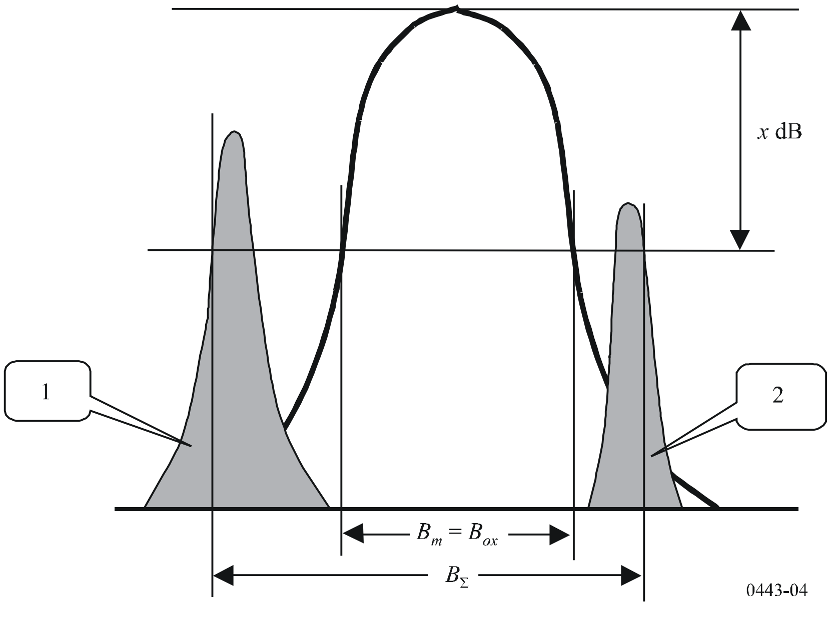
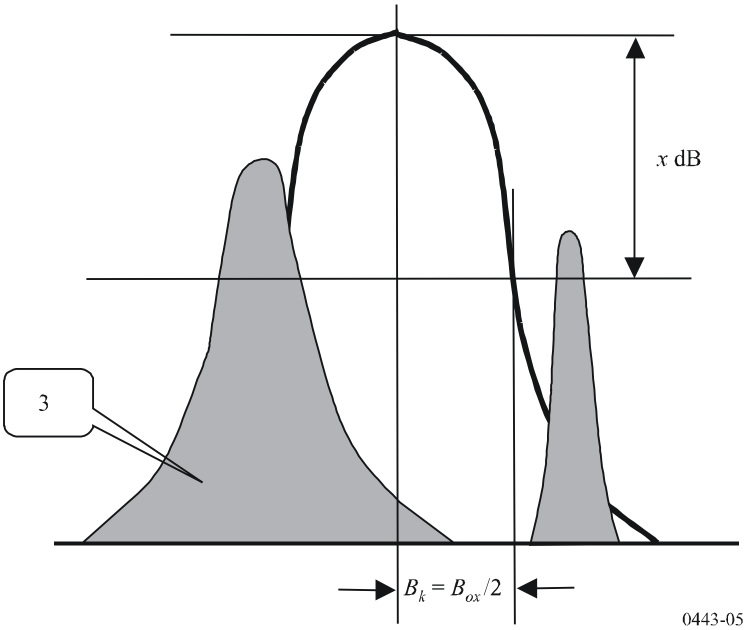


FIGURE 5

Bandwidth measurement by a half of the spectrum



Annex 3

Estimation of the occupied bandwidth using the *x* dB method

1 Introduction

In the following situations, the β% method cannot be applied to directly measure the occupied bandwidth:

– in-band interference at levels that are higher than the level of the wanted signal;

– suitable equipment capable of employing the β% method is not available.

In these cases, the *x* dB method described in Annex 2 can be used to estimate the occupied bandwidth.

To give the occupied bandwidth as a result of the *x* dB method, the values for the 0 dB reference level and for *x* have to be selected properly.

Generally, there are ~~two~~ three different approaches to compare the measured bandwidth with the necessary or occupied bandwidth:

– ~~Always m~~Measurement of the −26 dB bandwidth with ~~and~~ application~~y~~ of ~~a~~ conversion factors.

– Measurement of the ~~signal~~ bandwidth at specific values of *x* dB that are different for each class of emission~~.~~;

– Measurement of the −30 dB bandwidth for assessment with application of conversion factors.

2 Estimation of occupied bandwidth from the −26 dB bandwidth

With this method, the bandwidth is always measured at the −26 dB points following the procedure in Annex 2. The conversion factors between 26 dB bandwidth B_{26} and necessary bandwidth B_n in Table 1 should be used for estimation of occupied or necessary bandwidth.

TABLE 1

Class of emission	Relationship between B_{26} and B_n
A1A, A1B, A2A, A2B	$B_{26} = 0.9\ B_n$
F1B	$B_{26} = B_n$
F3C	$B_{26} = B_n$
F7BDX	$B_{26} = 0.9\ B_n$

3 Direct estimation of occupied bandwidth from *x* dB bandwidth measurement at different levels

With this method, the bandwidth is measured using the *x* dB method described in Annex 2.

The 0 dB reference level is always set to the peak level of the resulting curve. The values for *x* should be taken from Table 2 according to the modulation of the signal.

TABLE 2

Class of emission (See RR Appendix 1)	Values of "*x* dB" to be used when measuring *x* dB bandwidth for estimation of occupied bandwidth	Remarks
A1A A1B	–30	
A2A A2B	–32	
A3E	–35	
B8E	–26	
F1B	–25	
F3C	–25	
F3E G3E	–26	
F7B	–28	
H2B	–26	
H3E	–26	
J2B	–26	
J3E	–26	
R3E	–26	
C7W (8-VSB)	–12[(1)]	Average of more than 300 sweeps
G7W (T-DAB)	–8[(1), (2)]	Average of more than 100 sweeps

(1) According to Recommendation ITU-R SM.328, the unit of these values is dBsd because the reference level was chosen to the maximum value of power spectral density (psd) within the necessary bandwidth.

(2) This value is derived from experiments with T-DMB using a T-DAB network taken from Report ITU-R BT.2049.

The resulting value of the measurement is the estimation of the occupied bandwidth.

4 Evaluation of occupied bandwidth from −30 dB bandwidth for assessment

The conditions and procedures for the measurement of the −30 dB bandwidth for assessment correspond fully to the measurement of the −26 dB bandwidth, but based on a value of −30 dB and applying the conversion factors specified in Report ITU-R SM.2048. The advantage of this method is the fact that, for the −30 dB bandwidth for assessment, Report ITU-R SM.2048 provides conversion factors for around 180 classes of emission, instead of for seven classes at −26 dB (§ 2 above) and 18 classes when using different levels (§ 3 above).

As Table 2 above shows, a value of −30 dB represents an approximate mean value between the levels at which the measured *x* dB bandwidth values correspond to the occupied bandwidth values obtained using the β% method. For this reason, results of −30 dB bandwidth for assessment measurements immediately give the operator some idea of the occupied bandwidth value even before application of conversion factors.

Annex 4

Measurement of out-of-band emissions

As shown in Report ITU-R SM.2048, the *x* dB bandwidth criterion is the single metrological basis for the measurement of both the bandwidth of emissions of a transmitter and its out-of-band emissions, or, more precisely, its emissions in the out-of-band domain. For this reason, Report ITU-R SM.2048 serves as the single basis for both conversion factors for −30 dB, characterizing bandwidth for assessment, and for −40, −50 and −60 dB, characterizing out-of-band emissions. Consequently, measurements of out-of-band emissions follow the same conditions and procedures presented above for the *x* dB bandwidth measurement method, but at −40, −50 and −60 dB.

For out-of-band emissions, for which out-of-band spectra masks are provided (Recommendations ITU-R SM.1541 and ITU-R BT.1206), measurements may be performed at the break points of the masks, with subsequent determination of the relative frequencies for these points.

Out-of-band emissions at low reference levels, such as −50 dB and, in particular, −60 dB, may be affected by interference. Consequently, measurements can only be taken when the interference situation allows, e.g. measurements by a mobile radio control station in the vicinity of a monitored transmitter.

As with measurements of occupied bandwidth (Annex 1, § 2), measurements of out-of-band emissions must be performed by a sufficiently sophisticated spectrum analyser or measurement receiver.

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