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Recommendation ITU-R SM.443-5

(10/2026)

SM Series: Spectrum management

Bandwidth measurement at monitoring stations

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RA	Radio astronomy
RS	Remote sensing systems
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SA	Space applications and meteorology
SF	Frequency sharing and coordination between fixed-satellite and fixed service systems
SM	**Spectrum management**
SNG	Satellite news gathering
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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.443-5

Bandwidth measurement at monitoring stations

(1966-1978-1995-2005-2007-2026)

Scope

This Recommendation provides methods for determining and estimating occupied bandwidth at monitoring stations for different classes of emission.

Keywords

Occupied bandwidth measurements, β% method, *x* dB method, monitoring stations

Abbreviations/Glossary

8-VSB	8-level vestigial sideband modulation
AAS	Advanced antenna system
ACPR	Adjacent channel power ratio
FFT	Fast Fourier transform
IBW	Instantaneous bandwidth
I/Q	In-phase/Quadrature phase. Refers to the two components of an RF signal that has been split and separated in phase by 90 degrees. These components are synchronously digitized and combined into a complex-valued time series. The I/Q time-series data can be used to completely reconstruct the original signal (including the content) transmitted during the acquisition time.
LOS	Line of sight
PSD	Power spectral density
RBW	Resolution bandwidth
S/*N*	Signal to noise ratio
T-DAB	Terrestrial digital audio broadcast
T-DMB	Terrestrial digital multimedia broadcast
VBW	Video bandwidth

Related ITU-R Texts

Radio Regulations No. **1.153**

Recommendation ITU R SM.328 – Spectra and bandwidth of emissions

Report ITU R SM.2048 – Use of the *x* dB bandwidth criterion for determination of spectral properties of a transmitter in the out-of-band domain

Report ITU-R BT.2049 – Broadcasting of multimedia and data applications for mobile reception

The ITU Radiocommunication Assembly,

considering

a) the need for the measurement of bandwidths of emissions at monitoring stations to promote efficient use of the radio-frequency spectrum;

b) the need for uniform, easy-to-perform methods for bandwidth measurement at monitoring stations;

c) the need for reliable results to enable comparison of results obtained by different monitoring stations;

d) the increasing availability of equipment able to directly measure the occupied bandwidth;

e) the usefulness of the *x* dB bandwidth measurement method, especially in the case of unfavourable interference environments,

noting

Chapter 5.5, on bandwidth measurement, of the ITU-R Handbook on Spectrum Monitoring, (Edition 2026),

recognizing

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,

recommends

1 that the general conditions in the NOTE below should be used for bandwidth measurements whenever possible;

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

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

4 that the occupied bandwidth should be estimated from the *x* dB bandwidth using the procedures described in Annex 3 when necessary.

NOTE – The general conditions for bandwidth measurements are the following:

– In situations with static receiving conditions, such as for frequencies above 30 MHz, a LoS with no obstruction in the 1st Fresnel zone between the transmitting and receiving antenna is favoured to ensure a high degree of discrimination of the source of emission. In other cases, a limited accuracy has to be indicated by adding the letter 'E' as 'estimated'. As an example, an estimated bandwidth of 2.65 kHz reads: '2K65E'. This is in line with the approach chosen for the international monitoring programme in bands between 2 850 kHz and 28 000 kHz.

– An antenna with high directivity (narrow beamwidth and high front-back ratio) should be used to minimize the influence of multipath fading effects.

– Any suitable spectrum analyser or monitoring receiver (e.g. as described in the Handbook on Spectrum Monitoring) can be used.

– The measurement site should be clear of dominant sources of impulse power (for example, engine ignition, construction, or industrial equipment) as they can create interfering spectra.

Annex 1

Measurement method of occupied bandwidth (β% method)

1 Introduction

Radio Regulations 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 receivers capable of storing spectral traces for later graphical processing, or with equipment capable of storing I/Q time-series data and employing FFT techniques to directly measure occupied bandwidth.

2 Measurement procedure

The procedure should be followed carefully when setting up a spectrum analyser, monitoring receiver, and associated software to measure the occupied bandwidth of an emission:

1 Set the measuring equipment centre frequency, f_0 to the carrier frequency or the allocated centre frequency of the emission being evaluated.

2 Set the frequency span to 1.5 to 2 times the estimated bandwidth of the emission. For pulsed emissions, set the span such that the main lobe and several sidelobes are visible.

3 Adjust the measuring equipment attenuation so that the emission is displayed with a high *S*/*N* (30 dB or more is preferred).

4 Set the reference level to move the peak value of the emission near the top of the display.

5 Set the detector to peak or sample

6 If using an analogue spectrum analyser or monitoring receiver, set the RBW to less than 3% of the span and the VBW to 3 times RBW or more. If measuring a pulsed emission, set the RBW to 1% of the span or less.

7 If using a digital spectrum analyser or monitoring receiver, set the acquisition time for the FFT such that a suitable RBW is achieved.

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

– In digital systems using AAS and for systems with varying bandwidth such as IMT-2020/5G systems, the trace must be set to MaxHold, and the observation time long

enough to build up the spectral trace such that it is representative of the entire channel. For AAS, this is necessary because the measurement point is fixed while the beam of the emission source is moving. For IMT-2020/5G systems, it is necessary to capture times when all resource blocks are transmitted, and the full channel width is occupied. For this measurement, the IBW of the monitoring receiver or spectrum analyser has to be wider than the channel bandwidth.

– In analogue systems, the momentary occupied bandwidth changes rapidly with the modulation. This is especially true when audio signals are transmitted (F3E, A3E, J3E). In these cases, monitoring stations are primarily interested in the maximum occupied bandwidth within a certain observation time (e.g. one hour). To get this result, the "MaxHold" trace function should be applied.

– For pulsed emissions, it is important to use MaxHold and allow the trace to build long enough that the main lobe and side lobes are fully visible in the trace. If a swept receiver is used, set the sweep time long enough so that a pulse is received for each point on the trace.

9 After the traces have been recorded and processed, 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 determine the 100% reference power. In a second calculation, starting from the lowest frequency recorded, the spectral power of each frequency line is added until the sum reaches 0.5% of the predetermined total power. At this frequency point, a marker is set. The same calculation is then performed starting from the highest frequency recorded (the right edge of the display) until 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.

3 Measurement conditions and accuracy

The accuracy of the β% method (apart from equipment accuracy) depends on:

– *The spectral shape of the signal*

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

– *The resolution bandwidth*

Because the bandwidth calculation is based on the graphical shape of the spectral trace, the use of a smaller RBW results in higher accuracy. The graphical representation of the spectral trace is always affected by the width and shape of the measurement filter.

– *The frequency span*

If the frequency span is set too wide, more noise power will be included in the calculation process which produces a less accurate result. However, the span has to be wide enough to include at least some spectral components below the 0.5% points.

– *The noise level and interfering spectra*

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

– *Measurement trials*

The fluctuation of the shape of a signal due to variation of the modulation rate or type can lead to uncertainty of the measurement result. In this case, processing at least 400 traces during the measurement is recommended to obtain the occupied bandwidth.

Care should be taken that no interfering spectra can be seen inside the measurement span because this would be treated as part of the wanted signal which may result in a high measurement error. Therefore, it is necessary to visually analyse the measured spectrum for occurrence of interfering spectral components within the measurement span. If such spectral components are present, attempts should be made to eliminate them by adjusting the location or settings on the monitoring receiver and/or by using receiver filters.

FIGURE 1

Difference between peak level and level of outmost frequencies

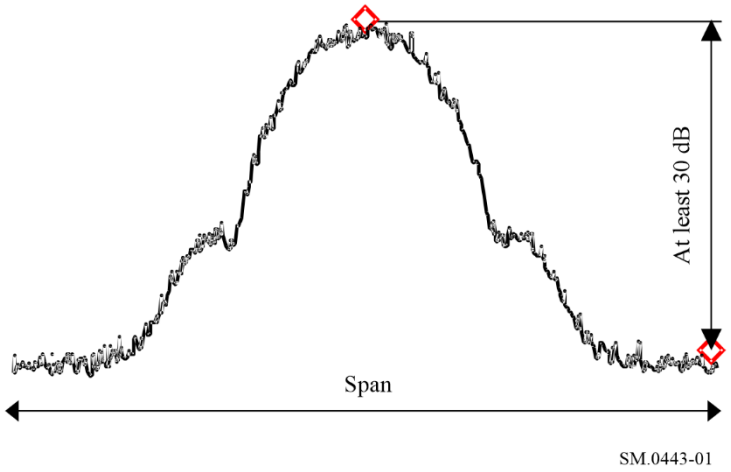
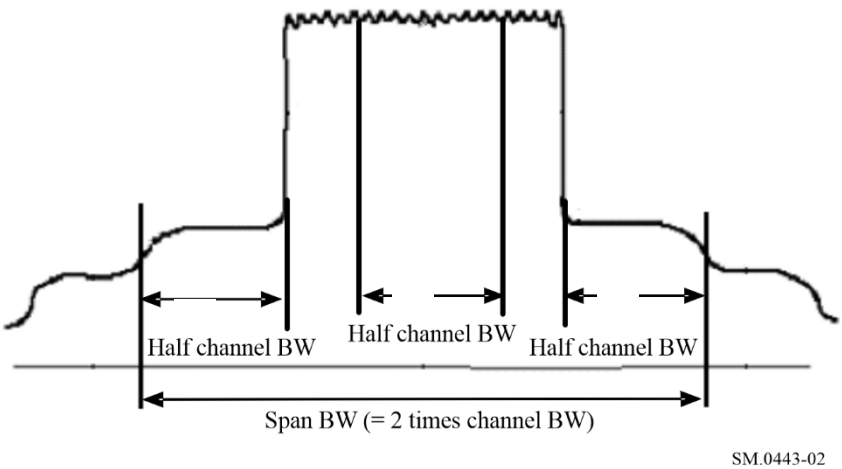


FIGURE 2

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.

2 Measurement procedure

The spectrum analyser/digital receiver should be adjusted with the same settings used for the β% method, except the trace should always be set to MaxHold.

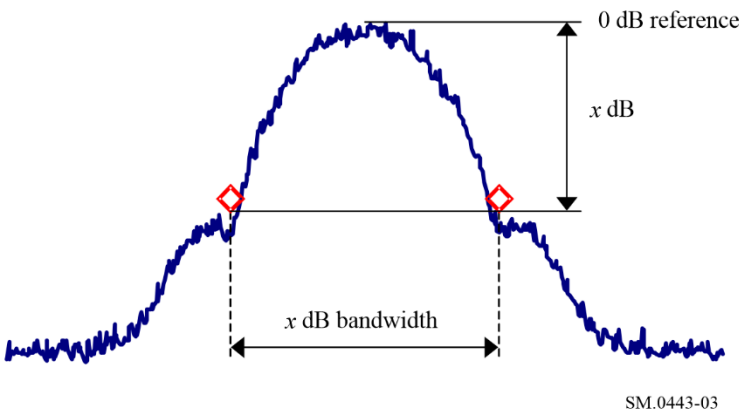
After the composite trace or file has been recorded and processed, the resulting spectrum is analysed to measure the *x* dB bandwidth as follows:

The peak level is searched and used as the 0 dB reference. This is usually the level of the highest spectral line of the trace. If the transmitter power returns to the carrier at least once during the measurement, the level of the carrier is equal to the total emitted power and should be used as the 0 dB reference. However, in most digitally modulated signals, the signal power does not return to the carrier. In this case, the 0 dB reference level is set to the level of the highest spectral line, but it is not representative of the total emitted power. For this reason, to achieve comparable measurement results using the *x* dB method, different *x* values are needed for estimating the occupied bandwidth of analogue and digital emissions (see Table 1). Additionally, a number of the provisions set out in § 5 of Report ITU-R SM.2048 can be used for establishing the 0 dB reference.

The *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 the 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 same conditions and provisions described when using the β% method (as described in Annex 1) except as described below:

– *The frequency span*

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

– *The noise level and interfering spectra*

The *S*/*N* 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%. When the signal strength is not sufficient at the monitoring station receiver, the measurement can be made with a mobile station in close proximity to the transmitter. This may also increase the level of the wanted signal relative to any interfering spectra and improve the measurement conditions.

Interfering spectra inside the displayed span will not influence the result of the *x* dB measurement, if the bandwidth is narrow compared to the bandwidth of the wanted signal and the frequency of the interfering spectra does not fall on one of the *x* dB points.

4 Measurement of *x* dB bandwidths in the presence of interfering spectra

In some cases, *x* dB bandwidth can be measured or, at least, estimated in the presence of interfering spectra with levels exceeding the *x* dB measuring level. As shown in Fig. 4, when the borders of the *x* dB bandwidth from each edge of the spectrum are not masked by interfering spectra (spectra 1 and 2), the bandwidth can still be measured. 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 doubt as to whether spectra 1 and 2 belong to sources of interfering spectra, the transmitters can be discriminated from the wanted signal using advanced techniques such as time domain analysis, adaptive filtering, direction finding/TDOA, or signal correlation (§ 5.8 of the ITU Spectrum Monitoring Handbook (Edition 2026)).

Even when one *x* dB bandwidth border is masked by an interfering spectra (Fig. 5 spectra 3), if the spectrum of the wanted signal is symmetrical, the bandwidth can still be estimated using half of the spectrum width, i.e. $B_{ox} = 2\ B_k$.

It is normal that measurements performed in the presence of interfering spectra are subject to greater errors than measurements made in the absence of other power contributions. However, estimations obtained in many cases are quite suitable for practical applications.

FIGURE 4

Bandwidth measurement in presence of interferences

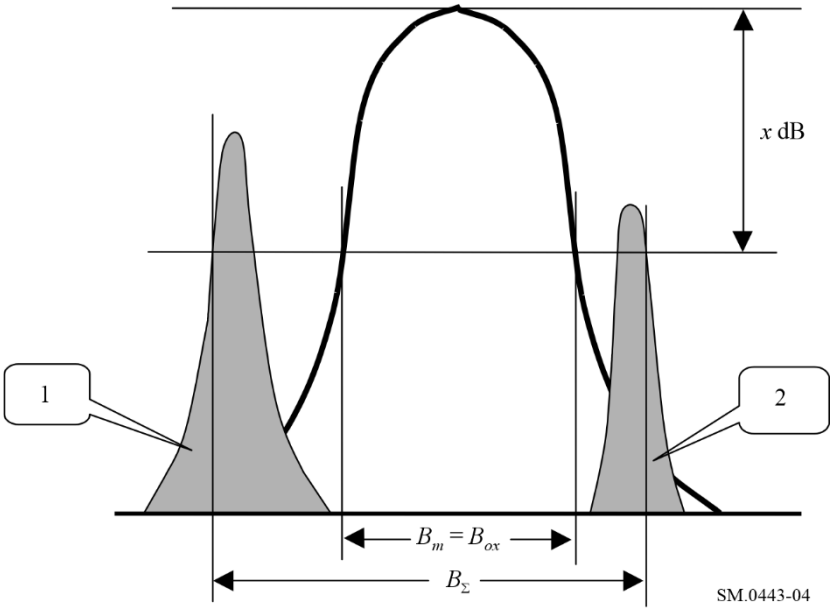
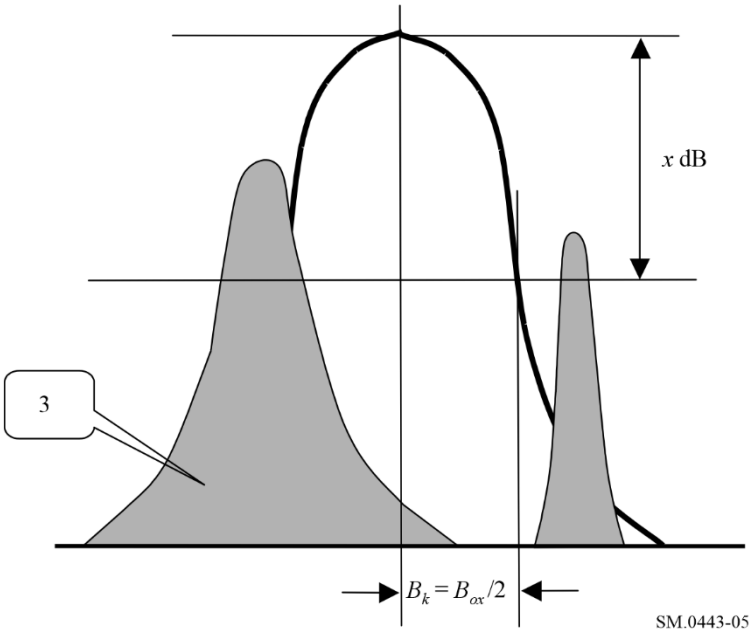


FIGURE 5

Bandwidth measurement by a half of the spectrum



Annex 3

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

1 Introduction

During normal operations of the monitoring service, there may be situations in which the β% method cannot be applied to directly measure the occupied bandwidth:

– in-band interfering spectra at levels higher than the level of the wanted signal (Figs 4 and 5);

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

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

2 Approaches

Generally, there are three different approaches to estimate the occupied bandwidth by using the measured *x* dB bandwidth. In all approaches, the 0 dB reference level is set to the peak level of the spectral trace.

2.1 −26 dB bandwidth

This approach has commonly been used for estimation of the occupied bandwidth. While there is no specific basis for $x = -26$ dB in the RR, it is the value corresponding to approximately 0.5% of the 0 dB reference level and can be directly applied in many cases.

2.2 *x* dB bandwidth method based on emission type

This approach measures the bandwidth at specific values of *x* dB that are different for each class of emission as shown in Table 1. The resulting value of the measurement is the estimation of the occupied bandwidth.

TABLE 1

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	

TABLE 1 (*end*)

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
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.

2.3 −30 dB bandwidth

This approach is similar to the −26 dB bandwidth but extends *x* to −30 dB which is also referred to as the "bandwidth for assessment". The advantage of the −30 dB bandwidth is that Report ITU-R SM.2048 provides conversion coefficients for more than 180 classes of emissions to determine the necessary bandwidth B_n of the emission.

According to § 2 of Recommendation ITU R SM.328, the optimum spectral efficiency of a transmitter is achieved when the occupied bandwidth is equal to the necessary bandwidth. The necessary bandwidth is a theoretical value based on the characteristics of the modulation and symbol rate and is typically used during frequency spectrum allocation. By using −30 dB for assessment and applying the appropriate conversion factor, an estimate of the necessary bandwidth can be achieved. While this is not always equal to the actual occupied bandwidth, it provides the operator with a useful estimate of the occupied bandwidth under ideal circumstances. Additionally, B_n can be used by the monitoring service to compare the actual spectral efficiency of a transmitter with the optimal value.