



WORKING PAPER

FREQUENCY SPECTRUM MANGEMENT PANEL (FSMP)

Seventeenth Working Group Meeting

Cairo, Egypt – 30 August – 7 September 2023

**Agenda Item 7 a): ICAO Frequency Spectrum Handbook (Doc 9718)
Restructure and update of Volume I**

**Volume B - Spectrum
Spectrum Guidance for the Development of Aeronautical systems**

(Presented by John Mettrop)

SUMMARY

This document proposes that the proposed revisions to Volume B Section 6 of the New ICAO Frequency Spectrum Handbook be included in the draft revision of the ICAO Frequency Spectrum Handbook (Doc 9718)..

1. INTRODUCTION

1.1 The development of a new ICAO Frequency spectrum Handbook to replace Doc 9718 (existing handbook) has opened the opportunity to include additional or expand on existing elements, that experience since the publication of the current handbook has shown, would be useful to the aviation community. This document proposes that the current draft Volume B Section 6 of the handbook be updated as shown in the annex to this document.

2. DISCUSSION

2.1 The International use of spectrum is governed through the Radio Regulations which are administered by the International Telecommunication Union (ITU), a sister UN body to ICAO. Those regulations contain provisions related to the required minimum spectral mask applicable to radio equipment (Tx & Rx) which every State ratifies and agrees to bring into national law at the end of each World Radiocommunication Conference. Within the ITU these regulations are then supplemented by various recommendations that provides additional guidance about a specific topic. Additionally there may be regional or national arrangements that impose additional constraints on the spectral mask.

2.2 The attachment to this document proposes a modification to the text previously included in Volume B Section 6 of the new ICAO Frequency Spectrum Handbook that describes those minimum requirements and provides references as to where additional information can be found.

2.3 This information is intended for use in the development of ICAO SARPs, and other standards that are applicable to aeronautical systems such as those developed by RTCA, EUROCAE, AEEC, ETSI etc.

3. **ACTION BY THE MEETING**

3.1 The meeting is invited to:

- a) note and review the contents of this working paper.
- b) Incorporate the attachment to this document into the Volume B of Section 6 of the draft new Frequency Spectrum Handbook
- c) Contribute to the further development of this section of Volume B of the new Frequency spectgrum Handbook.

— END —

Attachment
Suggested text for the New Version of the ICAO Spectrum Handbook – Vol. B, Section 6

Abbreviations

[Author's note: It is recognised that when the consolidated document is completed the first occurrence of an abbreviation may not be in this section and hence the first occurrence of an abbreviation where it is spelt out has been highlighted in yellow for ease of identification and potential modification.]

- BER: binary error ratio.
- Bd: Modulation rate
- EPIRB: Emergency position indication radio beacon
- FSK: frequency shifting key.
- ITU: International Telecommunication Union
- MSK: minimum shifting key.
- PSK: phase shift keying.
- QAM: quadrature amplitude modulation
- RR: Radio Regulations

References

1. International Telecommunication Union Radio Regulations
2. International Telecommunication Union Recommendations:
 - 2.1. ITU-R.M.1177 Techniques for measurement of unwanted emissions of radar systems
 - ~~1.1.2.2.~~ ITU-R SM.328 Spectra and bandwidth of emissions
 - 2.3. ITU-R SM.329 Unwanted emissions in the spurious domain
 - 2.4. ITU-R SM.331 Noise and sensitivity of receivers
 - 2.5. ITU-R SM.332 Selectivity of receivers
 - 2.6. ITU-R SM.852 Sensitivity of radio receivers for class of emissions F3E
 - 2.7. ITU-R SM.853 Necessary bandwidth
 - 2.8. ITU-R SM.1045 Frequency tolerance of transmitters
 - 2.9. ITU-R SM.1138 Determination of necessary bandwidths including examples for their calculation and associated examples for the designation of emissions
 - 2.10. ITU-R SM.1535 The protection of safety services from unwanted emissions
 - 2.11. ITU-R SM.1539 Variation of the boundary between the out-of-band and spurious domains required for the application of Recommendations ITU-R SM.1541 and ITU-R SM.329
 - 2.12. ITU-R SM.1540 Unwanted emissions in the out-of-band domain falling into adjacent allocated bands
 - 2.13. ITU-R SM.1541 Unwanted emissions in the out-of-band domain

6.1 Introduction

Spectrum is a scarce finite resource that is fundamental to the provision of services in various industry sectors such as aviation, broadcasting, radio astronomy and mobile communications. It is therefore essential that spectrum is managed and used in an efficient manner and that radio systems are designed to optimise their use of spectrum and avoid causing issues for other radio systems either operating in the same frequency band or adjacent to that frequency band.

The design and implementation of aviation systems that are spectrally efficient is a fundamental part of justifying the aviation's continued access to sufficient, suitable and appropriately protected ~~the promotion and protection of aeronautical~~ spectrum. Since aviation systems are built ~~upon~~ against international agreed standards that define ~~and certify~~ the required level of performance, spectrum efficiency and ~~protection~~ interference immunity from systems operating within and adjacent to the operational frequency band should be a ~~priority~~ considered as part of the ~~during~~ design and standardization of new and updated aviation systems. While this may increase the complexity of some system designs, the life cycle cost of inefficient or inflexible spectrum usage can often impact a system's operation by several orders of magnitudes greater than any savings achieved in the design phase. Such design improvements also increase the reliability ~~and~~ efficiency of the systems, supporting aviation safety.

To assist the many different standards organizations creating specifications for international aviation systems, the following spectrum guidance is provided to indicate the minimum performance required to conform with the Radio Regulations (RR) including recommendations incorporated by reference. Additionally, as well as information where other International Telecommunication Union (ITU) recommendations contain additional guidance material the relevant content of that material has been included for information and guidance. ~~on further recommendations made by the ITU-R~~. Where feasible, designs should further optimise spectral efficiency by exceeding these requirements.

It should be noted that there may be regional or national regulations that may impose additional constraints on the definition of the spectral mask.

6.4.2 Applicability

The requirements contained in this section, unless indicated as guidance, are the minimum requirement as defined by the Radio Regulations RR which any new aeronautical systems must meet.

6.3 Transmitter Spectral Mask Requirements

The Radio Regulations RR through Article 3 require that the technical characteristics of radio equipment should be designed to:

- take account of the technical characteristics of equipment likely to be employed in the same or neighbouring ~~neighboring~~ spectrum.
- apply signal processing methods which enable the most efficient use of the frequency spectrum.
- ensure that transmitters conform to the tolerance defined in Appendix 2 to the Radio Regulations RR (see later for details ~~section 6.3.1~~)
- Ensure that transmitters conform to the spurious emissions limits defined in Appendix 3 to the Radio regulations RR (see later for details).

6.3.1 Necessary Bandwidth

6.3.1.1 Regulatory requirement

Appendix 1 of the RR provides information on the classification of emissions and necessary bandwidth with section I of the annex dealing with the necessary bandwidth and section II the classification of emissions.

The necessary bandwidth is defined in Article 1.152 of the Radio Regulations for a given set of characteristics of an emission as “the width of the frequency band which is just sufficient to ensure the transmission of information at the rate and with the quality required under specified conditions”. Appendix 3 of the RR references recommendation ITU-R SM.1138-3 as providing formulae for calculating the necessary bandwidth for various types of emissions. By being referenced in the RR the recommendation therefore becomes part of those regulations and hence where the formulae are applicable, they are a regulatory requirement.

The table below is an extract from annex 1 of recommendation ITU-R SM.1138-3 potentially relevant to aeronautical systems:

Table 6.1 – Formulae for calculating the necessary bandwidth of various emission types relevant to aeronautical systems

Description of emission	Necessary bandwidth		Designation of emission
	Formula	Sample calculation	
<u>AMPLITUDE MODULATION</u>			
<u>Telephony, double-sideband (single channel)</u>	$B_n = 2M$	$M = 3\ 000$ Bandwidth: 6 000 Hz = 6 kHz	<u>6K00A3EJN</u>
<u>Telephony, single-sideband, full carrier (single channel)</u>	$B_n = M$	$M = 3\ 000$ Bandwidth: 3 000 Hz = 3 kHz	<u>3K00H3EJN</u>
<u>Telephony, single-sideband, suppressed carrier (single channel)</u>	$B_n = M$ – lowest modulation frequency	$M = 3\ 000$ lowest modulation frequency = 300 Hz Bandwidth: 2 700 Hz = 2.7 kHz	<u>2K70J3EJN</u>
<u>Selective calling signal using sequential single frequency code, single-sideband full carrier</u>	$B_n = M$	Maximum code frequency is: 2 110 Hz $M = 2\ 110$ Bandwidth: 2 110 Hz = 2.11 kHz	<u>2K11H2BFN</u>
<u>Double-sideband emission of VOR with voice (VOR: VHF omnidirectional radio range)</u>	$B_n = 2C_{max} + 2M + 2DK$ $K = 1$ (typically)	The main carrier is modulated by: – a 30 Hz sub-carrier – a carrier resulting from a 9 960 Hz tone frequency modulated by a 30 Hz tone – a telephone channel – a 1 020 Hz keyed tone for continual Morse identification $C_{max} = 9\ 960$ $M = 30$ $D = 480\ Hz$ Bandwidth: 20 940 Hz = 20.94 kHz	<u>20K9A9WWF</u>
<u>PULSE MODULATION</u>			
<u>Radar</u>			
<u>Unmodulated pulse emission</u>	$B_n = \frac{2K}{t}$ K depends upon the ratio of pulse duration to pulse rise time. Its value usually falls between 1 and 10 and in many cases it does not need to exceed 6	<u>Primary radar</u> range resolution = 150 m $K = 1.5$ (triangular pulse where $t \sim t_r$, only components down to 27 dB from the strongest are considered) Then: $t = \left[\frac{2 \times (\text{range resolution})}{\text{velocity of light}} \right]$ $= \frac{2 \times 150}{3 \times 10^8}$ $= 1 \times 10^{-6}\ s$ Bandwidth: $3 \times 10^6\ Hz = 3\ MHz$	<u>3M00P0NAN</u>

Where:

B_n : necessary bandwidth (Hz)

M : maximum modulation frequency (Hz)

C : sub-carrier frequency (Hz)

D: peak deviation, i.e., half the difference between the maximum and minimum values of the instantaneous frequency. The instantaneous frequency (Hz) is the time rate of change in phase (rad) divided by 2π

t: pulse duration (s) at half-amplitude

t_r: pulse rise time (s) between 10% and 90% amplitude.

K: an overall numerical factor which varies according to the emission, and which depends upon the allowable signal distortion. In the case of orthogonal frequency division multiplexed multi-carrier signal, K is the number of active sub-carriers as defined by equation (52) in Recommendation ITU-R SM.328

6.3.1.2 Additional guidance

6.3.1.2.1 ITU-R SM.328 Spectra and bandwidth of emissions

This recommendation provides definitions, analytical models and other considerations of the values of emission components for various emission types and can be used as guidance in deriving the limits for out-of-band emissions based on the x dB bandwidth. The recommendation does provide various formulae for calculating various emission types as provided below:

Table 6.2 Formulae for calculating the necessary bandwidth of various emission classes relevant to aeronautical systems

<u>Type of Emission</u>	<u>Class of Emission</u>	<u>SM.328-11 Reference</u>	<u>Necessary Bandwidth</u>
<u>Double Sideband</u>	<u>A1A & A1B</u>	<u>Annex 1, Para 1.1</u>	$B_n = 5 \cdot B$
	<u>A2A & A2B</u>	<u>Annex 1, Para 4.1</u>	$B_n = 2 \cdot M + 5 \cdot B$
	<u>A3E</u>	<u>Annex 1, Para 5.3.1</u>	$B_n = 2 \cdot M$
<u>Single Sideband</u>	<u>R3E & H3E</u>	<u>Annex 1, Para 5.4.1</u>	$B_n = 2 \cdot f_2$
	<u>J3E</u>	<u>Annex 1, Para 5.4.1</u>	$B_n = f_2 - f_1$
	<u>B8E</u>	<u>Annex 1, Para 5.4.1</u>	<u>Difference between the two radio frequencies most remote from the assigned frequency</u>
<u>Frequency Modulation</u>	<u>F1B</u>	<u>Annex 3, Para 1.1</u>	$B_n = 2.6 \cdot D + 0.55 \cdot B$ – <u>within 10% for $1.5 < m < 5.5$</u> $B_n = 2.1 \cdot D + 1.9 \cdot B$ – <u>within 2% for $5.5 < m < 20$</u>

Where:

B: modulation rate

- B_n : necessary bandwidth
- D : Peak frequency deviation or half the frequency shift
- f_1 : Lowest audio frequency intended to be transmitted
- f_2 : Highest audio frequency intended to be transmitted
- M : maximum modulation frequency (Hz)
- m : modulation index

6.3.1.1.2 ITU-R SM.853 - Necessary bandwidth

Recommendation ITU-R SM.853 provides the following additional guidance on the calculation of the necessary bandwidth for unmodulated pulses with either a trapezoidal or rectangular pulse shape:

Table 6.3 Formulae for calculating the necessary bandwidth of trapezoidal or rectangular unmodulated pulses relevant to aeronautical systems.

<u>Description of emission</u>	<u>Necessary bandwidth</u>		<u>Designation of emission</u>
	<u>Formula</u>	<u>Sample calculation</u>	
<u>Unmodulated pulse emission</u>	<p>Case 1:</p> $B_n = \frac{1.79}{\sqrt{t \cdot t_r}} \text{ Hz}$ <p>at points 20 dB below the peak envelope value of the spectrum of a trapezoidal pulse</p>	<p>$t = 3 \times 10^{-6} \text{ s}$</p> <p>$t_r = 0.06675 \times 10^{-6} \text{ s}$</p> <p>Bandwidth: $4 \times 10^6 \text{ Hz}$</p>	<u>4M00P0N</u>
	<p>Case 2:</p> $B_n = 1.27 \sqrt{\frac{\frac{1}{t_r} + \frac{1}{t_f}}{t}}$ <p>at points 20 dB below the peak envelope value of the spectrum of an unsymmetrical trapezoidal pulse</p>	<p>$t = 3 \times 10^{-6} \text{ s}$</p> <p>$t_r = 0.06675 \times 10^{-6} \text{ s}$</p> <p>$t_f = 0.167 \times 10^{-6} \text{ s}$</p> <p>Bandwidth: $3.36 \times 10^6 \text{ Hz}$</p>	<u>3M36P0N</u>
	<p>Case 3:</p> $B_n = \frac{6.36}{t} \text{ Hz}$ <p>at points 20 dB below the peak envelope value of the spectrum of a rectangular (ideal) pulse</p>	<p>$t = 1.41 \times 10^{-6} \text{ s}$</p> <p>$B_n = 4.5 \times 10^6 \text{ Hz}$</p>	<u>4M50P0N</u>

And for digital modulation:

Table 6.4 Formulae for calculating the necessary bandwidth for various digital signals relevant to aeronautical systems

<u>Modulation and conditions</u>	<u>Necessary bandwidth formula</u>	<u>Example K value</u>	<u>Percentage fractional power containment bandwidth⁽¹⁾</u>
2-PSK (unfiltered) $S = 2$ (computed)	$B_n = \frac{2RK}{\log_2 S}$	$\frac{10.28}{2.0}$	$\frac{99}{95}$
2-PSK (filtered, BER = 1×10^{-3}) $S = 2$ (computed)	$B_n = \frac{2RK}{\log_2 S}$	$\frac{1.0^{(2)}}{0.75^{(3)}}$	$\frac{100}{100}$
MSK (unfiltered) $S = 2$ (computed) $D = 0.25 R$	$B_n = \frac{R}{\log_2 S} + 2 DK$	$\frac{0.36}{3.52}$	$\frac{99}{99.9}$
Gaussian filtered MSK (GMSK) 3 dB premodulation Gaussian filter bandwidth = $0.25 R$ $S = 2$ (computed) $D = 0.25 R$	$B_n = \frac{R}{\log_2 S} + 2 DK$	$\frac{-0.28}{0.18}$	$\frac{99}{99.9}$
Digital FM (Continuous phase FSK) rectangular pulses $S = 2$ (computed) $D = 0.35 R$	$B_n = \frac{R}{\log_2 S} + 2 DK$	0.89	99
<i>m</i> -QAM Microwave digital $S = 2^n$ ($n \geq 2$) Roll-off = 0 to 1 50% splitted Tx/Rx optimally filtered (computed) ^{(4), (5)}	$B_n = \frac{2RK}{\log_2 S}$	See Fig. 1	See Fig. 1

⁽¹⁾ Recommendation ITU-R F.1191 foresees that for digitally modulated systems in the fixed service the necessary bandwidth should be defined for a percentage fractional power containment equal to 99%.

⁽²⁾ For this case $E_b/N_0 = 7.5$ dB.

⁽³⁾ For this case $E_b/N_0 = 9.3$ dB.

⁽⁴⁾ Practical filtering may give slight difference in the *K* value versus containment computed relationship.

⁽⁵⁾ 4- and 8- QAM formats coincide with filtered 4- and 8- PSK formats.

Where:

B_n : Necessary bandwidth

D : Frequency deviation

K : Factor

R : Bit rate

S : Number of signal states

t : Pulse width

t_f : Pulse fall time (90-10%)

t_r : Pulse rise time (10-90%)

6.3.2 Frequency Tolerance

6.3.2.1 Regulatory requirement

Frequency tolerance is defined in the [Radio RegulationsRR](#) as “*the maximum permissible departure by the centre frequency of the frequency band occupied by an emission from the assigned frequency or, by the characteristic frequency of an emission from the reference frequency*”. The maximum level of frequency tolerance is defined in Appendix 2 to the [Radio RegulationsRR](#) which for aeronautical systems requires the following:

Frequency bands (lower limit exclusive, upper limit inclusive) and categories of stations	Tolerances applicable to transmitters (parts per million)
<i>Band: 9 kHz to 535 kHz</i> <i>Radiodetermination stations</i>	100 Hz
<i>Band: 1 606.5 (1605 kHz in Region 2) to 4 000 kHz</i> <i>Aeronautical stations:</i> <i>Aircraft station</i> International National	10 Hz 20 Hz 50 Hz
<i>Band: 4 MHz to 29.7 MHz</i> <i>Aeronautical stations:</i> <i>Aircraft station</i> International National	10 Hz 20 Hz 50 Hz
<i>Band: 29.7 MHz to 100 MHz</i> <i>Radiodetermination stations</i>	50
<i>Band: 100 MHz to 470 MHz</i> <i>Aeronautical stations</i> <i>Aircraft stations</i> <i>Radiodetermination stations</i>	20 ¹ 30 ¹ 50 ²
<i>Band: 470 MHz to 2 450 MHz</i> <i>Aeronautical stations</i> <i>Aircraft station</i> <i>Radiodetermination stations</i>	20 ³ 20 ³ 500 ²
<i>Band: 2 450 MHz to 10 500 MHz</i> <i>Aeronautical stations</i> <i>Aircraft stations</i> <i>Radiodetermination stations</i> <i>Space stations</i> <i>Earth stations</i>	100 100 1 250 ² 50 50
<i>Band: 10.5 GHz to 40 GHz</i> <i>Radiodetermination stations</i> <i>Space stations</i> <i>Earth stations</i>	5 000 ² 100 100

Notes

- ¹ For a channel spacing of 50 kHz the tolerance is 50×10^{-6} .
- ² Where specific frequencies are not assigned to radar stations, the bandwidth occupied by the emissions of such stations shall be maintained wholly within the band allocated to the service and the indicated tolerance does not apply.
- ³ In applying this tolerance administrations should be guided by the latest relevant ITU-R Recommendations.

6.3.2.2 Guidance material

TBD based on

ITU-R SM.1045 “Frequency tolerance of transmitters”

6.3.32 ~~RF Spectral Mask~~Unwanted Emissions

6.3.3.1 Regulatory requirement

Appendix 3 of the RR provides information with respect to the maximum permitted power levels for unwanted emissions in the spurious domain indicated in table 6.1 below -subject to the following provisions:

~~are defined in Appendix 3 to the Radio Regulations noting that more stringent levels than those specified may be applied to protect specific services in certain frequency bands as defined in an allocation table footnote. a)~~

Spurious domain emissions from any part of the installation, other than the antenna and its transmission line, shall not have an effect greater than would occur if this antenna system were supplied with the maximum permitted power at the frequency of that emission

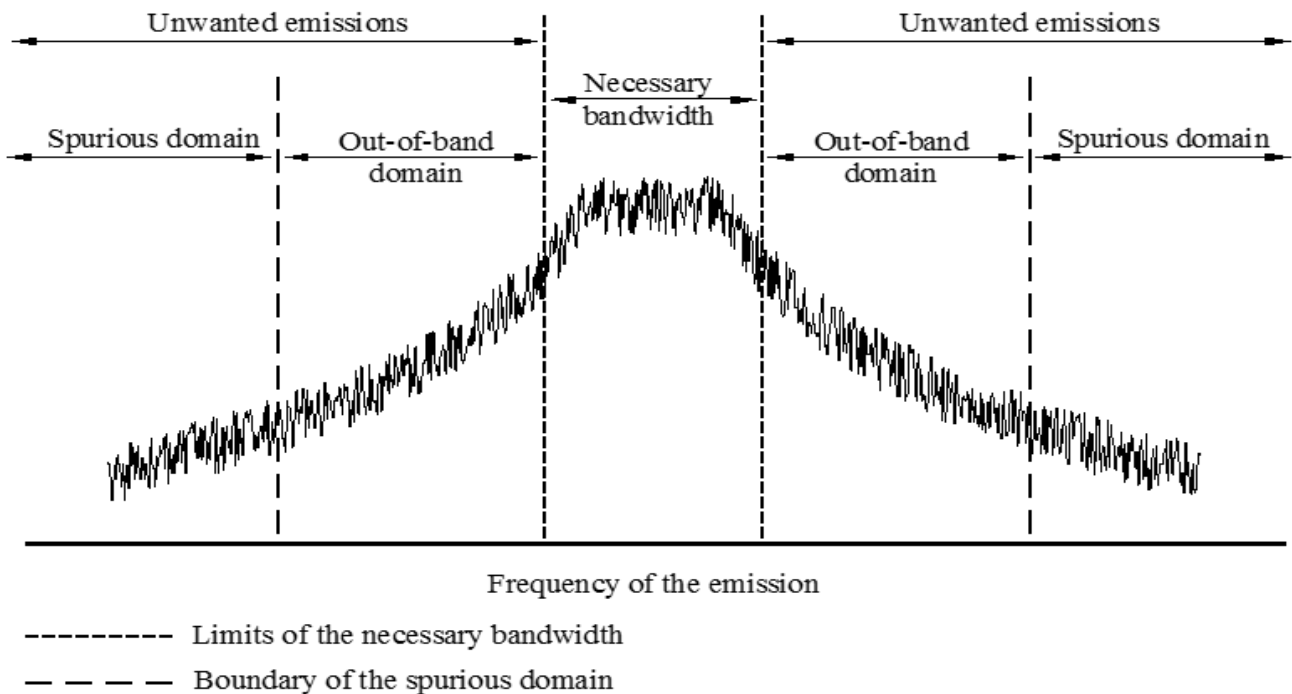
- b) These levels do not apply to emergency position-indicating radiobeacon (EPIRB) stations.
- c) For technical or operational reasons, more stringent levels than those specified may be applied to protect specific services in certain frequency bands as identified within the Radio Regulations.
- d) The frequency range of the measurement of spurious domain emissions is from 9 kHz to 110 GHz or the second harmonic if higher.
- e) Except as provided in provisions f & g of this Appendix, the spurious domain emission levels are specified in the following reference bandwidths:
 - 1 kHz between 9 kHz and 150 kHz
 - 10 kHz between 150 kHz and 30 MHz
 - 100 kHz between 30 MHz and 1 GHz
 - 1 MHz above 1 GHz.
- f) The reference bandwidth of all space service spurious domain emissions should be 4 kHz.
- g) For radar systems, the reference bandwidths for specifying spurious domain emission levels should be calculated for each particular system. Thus, for the four general types of radar the reference bandwidth values should be determined using the following:
 - for a fixed-frequency, non-pulse-coded radar, the reciprocal of the radar pulse length, in seconds (e.g. if the radar pulse length is 1 μ s, then the reference bandwidth is $1/(1 \mu\text{s}) = 1 \text{ MHz}$);
 - for a fixed-frequency, phase-coded pulsed radar, the reciprocal of the phase chip length, in seconds (e.g. if the phase-coded chip is 2 μ s long, then the reference bandwidth is $1/(2 \mu\text{s}) = 500 \text{ kHz}$);
 - for a frequency modulated (FM) or chirped radar, the square root of the quantity obtained by dividing the chirp bandwidth in MHz by the pulse length, in μ s (e.g. if the FM is from 1 250 MHz to 1 280 MHz, i.e. 30 MHz, during the pulse length of 10 μ s, then the reference bandwidth is $(30 \text{ MHz}/10 \mu\text{s})^{1/2} = 1.73 \text{ MHz}$);
 - for radars operating with multiple waveforms, the reference bandwidth for specifying spurious domain emission levels is determined empirically from observations of the radar emission and is obtained following the guidance given in the most recent version of Recommendation ITU-R M.1177.

In the case of radars, for which the bandwidth, as determined using the method above, is greater than 1 MHz, a reference bandwidth of 1 MHz should be used.
- h) Guidance regarding the methods of measuring spurious domain emissions is given in the most recent version of Recommendation ITU-R SM.329. Specific guidance regarding the methods of measuring spurious domain emissions from radar systems is given in the most recent version of Recommendation ITU-R M.1177.

To improve measurement accuracy, sensitivity and efficiency, the resolution bandwidth in which spurious domain emissions are measured can be different from the reference bandwidth used for specifying spurious domain emission levels.

- j) The emission limits of this Appendix apply to all emissions, including harmonic emissions, intermodulation products, frequency conversion products and parasitic emissions, at frequencies in the spurious domain (see Fig. 6.5). The upper and lower parts of the spurious domain extend outward from a boundary determined using XXX Figure 1 from Append 3 to the Radio Regulations, reproduced below, shows the relationship between the necessary bandwidth, out of band and spurious domains:

Figure 6.5: Out-of-band and spurious domains



The measurement range of the spurious domain is 9 kHz to 110 GHz or the second harmonic if higher with the following measurement bandwidths:

- Satellite systems — 4 kHz
- Radar systems — the reference bandwidths should be calculated for each system using the following noting that if the result is greater than 1 MHz then 1 MHz should be used:
 - for a fixed frequency, non-pulse coded radar, the reciprocal of the radar pulse length, in seconds (e.g. if the radar pulse length is 1 μs, then the reference bandwidth is $1/(1 \mu s) = 1 \text{ MHz}$);
 - for a fixed frequency, phase-coded pulsed radar, the reciprocal of the phase chip length, in seconds (e.g. if the phase-coded chip is 2 μs long, then the reference bandwidth is $1/(2 \mu s) = 500 \text{ kHz}$);
 - for a frequency modulated (FM) or chirped radar, the square root of the quantity obtained by dividing the chirp bandwidth in MHz by the pulse length, in μs (e.g. if the FM is from 1 250 MHz to 1 280 MHz, i.e. 30 MHz, during the pulse length of 10 μs, then the reference bandwidth is $(30 \text{ MHz}/10 \mu s)^{1/2} = 1.73 \text{ MHz}$);
 - for radars operating with multiple waveforms, the reference bandwidth for specifying spurious domain emission levels is determined empirically from

observations of the radar emission and is obtained following the guidance given in the most recent version of Recommendation ITU R M.1177.

— Other systems

- 1 kHz between 9 kHz and 150 kHz
- 10 kHz between 150 kHz and 30 MHz
- 100 kHz between 30 MHz and 1 GHz
- 1 MHz above 1 GHz.

6.3.2.1 Necessary bandwidth

The necessary bandwidth is defined in Article 1.152 of the Radio Regulations for a given set of characteristics of an emission as “the width of the frequency band which is just sufficient to ensure the transmission of information at the rate and with the quality required under specified conditions”. The method by which the necessary bandwidth of a signal is defined in Recommendation ITU R SM.1138-2.

Description of emission	Necessary bandwidth		Designation of emission
	Formula	Sample calculation	
H. AMPLITUDE MODULATION			
Telephony, double sideband (single channel)	$B_n = 2M$	$M = 3\,000$ Bandwidth: 6 000 Hz = 6 kHz	6K00A3EJN
Telephony, single sideband, full carrier (single channel)	$B_n = M$	$M = 3\,000$ Bandwidth: 3 000 Hz = 3 kHz	3K00H3EJN
Telephony, single sideband, suppressed carrier (single channel)	$B_n = M$ — lowest modulation frequency	$M = 3\,000$ lowest modulation frequency = 300 Hz Bandwidth: 2 700 Hz = 2.7 kHz	2K70J3EJN
Selective calling signal using sequential single frequency code, single sideband full carrier	$B_n = M$	Maximum code frequency is: 2 110 Hz $M = 2\,110$ Bandwidth: 2 110 Hz = 2.11 kHz	2K11H2BFN
PULSE MODULATION			
1. Radar			
Unmodulated pulse emission	$B_n = \frac{2K}{t}$ <i>K depends upon the ratio of pulse duration to pulse rise time. Its value usually falls between 1 and 10 and in many cases it does not need to exceed 6</i>	Primary radar range resolution = 150 m $K = 1.5$ (triangular pulse where $t_r = t_f$, only components down to 27 dB from the strongest are considered) Then: $t = \left[\frac{2 \times (\text{range resolution})}{\text{velocity of light}} \right]$ $= \frac{2 \times 150}{3 \times 10^8}$ $= 1 \times 10^{-6}$ s Bandwidth: 3×10^6 Hz = 3 MHz	3M00P0NAN

Further guidance is provided by ITU R SM.853 “Defining necessary bandwidth”

6.3.2.2 Out of band domain

6.3.3.2 Guidance material

TBCD based on

- ITU-R SM.328 “Spectra and bandwidth of emissions”

- [ITU-R SM.329 “Unwanted emissions in the spurious domain](#)
- ITU-R SM.1540 “Unwanted emissions in the out-of-band domain falling into adjacent allocated bands”²²
- ITU-R SM.1541 “Out of band emissions limits”

~~6.3.2.3 Spurious domain~~

~~TBC~~ based on

- ~~— ITU-R SM.328 “Spectra and bandwidth of emissions”~~
- ~~— ITU-R SM.329 “Unwanted emissions in the spurious domain”~~

6.4 Receiver Requirements

[6.4.1 Regulatory Requirements](#)

[6.4.2 Guidance Material](#)

TBCD based on:

- ITU-R SM.331 “Noise and sensitivity of receivers”
- ITU-R SM.332 “Selectivity of receivers”-