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

(2004)

1 Description of the approach

1.1 A method, used by some administrations, is described for specifying and measuring the following spectral properties of transmitters in the out-of-band (OoB) domain (§ 1.2 of Recommendation ITU-R SM.1541 refers): the bandwidth of a transmitter emission beyond which OoB emission begins, and OoB emissions as such.

1.2 The transmitter spectral properties indicated in § 1.1 are specified and measured on the basis of a single criterion: the *x* dB bandwidth (§ 1.14 of Recommendation ITU-R SM.328 refers).

1.3 The bandwidth of a transmitter emission is specified and measured on the basis of –30 dB occupied bandwidth, B_c.

1.4 OoB emissions are specified and measured using values of bandwidths of their spectra obtained at the –40 dB ($B_{–40}$), –50 dB ($B_{–50}$) and –60 dB ($B_{–60}$) levels, and additionally at –35 dB ($B_{–35}$) level for certain classes of emissions, and they are compared with relevant value for the –30 dB occupied bandwidth, B_c, and through it with the necessary bandwidth, B_n.

1.5 For certain classes of radar emissions only OoB bandwidths starting from $B_{–40}$ are given as the only available at the moment. On the other hand, for some classes of radar emissions bandwidths of in-band spectra at level –20 dB ($B_{–20}$) are additionally presented for better characterization of spectral properties of emissions in border area between in-band and OoB spectra. In other separate cases other *x* dB levels are also used for the same purpose.

1.6 Data of Tables 1-3 can be also used for purposes of radio monitoring by procedures given in Recommendation ITU-R SM.443.

2 Terms and definitions

Terms and definitions used herein are those given in the Radio Regulations (RR) and in Recommendation ITU-R SM.328.

3 Emission classes

Classes of emissions are provided in RR Appendix 1.

4 Requirements concerning –30 dB occupied bandwidth and OoB emissions

4.1 The basis for specifying –30 dB bandwidth and OoB emissions is the necessary bandwidth, B_n; it is determined using the formulas in Table 1 based on values given in Recommendations ITU-R SM.328, ITU-R SM.853 and ITU-R SM.1138. In calculating the necessary bandwidth, the modulation parameters provided in these requirements for the class of emission and transmitter type in question must be used. Symbols and abbreviations for types of modulation in this Report are explained in Annex 5. The figures, units and remarks in Table 1 are based on the experience of the administrations mentioned in § 1.

4.2 The requirements concerning bandwidths of emissions are determined using the formulas in Table 1 and correspond to the values of –30 dB bandwidth, B_c, specified and measured with respect to the defined 0 dB (reference) level.

4.3 The requirements concerning OoB emissions are given in the form of bandwidths of their spectra at fixed x dB levels, where x values are –35, –40, –50 and –60 dB (and corresponding bandwidths are B_{-35}, B_{-40}, B_{-50} and B_{-60}) with respect to the defined 0 dB (reference) level. Section 5.27 explains how the reference level is determined. The formulas in Table 1 are used to specify bandwidth values at those x dB levels. By joining points having as their ordinate the dB levels and as their abscissa the logarithm of the frequency separation from the carrier, a limiting mask for emissions in the OoB domain can be obtained.

4.4 It can be also required that measured values of the –30 dB bandwidth and of bandwidths of OoB spectra, as defined in § 4.3, should not exceed the specified values of those parameters by more than 10%; this figure includes the measurement uncertainty associated with the method described in § 5.

4.5 The requirements concerning OoB emissions of HF transmitters on board aircraft operating in the classes of emissions H2BBN, H3EJN, J3EJN, J7BCF and JXX--[(1)] are listed in Table 2.

4.6 The requirements concerning OoB emissions of transmitters of the maritime mobile service operating in the classes of emissions H2BBN, H3EJN, J3EJN and R3EJN are given in Table 3.

[(1)] Hyphens are used to indicate unused additional parameters in the designation of the class of emissions (see Annex 5).

TABLE 1

Calculation of –30 dB bandwidth and bandwidths of OoB spectra

Class of emission	**Additional characteristics**	**Calculation of:** Necessary bandwidth B_n (Hz)	**Calculation of:** –30 dB occupied bandwidth, B_c, and bandwidths of OoB spectra (Hz)	**Remarks**
1. Amplitude modulation				
1.A Signal with quantized or digital information				
Telegraphy, continuous wave **A1AAN, A1BBN**	Transmitters in the mobile service Transmitters in the land and maritime mobile service > 100 W	$B_n = K_{fade}\,B$ K_{fade} = 5 for links with fading K_{fade} = 3 for links without fading	$B_{c-30} = B_n$ $B_{-40} = 1.3B_c$ $B_{-50} = 1.6B_c$ $B_{-60} = 2B_c$	The coefficient K_{fade} is determined in the technical instructions for various types of transmitter, depending on transmitter function and the frequency band used
	Transmitters in the land and maritime mobile service ≤ 100 W	$B_n = 5B$	$B_{c-30} = 7B$ $B_c = 1.4B_n$ $B_{-40} = 1.86B_c$	
	Aircraft transmitters in the aeronautical mobile service	$B_n = 5B$	$B_{c-30} = 7B$ $B_c = 1.4B_n$ $B_{-40} = 1.86B_c$ $B_{-50} = 3.3B_c$ $B_{-60} = 5.8B_c$	Requirements apply for manipulation speeds below 20 baud; for speeds above 20 baud limits are introduced in consultation with the customer
Binary amplitude-shifted carrier **A1D**		$B_n = 5B$	$B_{c-30} = 1.4\,B_n = 7B$ $B_{-40} = 1.4B_c$ $B_{-50} = 2.5B_c$ $B_{-60} = 4.5B_c$	$B_{-25} = B_n$
	Radio link	$B_n = K_{fade}\,B$ K_{fade} = 3 for links without fading K_{fade} = 5 for links with fading	$B_{c-30} = 1.05B_n$ $B_{-40} = 1.3B_c$ $B_{-50} = 1.6B_c$ $B_{-60} = 2B_c$	
Voice-frequency telegraphy **A2AAN, A2BBN**		$B_n = 2F_U + 5B$	$B_{c-30} = 2F_U + 6.8B$ $B_{-40} = 2F_U + 13B$	

TABLE 1 (*continued*)

Class of emission	Additional characteristics	Calculation of: Necessary bandwidth B_n (Hz)	Calculation of: –30 dB occupied bandwidth, B_c, and bandwidths of OoB spectra (Hz)	Remarks
Multichannel telegraphy **A7B, A7D**		$B_n = 2B_{ch}$	$B_{c–30} = B_n$ $B_{–40} = 1.3B_c$ $B_{–50} = 1.6B_c$ $B_{–60} = 2B_c$	
Voice-frequency telegraphy, single sideband, full carrier **H2BBN** **H2BFN**		$B_n = 2F_U + 5B$	$B_{c–30} = B_n$ $B_{–40} = 1.25B_c$ $B_{–50} = 1.55B_c$ $B_{–60} = 2B_c$	Does not apply to transmitters of the aeronautical and maritime mobile service, the requirements for which are given in Tables 2 and 3 respectively
	Selective calling signal using sequential single-frequency code	$B_n = F_U$	$B_{c–30} = B_n$ $B_{–40} = 1.25B_c$ $B_{–50} = 1.55B_c$ $B_{–60} = 2B_c$	
Single-sideband telegraphy, suppressed carrier **J2A--**(1)		$B_n = 5B$	$B_{c–30} = B_n$ $B_{–40} = 1.3B_c$ $B_{–60} = 2B_c$	
Narrow-band voice-frequency telegraphy **J2B, J2D**	Maritime mobile service NBPM	$B_n = 1.1B$	$B_{c–30} = 2.5B$ $B_{–40} = 2B_c$ $B_{–50} = 2.8B_c$ $B_{–60} = 3.6B_c$	
Voice-frequency telegraphy, single sideband, suppressed carrier **J2BBN**	Secondary multiplexing of channel formed by single-sideband transmitter with suppressed carrier and voice packets on 1 kHz or 1.6 kHz subcarrier	$B_n = 5B$	$B_{c–30} = B_n$ $B_{–40} = 1.3B_c$ $B_{–50} = 1.6B_c$ $B_{–60} = 2B_c$	
		$B_n = 5B$	$B_{c–30} = 1.36B_n = 6.8B$ $B_{–40} = 1.9B_c$	Applies to transmitters in the land mobile service ≤ 100 W

TABLE 1 (*continued*)

Class of emission	Additional characteristics	Calculation of: Necessary bandwidth B_n (Hz)	–30 dB occupied bandwidth, B_c, and bandwidths of OoB spectra (Hz)	Remarks
Voice-frequency telegraphy, single sideband, suppressed carrier **J2BBN**	2-position code without error correction, transmitters in the land mobile service ≤ 100 W	$B_n = 5B$	$B_{c-30} = 1.36B_n = 6.8B$ $B_{-40} = 1.25B_c$	
Voice-frequency telegraphy, single sideband, suppressed carrier **J2BCN**	2-position code with error correction, transmitters in the land mobile service	$B_n = 5B$	$B_{c-30} = B_n$ $B_{-40} = 1.3B_c$ $B_{-50} = 1.6B_c$ $B_{-60} = 2B_c$	
		$B_n = 5B$	$B_c = 1.36B_n = 6.8B$ $B_{-40} = 1.9B_c$	Applies to transmitters in the land mobile service ≤ 100 W
Multichannel voice-frequency telegraphy, single sideband, reduced carrier **R7BCF, R7BCN, R7DCN**		$B_n = F_U$, where F_U is the upper frequency of the SSB channel	$B_c = 1.2B_n = 1.2F_U$ $B_{-40} = 1.75B_c$ $B_{-50} = 3.33B_c$ $B_{-60} = 5.75B_c$	
Multichannel voice-frequency telegraphy, single sideband, suppressed carrier **J7BCF**		$B_n = F_{uc} - F_{lc}$, where: F_{uc}: upper frequency of the SSB channel F_{lc}: lower frequency SSB channel	$B_c = 1.2B_n = 1.2(F_{uc} - F_{lc})$ $B_{-40} = 1.75B_c$ $B_{-50} = 3.33B_c$ $B_{-60} = 5.75B_c$	
Narrow-band voice-frequency telegraphy **J7B**	Maritime mobile service NBPM	$B_n = 1.1B$	$B_c = 2.3B_n = 2.5B$ $B_{-40} = 2B_c$ $B_{-50} = 2.8B_c$ $B_{-60} = 3.6B_c$	
Multichannel telegraphy **J7B**	Excludes transmitters in the maritime mobile service	$B_n = F_{uc} - F_{lc}$	$B_c = 1.4B_n$ $B_{-40} = 1.6B_c$ $B_{-50} = 2.2B_c$ $B_{-60} = 2.9B_c$	

TABLE 1 (*continued*)

Class of emission	Additional characteristics	Calculation of: Necessary bandwidth B_n (Hz)	–30 dB occupied bandwidth, B_c, and bandwidths of OoB spectra (Hz)	Remarks
		1.B Telephony (not sound broadcasting)		
Telephony, double-sideband, single-channel **A3EJN**	Transmitters in the mobile service without frequency response correction	$B_n = 2F_U$	$B_c = 1.9B_n = 3.8F_U$ $B_{-40} = 1.74B_c$ $B_{-50} = 3.16B_c$ $B_{-60} = 5.53B_c$	
	Transmitters in the mobile service with frequency response correction and transmitters in the mobile service	$B_n = 2F_U$	$B_c = 2.5B_n = 5F_U$ $B_{-40} = 1.8B_c$ $B_{-50} = 3.12B_c$ $B_{-60} = 5.52B_c$	
	Aircraft transmitters in the aeronautical mobile service	$B_n = 2F_U$	$B_c = 2.5B_n = 5F_U$ $B_{-40} = 1.8B_c$ $B_{-50} = 3.2B_c$ $B_{-60} = 5.6B_c$	
Telephony, single sideband, full carrier **H3EJN** Reduced carrier **R3EJN**	Transmitters in the mobile service	$B_n = F_U$	$B_c = 1.15B_n = 1.15F_U$ $B_{-35} = 1.09B_c$ $B_{-40} = 1.39B_c$ $B_{-50} = 2.52B_c$ $B_{-60} = 4.7B_c$	
	Transmitters in the land mobile service > 100 W	$B_n = F_U$	$B_c = 1.2B_n = 1.2F_U$ $B_{-40} = 1.75B_c$ $B_{-50} = 3.33B_c$ $B_{-60} = 5.75B_c$	
Telephony, single sideband, full carrier **H3EJN** Reduced carrier **R3EJN**	Transmitters in the land mobile service ≤ 100 W	$B_n = F_U$	$B_c = 1.8B_n = 1.8F_U$ $B_{-40} = 1.9B_c$ $B_{-50} = 3.33B_c$ $B_{-60} = 6.11B_c$	

TABLE 1 (*continued*)

Class of emission	Additional characteristics	Calculation of: Necessary bandwidth B_n (Hz)	Calculation of: –30 dB occupied bandwidth, B_c, and bandwidths of OoB spectra (Hz)	Remarks
Two or more telephony channels with frequency multiplexing **A8EJN**	Radio links in the fixed service	$B_n = 2F_U$ F_U : upper frequency of the group band	$B_c = 5F_U = 2.5B_n$ $B_{-40} = 1.8B_c$ $B_{-50} = 3.2B_c$ $B_{-60} = 5.6B_c$	
Two or more telephony channels combining different types of transmission **A8W**	Television relay	$B_n = 2F_{sc} + 2F_U + 2D$	$B_c = 2.5B_n$ $B_{-40} = 1.8B_c$ $B_{-50} = 3.2B_c$ $B_{-60} = 5.6B_c$	
Telephony, single sideband, suppressed carrier **J3EJN**	Transmitters in the mobile service	$B_n = F_{uc} - F_{lc}$	$B_c = 1.15B_n = 1.15(F_{uc} - F_{lc})$ $B_{-35} = 1.09B_c$ $B_{-40} = 1.39B_c$ $B_{-50} = 2.52B_c$ $B_{-60} = = 4.7B_c$	
	Transmitters in the land and maritime mobile service > 100 W	$B_n = F_{uc} - F_{lc}$	$B_c = 1.2B_n = 1.2(F_{uc} - F_{lc})$ $B_{-40} = 1.91B_c$ $B_{-50} = 3.33B_c$ $B_{-60} = 5.75B_c$	
	Transmitters in the land and maritime mobile service ≤ 100 W	$B_n = F_{uc} - F_{lc}$	$B_c = 1.8B_n = 1.8(F_{uc} - F_{lc})$ $B_{-40} = 1.9B_c$ $B_{-50} = 3.3B_c$ $B_{-60} = 6.1B_c$	
Telephony, transmission in independent sidebands, reduced or suppressed carrier **B8EJN**	Telephony in two independent bands	$B_n = 2F_U$	$B_c = 1.05B_n = 2.1F_U$ $B_{-40} = 1.43B_c$ $B_{-50} = 2.57B_c$ $B_{-60} = 4.67B_c$	
	Telephony in four independent bands	$B_n = 4F_U$	$B_c = 1.05B_n = 4.2F_U$ $B_{-40} = 1.43B_c$ $B_{-50} = 2.57B_c$ $B_{-60} = 4.67B_c$	

TABLE 1 (*continued*)

Class of emission	**Additional characteristics**	**Calculation of:**		**Remarks**
		Necessary bandwidth B_n (Hz)	**–30 dB occupied bandwidth, B_c, and bandwidths of OoB spectra (Hz)**	
Telephony, transmission in independent bands **B9WWF**		$B_n = Np\ F_U$, where Np is the number of independent bands	$B_c = 1.8B_n$ $B_{-40} = 1.2B_c$ $B_{-50} = 2.2B_c$ $B_{-60} = 3.7B_c$	
Two or more channels, single sideband **J8EKF**	Telephony with privacy	$B_n = Np(F_{uc} - F_{lc})$, where Np is the number of independent frequency bands	$B_c = 1.2B_n$ $B_{-40} = 1.83B_c$ $B_{-50} = 3.33B_c$ $B_{-60} = 5.83B_c$	
1.C Sound broadcasting				
Sound broadcasting, double-sideband **A3EGN**		$B_n = 2F_{uc}$	$B_c = 1.2B_n = 2.4\ F_{uc}$ $B_{-40} = 1.13B_c$ $B_{-50} = 2.42B_c$ $B_{-60} = 2.75B_c$	
Sound broadcasting, single sideband, reduced carrier **R3EGN**		$B_n = F_{uc}$	$B_c = 1.15B_n = 1.15\ F_{uc}$ $B_{-40} = 1.22B_c$ $B_{-50} = 2.09B_c$ $B_{-60} = 3.83B_c$	
Sound broadcasting, single sideband, suppressed carrier **J3EGN**		$B_n = F_{uc} - F_{lc}$	$B_c = 1.15B_n$ $B_{-40} = 1.22B_c$ $B_{-50} = 2.09B_c$ $B_{-60} = 3.83B_c$	
Sound broadcasting, transmission in independent sidebands, reduced or suppressed carrier **B8EGN**		$B_n = 2F_{uc}$	$B_c = 1.05B_n = 2.1F_{uc}$ $B_{-40} = 1.43B_c$ $B_{-50} = 2.57B_c$ $B_{-60} = 4.29B_c$	

TABLE 1 (*continued*)

Class of emission	Additional characteristics	Calculation of: Necessary bandwidth B_n (Hz)	Calculation of: –30 dB occupied bandwidth, B_c, and bandwidths of OoB spectra (Hz)	Remarks
Single-sideband broadcasting **H3EGN, J3EGN**		$B_n = F_{uc} - F_{lc}$	$B_c = 1.15\ B_n$ $B_{-40} = 1.22\ B_c$ $B_{-50} = 2.1\ B_c$ $B_{-60} = 3.83\ B_c$	
1.D Facsimile				
Facsimile with carrier modulation, frequency-modulated subcarrier, double-sideband **A3C--**(1)		$B_n = 2F_{sc} + 3F_U$, where F_{sc} is the subcarrier frequency	$B_c = B_n$ $B_{-35} = B_n + 2F_U$	
Facsimile with carrier modulation, frequency-modulated subcarrier, single sideband, reduced carrier **R3C, R3CMN**		$B_n = F_{sc} + 1.5F_U$	$B_c = B_n + F_U = F_{sc} + 2.5F_U$ $B_{-40} = B_c + F_U$ $B_{-50} = B_c + 2F_U$ $B_{-60} = B_c + 3F_U$	
1.E Composite emissions				
Composite emissions in two independent bands, suppressed or reduced carrier **B9WWX**	One sideband for SSB telephony, the other for multichannel voice-frequency telegraphy	$B_n = 2F_U$ or $B_n = 2B_{ch}$, where B_{ch} is the overall channel speed	$B_c = 1.1B_n\ B_c = 2.2B_{ch}$ $B_{-40} = 1.8B_c$ $B_{-50} = 3.36B_c$ $B_{-60} = 5.8B_c$	B_n if upper frequency F_U of SSB channel greater than voice-frequency telegraphy speed; otherwise, B_{ch} is used in place of B_n

TABLE 1 (*continued*)

Class of emission	Additional characteristics	Calculation of: Necessary bandwidth B_n (Hz)	–30 dB occupied bandwidth, B_c, and bandwidths of OoB spectra (Hz)	Remarks
		2. Frequency modulation		
		2.A Telegraphy		
Frequency-shift telegraphy, single-channel **F1B, F1D**		$B_n = 2.4B\sqrt{m'}$ for $0.5 \le m_p < 1.5$ $B_n = 1.2B + 2.4D$ for $1.5 \le m_p < 5.5$ $B_n = 1.9B + 2.1D$ for $5.5 \le m_p \le 20$	$B_c = 2.3B_n/(m_p + 12)^{1/6}$ $B_{-40} = B_c[2.86 - (m_p + 12)^{1/6}]$ $B_{-50} = B_c[4 - (m_p + 8)^{1/4}]$ $B_{-60} = B_c[4.8 - (m_p + 5)^{1/3}]$	$m_p = 2D/B$
Narrow-band direct-printing telegraphy with error correction **F1BCN**		$B_n = 2B + 2.4D$ $D = 85$ Hz		
Frequency manipulation of subcarriers **F2B**		$B_n = (N_f - 1)\Delta F + B_{nF1B}$ N_f: number of subcarriers ΔF: subcarrier separation (Hz) B_{nF1B}: necessary bandwidth calculated for $F1B$	$B_c = B_n$ $B_{-40} = 1.3\ B_c$ $B_{-50} = 1.6B_n$ $B_{-60} = 3B_n$	
Multichannel frequency shift telegraphy **F7B, F7D**		$B_n = 2.4B\sqrt{m'}$ for $0.5 \le m_p < 1.5$ $B_n = 1.2B + 2.4D$ for $1.5 \le m_p < 5.5$ $B_n = 1.9B + 2.1D$ for $5.5 \le m_p \le 20$	$B_c = 2.3B_n/(m_p + 12)^{1/6}$ $B_{-40} = B_c[2.86 - (m_p + 12)^{1/6}]$ $B_{-50} = B_c[4 - (m_p + 8)^{1/4}]$ $B_{-60} = B_c[4.8 - (m_p + 5)^{1/3}]$	$m_p = 2D/B$ where B is the maximum transmission speed in the channels

TABLE 1 (*continued*)

Class of emission	Additional characteristics	Calculation of: Necessary bandwidth B_n (Hz)	–30 dB occupied bandwidth, B_c, and bandwidths of OoB spectra (Hz)	Remarks
Four-frequency duplex telegraphy **F7BDX**	Transmitters in the fixed and mobile service	a) $B_n = B + 2.2D$ for synchronized channels	$B_c = B_n$ $B_{-40} = (4m_p + 13)B$ $B_{-50} = (4.6m_p + 26)B$ $B_{-60} = (5.1m_p + 47)B$	$m_p = 2D/3B$
	Aircraft transmitters in the aeronautical mobile service	b) $B_n = 4B + 2.2D$ for non-synchronized channels where B is the maximum transmission speed in the channels	$B_c = B_n$ $B_{-40} = 13m_p^{2/3}B$ $B_{-50} = 18\ m_p^{2/3}B$ $B_{-60} = 37\ m_p^{2/3}B$	$m_p = 2D/3B$, for $(1.3 < m_p < 5)$
2.B Telephony				
Commercial telephony **F3EJN**		$B_n = 2F_U + 2D$	$B_c = B_n = 2F_U + 2D$ $B_{-40} = (7.8m_p + 3)F_U$ for $0.25 \le m_p \le 1.3$ $B_{-40} = (7.8m_p + 4)F_U$ for $m_p > 1.3$ $B_{-50} = (8.4m_p + 4.4)F_U$ for $0.25 \le m_p \le 1.3$ $B_{-50} = (8.4m_p + 6)F_U$ for $m_p > 1.3$ $B_{-60} = (9m_p + 6)F_U$ for $0.25 \le m_p \le 1.3$ $B_{-60} = (8.8m_p + 8)F_U$ for $m_p > 1.3$	$m_p = D/3F_U$
2.C Sound and television broadcasting				
Sound broadcasting (monaural) **F3EGN**	D = 50 kHz, D = 75 kHz	$B_n = 2F_U + 2D$ for $1 \le m_p \le 1.7$	$B_c = (6.7m_p + 2)F_U$ $B_{-40} = (7.8m_p + 3)F_U$ $B_{-50} = (8.4m_p + 4.4)F_U$ $B_{-60} = (9m_p + 6)F_U$ for $1 \le m_p \le 1.7$	$m_p = D/3F_U$

TABLE 1 (*continued*)

Class of emission	Additional characteristics	Calculation of: Necessary bandwidth B_n (Hz)	Calculation of: –30 dB occupied bandwidth, B_c, and bandwidths of OoB spectra (Hz)	Remarks
Television transmission with FM **F3FM, F3FN, F3FW**		$B_n = 2F_U + 2D$	$B_c = 1.2B_n = 2.4F_U + 2.4D$ $B_{-60} = 1.67B_c$	
Sound broadcasting (stereo channel) **F8EHN**	$D = 50$ kHz, $D = 75$ kHz	$B_n = 2.4F_U + 2.4D$ for $0.3 \leq m_p \leq 1.7$	$B_c = (8m_p + 2.4)F_U$ $B_{-40} = (9.36m_p + 3.6)F_U$ $B_{-50} = (10m_p + 5.28)F_U$ $B_{-60} = (10.8m_p + 7.2)F_U$ for $0.3 \leq m_p \leq 1.7$	$m_p = D/3F_U$
Sound broadcasting, FM **F8E, F9E, F9W**		$2F_U + 2D$	$B_c = 2F_U + 2.3D$ $B_{-60} = 6F_U + 3D$	
Sound broadcasting with subsidiary channel **F8EHF**	$D = 75$ kHz	$B_n = 2F_U + 2D$ for $0.3 \leq m_p \leq 0.5$		$m_p = D/3F_U$
2.D Facsimile				
Facsimile, with frequency modulation of carrier by image pulse signal **F1CMN F3CMN** (monochrome signal) **F3C, F1CNN, F3CNN** (colour signal)	Transmission of black-and-white facsimile (text) images	$B_n = 2F_U + 2.2D$, $F_U = Z/2$	$B_c = 1.2B_n = 2.4F_U + 2.64D$ $B_{-40} = 1.33B_c$ $B_{-50} = 1.75B_c$ $B_{-60} = 2.25B_c$	
	Transmission of half-tone and colour images	$B_n = 2F_U + 2.2D$, $F_U = Z/2$	$B_c = 1.2B_n = 2.4F_U + 2.64D$ $B_{-40} = 0.83B_c \cdot 10^{5.1/(11.8+3.2m_p)}$ $B_{-50} = 0.83B_c \cdot 10^{8.1/(11.8+3.2m_p)}$ $B_{-60} = 0.83B_c \cdot 10^{11.1/(11.8+3.2m_p)}$	$m_p = D/F_U$

TABLE 1 (*continued*)

<table>
<tr><th rowspan="2">Class of emission</th><th rowspan="2">Additional characteristics</th><th colspan="2">Calculation of:</th><th rowspan="2">Remarks</th></tr>
<tr><th>Necessary bandwidth B_n
(Hz)</th><th>–30 dB occupied bandwidth, B_c, and bandwidths of OoB spectra
(Hz)</th></tr>
<tr><td colspan="5">2.E Composite emissions</td></tr>
<tr><td>Frequency modulation by two or more frequencies
F8B, F9B
F8BBT, F8BBN,
F9BBT, F9BBN</td><td></td><td>$B_n = 2B + 2D$,
with $D = 0.25B$,
where B is the maximum transmission speed in the channels</td><td>$B_c = 2.5B_n$
$B_{-60} = 2.8B_c$</td><td></td></tr>
<tr><td rowspan="2">FM oscillation modulated with signal from FDM transmission system
F8EJF</td><td rowspan="2">Line-of-sight and tropospheric relays</td><td rowspan="2">$B_n = 2F_U + 2D$,
where D is determined from Table 1A</td><td>$B_c = 0.3B_n$
for $60 \leq N600$</td><td rowspan="2">For systems with a pilot signal, use F_{ps} instead of F_U</td></tr>
<tr><td>$B_c = 0.7B_n$
for $N \geq 720$</td></tr>
<tr><td>FM oscillation modulated with television signal and sound subcarriers
F8WWN</td><td>Line-of-sight relay systems</td><td>$B_n = 2F_U + 2D_{MAX.TV}$,
where:
$D_{MAX.TV}$: peak frequency deviation created by the video signal (Hz)
F_U: frequency of upper sound subcarrier</td><td>$B_c = 0.7B_n$</td><td>For systems with a pilot signal, use F_{ps} instead of F_U</td></tr>
<tr><td>Frequency MSK (unfiltered)
F9E, F9D
F9EBT, F9EBN
F9DBT, F9DBN</td><td></td><td>$B_n = 1.18B$,
for $D \approx B/4$</td><td>$B_c = 1.18B_n = 1.4B$
$B_{-40} = 1.3B_c$
$B_{-50} = 1.56B_c$
$B_{-60} = 1.74B_c$</td><td></td></tr>
</table>

TABLE 1 (*continued*)

Class of emission	Additional characteristics	Calculation of: Necessary bandwidth B_n (Hz)	Calculation of: –30 dB occupied bandwidth, B_c, and bandwidths of OoB spectra (Hz)	Remarks
Frequency MSK with Gaussian filter **F9E, F9D**	With normalized Gaussian shaping filter bandwidth, $\varphi = \Delta F_G T$	If $\varphi = 1$ then $B_n = 1.14B$ If $\varphi = 0.7$ then $B_n = 1.1B$ If $\varphi = 0.5$ then $B_n = 1.07B$ If $\varphi = 0.3$ then $B_n = 0.93B$	If $\varphi = 1$ then $B_c = 1.34B$ $B_{-40} = 1.3B_c$, $B_{-60} = 1.74B_c$ If $\varphi = 0.7$ then $B_c = 1.21B$ $B_{-40} = 1.2B_c$, $B_{-60} = 1.51B_c$ If $\varphi = 0.5$ then $B_c = 1.16B$ $B_{-40} = 1.14B_c$, $B_{-60} = 1.4B_c$ If $\varphi = 0.3$ then $B_c = 0.95B$ $B_{-40} = 1.1B_c$, $B_{-60} = 1.3B_c$	If $T = 1/B$ and $D \cong B/4$
FM oscillation with FDM **F9WWF**	FDM-FM, Line-of-sight relay link	$2F_U + 2D_m$, where D_m is determined from Table 1A	$B_c = 0.3B_n$ for $60 \leq N_C \leq 600$ $B_c = 0.7B_n$ for $N_C \geq 720$	For systems with a pilot signal, use F_{ps} instead of F_U

TABLE 1 (*continued*)

TABLE 1a

Calculation of peak frequency deviation of multichannel message, $D = 3.76\ \Delta fch \cdot 10^{0.05P_{load}}$

Number of voice channels, N_c	**Effective frequency deviation created by the measured level of one voice channel, Δf_{ch} (MHz)**	**Mean power of multichannel message (P_{load}) (dBm)**	**Mean power of one voice channel $\lambda(P_{ch.mean})$ (dBm)**
$12 \le N_c < 60$	0.1	$2.6 + 2 \log N_c$	
$60 \le N_c \le 240$	0.2	$\approx 5.5 \log N_c - 1.5$	
$240 < N_c \le 1\,020$	0.2	$P_{ch.mean} + 10 \log N_c$	–13
$N_c > 1\,020$	0.14	$P_{ch.mean} + 10 \log N_c$	–13

Class of emission	**Additional characteristics**	**Calculation of:**		**Remarks**
		Necessary bandwidth B_n (Hz)	**–30 dB occupied bandwidth, B_c, and bandwidths of OoB spectra (Hz)**	
2. Frequency modulation (*continued*)				
2.F Phase modulation				
Single-channel telegraphy, phase-shift **G1B, G1D**	$K_{fade} = 3$ for links not subject to fading, $K_{fade} = 5$ for links subject to fading	$B_n = K_{fade}B$	$B_c = 1.4B_n = 1.4K_{fade}B$ $B_{-40} = 1.86B_c$ $B_{-50} = 3.29B_c$ $B_{-60} = 5.7B_c$	
Continuous phase manipulation telegraphy **G1BCN**		$B_n = 11B$	$B_c = B_n = 11B$ $B_{-40} = 1.7B_c$ $B_{-50} = 2.7B_c$ $B_{-60} = 5.5B_c$	
	Narrow-band relative phase-shift keying; recommended transmission speed 100 or 200 Bd NBPM	$B_n = 1.1B$	$B_c = 2.4B_n = 2.64B$ $B_{-40} = 1.5B_c$ $B_{-50} = 2.12B_c$ $B_{-60} = 2.75B_c$	MF and HF transmitters in the maritime mobile service

TABLE 1 (*continued*)

Class of emission	**Additional characteristics**		**Calculation of:**		**Remarks**
			Necessary bandwidth B_n (Hz)	**–30 dB occupied bandwidth, B_c, and bandwidths of OoB spectra (Hz)**	
3. Digital transmission[(2)]					
3.A Amplitude-phase shift keying[(3)]					
Carrier amplitude and phase-modulated **D7D,** **D1W, D7W,** **D9W**			$B_n = R/\log_2 S$, where: *R:* transmission speed in bit/s *S:* number of states	$B_c = 1.5B_n = 1.5R/{*}\log_2 S$ $B_{-40} = 1.13B_c$ B_n with $S = 4$	For signals having $\alpha \approx 0.5$ (see Table 1B)
	QPSK, encoding with error correction	CDMA	$B_n = 1.5\ K_{red}\ R$ K_{red} is the coefficient of redundancy for encoding with error-correction	$B_c = 1.8\ K_{red}\ R$ $B_{-40} = 1.3B_c$ $B_{-50} = 2B_c$ $B_{-60} = 4B_c$	ψ: redundancy $K_R = 1 + \psi$
	QPSK	TDMA, FDMA	$B_n = KR$ $K = 1.25 \div 2$	$B_c = 1.2RK$ $B_{-40} = 1.17B_c$ $B_{-50} = 1.67B_c$ $B_{-60} = 3.33B_c$	
D8E, D9E	*M*-ary PSK (M = 4, 8, 16)		$B_n = 1.25\ R/\log_2 S$	$B_c = 1.2B_n$ B_n with $S = 4$ $B_{-40} = 1.17B_c$ $B_{-50} = 1.67B_c$ $B_{-60} = 3.33B_c$	
K7D, **K7WWT**	APSK	cosine root filter	$B_n = 2K_\alpha\ (\alpha)/\tau$ K_α – see Table 1B	$B_c = 1.2\ B_n$ $B_{-40} = 1.7B_c$ $B_{-50} = 2.3B_c$ $B_{-60} = 3\ B_c$	
K7E	32 APSK	DBS	$B_n = 1.25\ R/\log_2 S$	$B_c = 1.2\ B_n$ B_n with $S = 4$ $B_{-40} = 1.7B_c$ $B_{-50} = 2.3B_c$ $B_{-60} = 3\ B_c$	DMW digital broadcasting system

TABLE 1 (*continued*)

TABLE 1b

Dependency of the coefficient $K\alpha$ (α) for signals using cosine root pulse-shaping filters

α	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
K_α (α)	0.51	0.537	0.567	0.6	0.634	0.669	0.705	0.742	0.779	0.816

Class of emission	Additional characteristics		Calculation of: Necessary bandwidth B_n (Hz)	Calculation of: –30 dB occupied bandwidth, B_c, and bandwidths of OoB spectra (Hz)	Remarks
3. Digital transmission[(2)] (*continued*)					
3.B Frequency-shift keying[(3)]					
Single-channel FM telegraphy and coding with digital transmission **F1B, F1E, F1D, F1W,F7B, F7D, F7E,F7W**			$B_n = 2.4R\sqrt{m'}$ for $0.5 \le m_p < 1.5$ $B_n = 1.2R + 2.4D$ for $1.5 \le m_p < 5.5$ $B_n = 1.9R + 2.1D$ for $5.5 \le m_p \le 20$	$B_c = 2.3B_n/(m_p + 12)^{1/6}$ $B_{-40} = B_c[2.86 - (m_p + 12)^{1/6}]$ $B_{-50} = B_c[4 - (m_p + 8)^{1/4}]$ $B_{-60} = B_c[4.8 - (m_p + 5)^{1/3}]$	$m_p = 2D/R$
F1WD-, F7DD-, F7WD-	CPFSK	CDMA	$B_n = 0.5R + 1.78D$	$B_c = 1.4B_n$ $B_{-40} = 1.9B_c$ $B_{-50} = 3.3B_c$ $B_{-60} = 5.7B_c$	
Frequency modulation, multichannel transmission **F7D, F7W F7DD, F7WD**	Frequency modulation with Gaussian filter	GMSK (carrier)	$B_n = K_G R$ K_G (BT) – see Table 1C	$B_c = 1.2K_G R$ $B_{-40} = 1.2B_c$ $B_{-50} = 1.4B_c$ $B_{-60} = 1.6B_c$	GSM900
F9D, F9E, F9W (G9D, G9E, G9W)		FMSK (subcarrier)	$B_n = K_G R$ K_G (BT) – see Table 1C $B_n = R/\log_2 S + KD$ with $0.4 < K < 0.6$	$B_c = 1.2 \div 1.4B_n$ $B_{-40} = 1.2B_c$ $B_{-50} = 1.4B_c$ $B_{-60} = 1.6B_c$	Second B_n formula for frequency-phase modulation systems

TABLE 1 (*continued*)

TABLE 1c

Dependency of the coefficient *KG* (*BT*)

BT is the normalized filter bandwidth, given by the product of the bandwidth at the –3 dB level and the time to transmit one coded element (sub-impulse).

BT	∞	1	0.7	0.5	0.3	0.25	0.15	Remarks
K_G (*BT*)	1.28	1.14	1.1	1.07	0.93	0.86	0.70	Mean
	0.94			0.80	0.70	0.67	0.53	Span 95%
	1.28			1.03	0.91	0.86	0.70	Span 99%
	2.81			1.20	1.06	1.00	0.83	Span 99.8%
System examples				DECT	GSM, DCS, PCS	Tetrapol		
Type of modulation	MSK	GMSK						

Class of emission	Additional characteristics		Calculation of:		Remarks
			Necessary bandwidth B_n (Hz)	**–30 dB occupied bandwidth, B_c, and bandwidths of OoB spectra (Hz)**	
3. Digital transmission[(2)] (*continued*)					
3.C Phase-shift keying[(3)]					
1	**2a**	**2b**	**3**	**4**	**5**
Single-channel transmission, phase-shift keying **G1D, G1E, G1F, G1W**		The limiting value of the coefficient K is determined depending on the signal modulation method used	$B_n = KR/\text{Log}_2S$, where: *R*: transmission speed in bit/sec, *K:* coefficient *S*: number of states	$B_c = 1.4B_n$ $B_c = 2.8KR/\log_2S$[(3)] $B_{-40} = 1.86B_c$ $B_{-50} = 3.28B_c$ $B_{-60} = 5.7B_c$	$4 < K < 20$ for BPSK unfiltered; $1.5 < K < 4$ for BPSK unfiltered

TABLE 1 (*continued*)

Class of emission	Additional characteristics		Calculation of: Necessary bandwidth B_n (Hz)	Calculation of: –30 dB occupied bandwidth, B_c, and bandwidths of OoB spectra (Hz)	Remarks
1	2a	2b	3	4	5
Single-channel transmission, phase modulation **G1E**	π/4QPSK, π/4DQPSK	TDMA, FDMA; raised cosine filter	$B_n = K_\beta R$ $0.6 < K_\beta < 1$	$B_c = 1.05B_n$ $B_{-40} = 1.1B_c$ $B_{-50} = 4B_c$ $B_{-60} = 8B_c$	
	QPSK	TDMA, FDMA	$B_n = KR$ $K = 1.25 \div 2$	$B_c = 1.2B_n$ $B_{-40} = 1.17B_c$ $B_{-50} = 1.67B_c$ $B_{-60} = 3.33B_c$	
Relative phase-shift of subcarriers G2B, G2D			$B_n = (N_f - 1)\Delta F + 5R$	$B_c = (N_f - 1)\Delta F + 7R$ $B_{-50} = 1.6(N_f - 1)\Delta F + 8R$ $B_{-60} = 3(N_f - 1)\Delta F + 15R$	ΔF: subcarrier separation N_f: number of subcarriers
Multichannel transmission **G7B, G7D, G7E, G7F, G7W**	M-ary PSK (M = 8, 16)		$B_n = 2.5\ R/\log_2 S$	$B_c = 1.2B_n$(3) $B_{-40} = 1.17B_c$ $B_{-50} = 1.67B_c$ $B_{-60} = 3.33B_c$	If redundancy ψ is given in %, then $K_R = 1 + \psi//100$
	M-ary QAM, M-ary PSK, encoding with error correction		$B_n = K_{red}\ R/\log_2 S$ K_{red} is the coefficient of redundancy for encoding with error-correction	$B_c = 1.4B_n$ $B_{-40} = 1.4B_c$ $B_{-50} = 1.8 \div 2.3B_c$ $B_{-60} = 2.5 \div 3B_c$	
	GMSK filtered and submodulation 3 dB		$B_n = (R/\log_2 S) + +2DK_G$ $D = 0.25R$ (for value of K_G see Table 1C)	$B_c = 1.4B_n$ $B_c = 1.4(R/\log_2 S) + 2.8DK_G$ $B_{-60} = 2.7B_c$	

TABLE 1 (*continued*)

Class of emission	Additional characteristics		Calculation of: Necessary bandwidth B_n (Hz)	Calculation of: –30 dB occupied bandwidth, B_c, and bandwidths of OoB spectra (Hz)	Remarks
1	2a	2b	3	4	5
G7D, G7E, G7F, G7W	BPSK unfiltered BPSK unfiltered		$B_n = KR$ $K = 1.5 \div 2$ $B_n = KR$ $K = 4$ (95%) $\div$ 20 (99%)	$B_c = 1.4B_n$ $B_{-40} = 2.6B_c$ $B_{-50} = 4.6B_c$ $B_{-60} = 8.2B_c$	
	π/4QPSK, π/4DQPSK	TDMA, FDMA raised cosine filter	$B_n = K_\beta R$ $0.6 < K_\beta < 1$	$B_c = 1.05B_n$ $B_{-40} = 1.1B_c$ $B_{-50} = 4B_c$ $B_{-60} = 8B_c$	
G9D	*M*-ary QAM 4-, 16- ($M = 4$, 16)	TDMA	$B_n = KR/\log_2 S$ $1.5 < K < 1.7$	$B_c = 1.4B_n$(3) $B_{-40} = 1.4B_c$ $B_{-50} = 1.8 \div 2.3B_c$ $B_{-60} = 2.5 \div 3B_c$	
G9D	*M*-ary PSK ($M = 8$, 16)	TDMA	$B_n = KR/\log_2 S$ $K = 2.5$	$B_c = 1.2B_n$(3) $B_{-40} = 1.17B_c$ $B_{-50} = 1.67B_c$ $B_{-60} = 3.33B_c$	
	M-ary QAM, encoding with error correction		$B_n = K_{red}\, R/\log_2 S$ K_{red} is the coefficient of redundancy for encoding with error-correction	$B_c = 1.2B_n$(3) $B_{-40} = 1.3B_c$ $B_{-50} = 1.7B_c$ $B_{-60} = 2.2B_c$	
	QPSK	Radio link	$B_n = R$	$B_c = 1.2\ R = 1.2B_n$ $B_{-40} = 1.17B_c$ $B_{-50} = 1.7B_c$ $B_{-60} = 3.3B_c$	

TABLE 1 (*continued*)

Class of emission	Additional characteristics		Calculation of: Necessary bandwidth B_n (Hz)	Calculation of: –30 dB occupied bandwidth, B_c, and bandwidths of OoB spectra (Hz)	Remarks
1	**2a**	**2b**	**3**	**4**	**5**
G9W **G9WDN,** **G9WDT**	QPSK *M*-ary PSK (M = 8, 16)	TDMA, FDMA	$B_n = KR$ K = 1.25 ÷ 2	$B_c = 1.2B_n$ $B_{–40} = 1.17B_c$ $B_{–50} = 1.67B_c$ $B_{–60} = 3.33B_c$	
G9W	QPR, QPR, AZD		$B_n = K_C R$ K_C – see Table 1D	$B_c = 1.4B_n$ $B_{–40} = 1.4B_c$ $B_{–50}$ = 1.8 to $2.3B_c$ $B_{–60}$ = 2.5 to $3B_c$	
			3.D Step quadrature and code modulation[(3)]		
D7D, D7W, D9E ***C-, D-,T-, F[(4)]**-**	*M*-ary QAM		$B_n = R/\log_2 S$	$B_c = 1.2B_n$[(3)] $B_{–40} = 1.3B_c$ $B_{–50} = 1.7B_c$ $B_{–60} = 2.2B_c$	
	M-ary QAM, encoding with error correction		$B_n = K_{red} R/\log_2 S$ K_{red} is the coefficient of redundancy for encoding with error-correction		
	M-ary QAM with code modulation		$B_n = K_C R/\log_2 S$ K_C – see Table 1D		
G7C, G7W, G9D ***C-, D-, T-, F-	*M*-ary QAM		$B_n = R/\log_2 S$	$B_c = 1.2B_n$[(3)] $B_{–40} = 1.3B_c$ $B_{–50} = 1.7B_c$ $B_{–60} = 2.2B_c$	
	M-ary QAM, encoding with error correction		$B_n = K_{red} R/\log_2 S$ K_{red} is the coefficient of redundancy for encoding with error-correction		
	M-ary QAM with code modulation		$B_n = K_C R/\log_2 S$ K_C – see Table 1D		

TABLE 1 (*continued*)

Class of emission	Additional characteristics		Calculation of: Necessary bandwidth B_n (Hz)	Calculation of: –30 dB occupied bandwidth, B_c, and bandwidths of OoB spectra (Hz)	Remarks
1	2a	2b	3	4	5
K7D, K7E, K7W	4-, 16-, 32-, 64-QPAM		$B_n = KR/\log_2 S$ $K = 1 \div 2$	$B_c = 1.4B_n$(3) $B_{-40} = 1.4B_c$ $B_{-50} = 2.3B_c$ $B_{-60} = 3B_c$	
Q7D, Q7E, Q7W *****C-, D-,T-, F**	*M*-ary QAM		$B_n = R/\log_2 S$	$B_c = 1.2B_n$(3) $B_{-40} = 1.3B_c$ $B_{-50} = 1.7B_c$ $B_{-60} = 2.2B_c$	
	M-ary QAM, encoding with error correction		$B_n = K_{red}\, R/\log_2 S$ K_{red} is the coefficient of redundancy for encoding with error-correction		
	M-ary QAM with code modulation		$B_n = K_C\, R/\log_2 S$ K_C – see Table 1D		

TABLE 1 (*continued*)

TABLE 1d

Code modulation of data *(BCM, TCM, MLCM)* in digital radio transmission systems in accordance with Recommendation ITU-R F.1101

Method of modulation (complete designation)	K_C
16 BCM-8D (one-step QAM)	0.267
96 BCM-4D, 88 BCM-6D, 80 BCM-8D (all one-step QAM)	0.167
128 BCM-8D (two-step QAM)	0.167
16 TCM-2D	0.333
32 TCM-2D	0.250
128 TCM-2D	0.167
512 TCM-2D	0.125
32 MLCM	0.222
9-QPR	0.5
25-QPR	0.33
64 TCM-4D, 64 MLCM	0.182
128 TCM-4D, 128 MLCM	0.154
512 TCM-4D	0.118

TABLE 1 (*continued*)

Class of emission	Additional characteristics		Calculation of: Necessary bandwidth B_n (Hz)	Calculation of: –30 dB occupied bandwidth, B_c, and bandwidths of OoB spectra (Hz)	Remarks
4. Pulse modulation					
4.A Amplitude-modulated carrier					
1	**2a**	**2b**	**3**	**4**	**5**
Amplitude-modulated carrier **K1N, K1D, K1W**	PAM, PACM	Output-electronic/ vacuum unit with network control	$B_n = 2F_U + 4/\tau$ B_n, F_U (MHz), τ (μs)	$B_c = 4B_n = 8F_U + 16/\tau$ $B_{-40} = 1.4B_c$ $B_{-50} = 2B_c$ $B_{-60} = 3.75B_c$	
4.B Duration-modulated carrier					
Pulse-duration modulation pulse-code modulation (*M*-ary) **L1N, LXN**(5)	PDM, PCM, PNM	Pulses with steep leading edge, i.e. $\tau_r \leq 0.008\ t$	$B_n = 6.36/\tau\delta$	$B_{-20} = 6.36/\tau$ $B_c = 9.14/\tau$ $B_{-40} = 63.6/\tau = 7B_c$	
Pulse duration modulation pulse code modulation (*M*-ary) **L1N, LXN**(5)	PDM, PCM, PNM	Trapezoid pulse with $\tau_r > 0.008\ t$	$B_n = 1.79/(\tau\ \delta)^{½}$	Radars with pulse power > 100 W $B_{-20} = 1.8/(\tau\ \delta)^{1/2}$ $B_c = 2.17/(\tau\ \delta)^{1/2}$ $B_{-40} = 6.2/(\tau\ \tau_r)^{1/2} = 2.9B_c$ $B_{-60} = 17.9/(\tau\ \delta)^{1/2} = 8B_c$ Radars with pulse power ≤ 100 kW $B_{-20} = 1.8/(\tau\ \delta)^{1/2}$ $B_c = 2.2/(\tau\ \delta)^{1/2}$ $B_{-40} = 7.6/(\tau\ \tau_r)^{1/2} = 3.5B_c$ $B_{-60} = 18/(\tau\ \delta)^{1/2} = 8B_c$	

TABLE 1 (*continued*)

Class of emission	Additional characteristics		Calculation of: Necessary bandwidth B_n (Hz)	Calculation of: –30 dB occupied bandwidth, B_c, and bandwidths of OoB spectra (Hz)	Remarks
4.C Pulse-position modulation					
1	**2a**	**2b**	**3**	**4**	**5**
Phase-shifted carrier with Barker code **M0N, MXN**	PPM	Radars	$B_n = 2/\tau_d\delta_d$ where τ_d is the sample length	$B_c = 3.6/(\tau_d\ \delta_d)^{1/2}$ $B_{-40} = 1.77B_c$ $B_{-50} = 3.16B_c$ $B_{-60} = 5.6B_c$	For coded pulses, use sample length (sub-pulse)
Pulse-phase modulation **M7EJT**	PPM	Radio-relay links (FXR code)	$B_n = 3.2/\tau\ \delta$ B_n (MHz), τ (μs)	$B_c = 1.12B_n\ (\tau/\delta)^{1/2}$ $B_{-40} = 1.79B_c$ $B_{-50} = 3.18B_c$ $B_{-60} = 5.64B_c$	
4.D Continuous wave emission					
Unmodulated continuous wave emission **N0N**	Unmodulated carrier	"Hawk" radar (standing wave)	$B_n = 2K_d\ F_0$ where K_d is the magnitude of the permissible frequency deviation from F_0	$B_c = B_n = 2K_d\ F_0$ (K_d for station with quartz stabilization) $B_{-40} = 0.0003F_0$	
Continuous-wave emission **M0N**	Frequency-modulated carrier	"Hawk" radar (standing wave)	$B_n = 2D$	$B_{-40} = 2D + 0.0003F_0$	
Chirp **W0N, Q0N**	Frequency-modulated carrier		$B_n = 2D$	$B_{-40} = 2D + 0.0003F_0$	

TABLE 1 (*continued*)

Class of emission	Additional characteristics		Calculation of:		Remarks
			Necessary bandwidth B_n (Hz)	**–30 dB occupied bandwidth, B_c, and bandwidths of OoB spectra (Hz)**	
4.E Unmodulated pulsed carrier					
1	**2a**	**2b**	**3**	**4**	**5**
Unmodulated pulsed carrier(5) **P0N, P0NAN**		Pulses with steep leading edge, i.e. $\tau_r \leq 0.008\ t$	$B_n = 6.36/\tau$	$B_{-20} = 6.36/\tau$ $B_c = 9.14/\tau$ $B_c = 1.44B_n$ $B_{-40} = 63.6/\tau$	
		Trapezoid pulses with $\tau_r > 0.008\ t$	$B_n = 1.79/(\tau\ \delta)^{½}$	Radars with pulse power > 100 W $B_{-20} = 1.8/(\tau\ \delta)^{1/2}$ $B_c = 2.17/(\tau\ \delta)^{1/2}$ $B_{-40} = 6.2/(\tau\ t_r)^{1/2}$ $B_{-60} = 18/(\tau\ \delta)^{1/2}$	
				Radars with pulse power ≤ 100 kW Radionavigation radars in the bands 2.9-3.1 and 9.2-9.5 GHz $B_{-20} = 1.8/(\tau\ \delta)^{1/2}$ $B_c = B_{-30} = 2.2/(\tau\ \delta)^{1/2}$ $B_{-40} = 7.6/(\tau\ \tau_r)^{1/2}$ $B_{-60} = 18/(\tau\ \delta)^{1/2}$	

TABLE 1 (*continued*)

Class of emission	Additional characteristics		Calculation of: Necessary bandwidth B_n (Hz)	Calculation of: –30 dB occupied bandwidth, B_c, and bandwidths of OoB spectra (Hz)	Remarks
4.F Frequency-modulated carrier					
1	**2a**	**2b**	**3**	**4**	**5**
Linear and non-linear FM pulsed carrier(6) **Q1N, QXN, Q1D, Q1W**	PDM-FM, PCM-FM, SFM, LFM	Pulses with steep leading edge, i.e. $\tau_r \leq 0.008\ t$	$B_n = 2D + 6.36/\tau$	Radars with pulse power > 100 W $B_{-40} = 2(D + 0.105/\tau_r) + 6.2/(\tau\ \tau_r)^{1/2}$ $B_{-60} = 2D + 63.6/\tau$	
				Radars with pulse power ≤ 100 kW Radionavigation radar in the bands 2.9-3.1 and 9.2-9.5 GHz $B_{-40} = 2(D + 0.065/\tau_r) + 7.6/(\tau\ \tau_r)^{1/2}$ $B_{-60} = 2D + 63.6/\tau$	
		Trapezoid pulse with $\tau_r > 0.008\ t$	$B_n = 2D + 1.79/(\tau\ \delta)^{1/2}$	Radars with pulse power > 100 W $B_{-40} = 2(D + 0.105/\tau_r) + 6.2/(\tau\ \tau_r)^{1/2}$ $B_{-60} = 2D + 18/(\tau\ \delta)^{1/2}$	
				Radars with pulse power ≤ 100 kW Radionavigation radar in the bands 2.9-3.1 and 9.2-9.5 GHz $B_{-40} = 2(D + 0.065/\tau_r) + 7.6/(\tau\ \tau_r)^{1/2}$ $B_{-60} = 2D + 18/(\tau\ \delta)^{1/2}$	

TABLE 1 (*continued*)

Class of emission	**Additional characteristics**		**Calculation of:** Necessary bandwidth B_n (Hz)	**Calculation of:** –30 dB occupied bandwidth, B_c, and bandwidths of OoB spectra (Hz)	**Remarks**
1	**2a**	**2b**	**3**	**4**	**5**
Pulsed carrier with intra-pulse frequency modulation **Q1N, QXN**	PFM		$B_n = 2D + 2/\tau_d$	$B_{-20} = 2(D + 1/\tau_d)$ $B_c = 2(D + 2.5/\tau_d)$ $B_{-40} = 2(D + 3.5/\tau_d)$ $B_{-50} = 2(D + 5/\tau_d)$ $B_{-60} = 2(D + 7/\tau_d)$	
			4.G Pulse modulation with frequency hopping		
Pulse modulation with frequency hopping **VXN**	PDM-FM, PCM-FM, SFM, LFM, PFM		$B_n = B_s + 2D + 2/\tau_d$ B_s is the maximum carrier frequency shift	$B_{-20} = 2(D + 1/\tau_d) + B_s$ $B_c = 2(D + 2.5/\tau_d) + B_s$ $B_{-40} = 2(D + 3.5/\tau_d) + B_s$ $B_{-50} = 2(D + 5/\tau_d) + B_s$ $B_{-60} = 2(D + 7/\tau_d) + B_s$	
Pulse frequency modulation with frequency hopping **VXN**		Radars with pulse power > 100 W	$B_n = 2D + B_s + 1.79/(\tau\ \tau_r)^{1/2}$ B_s is the maximum carrier frequency shift	$B_{-40} = 2(D + 0.105/\tau_r) + B_s +$ $+ 6.2/(\tau\ \tau_r)^{1/2}$ $B_{-60} = 2D + B_s + 17.9/(\tau\ \tau_r)^{1/2}$	
		Radars with pulse power > 100 W and radars of the radionavigation service in the bands 2.9-3.1 and 9.2-9.5 GHz	$B_n = 2D + B_s + 1.79/(\tau\ \tau_r)^{1/2}$	$B_{-40} = 2(D + 0.065/\tau_r) + B_s +$ $+ 7.6/(\tau\ \tau_r)^{1/2}$ $B_{-60} = 2D + B_s + 17.9/(\tau\ \tau_r)^{1/2}$	

TABLE 1 (*end*)

Class of emission	Additional characteristics		Calculation of: Necessary bandwidth B_n (Hz)	Calculation of: –30 dB occupied bandwidth, B_c, and bandwidths of OoB spectra (Hz)	Remarks
1	2a	2b	3	4	5
Pulse code, pulse amplitude and broadband modulation with frequency hopping **VXN**		Radars with pulse power > 100 W	$B_n = B_s + 1.79/(\tau\ \tau_r)^{1/2}$	$B_{-40} = B_s + 6.2/(\tau\ \tau_r)^{1/2}$ $B_{-60} = 2D + B_s + 17.9/(\tau\ \tau_r)^{1/2}$	
		Radars with power ≤ 100 kW and radars of the radionavigation service in the bands 2.9-3.1 and 9.2-9.5 GHz	$B_n = B_s + 1.79/(\tau\ \tau_r)^{1/2}$	$B_{-40} = B_s + 7.6/(\tau\ \tau_r)^{1/2}$ $B_{-60} = 2D + B_s + 17.9/(\tau\ \tau_r)^{1/2}$	

(1) Hyphens are used to indicate unused additional parameters in the designation of the class of emissions (see Annex 5).

(2) For digital transmission systems using digital pulse shaping filters it is necessary to take into account the filter's rolloff factor (approximate cosine).

(3) For calculating the spectrum envelope (values of B_c, B_{-40}, B_{-50}, B_{-60}), B_n is used with $S = 4$.

(4) Three leading asterisks indicate that the additional symbols refer to the classes of emissions referred to in the item, including additional ones.

(5) For radars using different pulse shapes, the bandwidth is calculated separately for each pulse shape and the highest of the values thus obtained is then taken.

(6) For radars using different pulse shapes, the bandwidth is calculated separately for each pulse shape and the highest of the values thus obtained is then taken. For coded pulses, take sample length (sub-pulse).

TABLE 2

Requirements for bandwidths of OoB spectra of HF transmitters of the aeronautical mobile service on board aircraft, operating in the classes of emissions H2BBN, H3EJN, J3EJN, J7BCF and JXX

Band (kHz)	**Minimum value by which spectral components must be attenuated below the level corresponding to the envelope peak power (dB)**
From f_{tx} ± 1.5 to f_{tx} ± 4.5	30
From f_{tx} ± 4.5 to f_{tx} ± 7.5	38
f_{tx} ± 7.5 and above	43

Remarks: The assigned transmitter frequency f_{tx} is 1 400 Hz higher than the carrier or residual carrier.

The necessary bandwidth is calculated using the formulae given in Table 1.

TABLE 3

Requirements for bandwidths of OoB spectra of transmitters of the maritime mobile service, operating in the classes of emissions H2BBN, H3EJN, J3EJN and R3EJN

Bandwidth (kHz)	**Order of spectral components of dual-tone signal falling within the given frequency bands for the classes of emissions H3EJN, J3EJN, (H2BBN)**	**Level of OoB components at a given sampled frequency, measured in dB with respect to:**	
		the level corresponding to peak envelope power	**the level of one of the fundamental spectral components of the modulating dual-tone signal**
From f_{tx} ± 1.5 to f_{tx} ± 4.5	3	31	25
From f_{tx} ± 4.5 to f_{tx} ± 7.5	5 or 7	38	32
f_{tx} ± 7.5 and above	9	43(1)	37(1)

(1) Absolute power not to exceed 50 mW.

Remarks: The assigned transmitter frequency f_{tx} is 1 400 Hz higher than the carrier or residual carrier.

The necessary bandwidth is calculated using the formulae given in Table 1.

5 Method of measuring –30 dB bandwidth and bandwidths of OoB spectra

General requirements for measurements

5.1 The results of measurements must not be affected by emissions of industrial sources of radio interference or by the emissions of other radio systems.

5.2 In measuring transmitters with frequency overlap greater than two, measurement is performed at three frequencies within the band: at the lower edge, the upper edge and in the middle of the band.

If the overlap coefficient is less than two, measurement is performed at one frequency, close to the middle of the band.

5.3 The equipment used for measurements should meet the requirements given in Annex 3.

5.4 The nomenclature for classes of emissions is given in RR Appendix 1.

5.5 Concerning transmitters operating in the classes of emissions R3EGN, R3EJN, J3EJN, H3EJN, R7BCF and J7BCF, measurements of compliance with the present requirements are requested for the J3EJN class only.

Concerning transmitters operating in the classes of emissions B8EJN, B8EGN and B9WWX, measurements are limited to the B8EJN class.

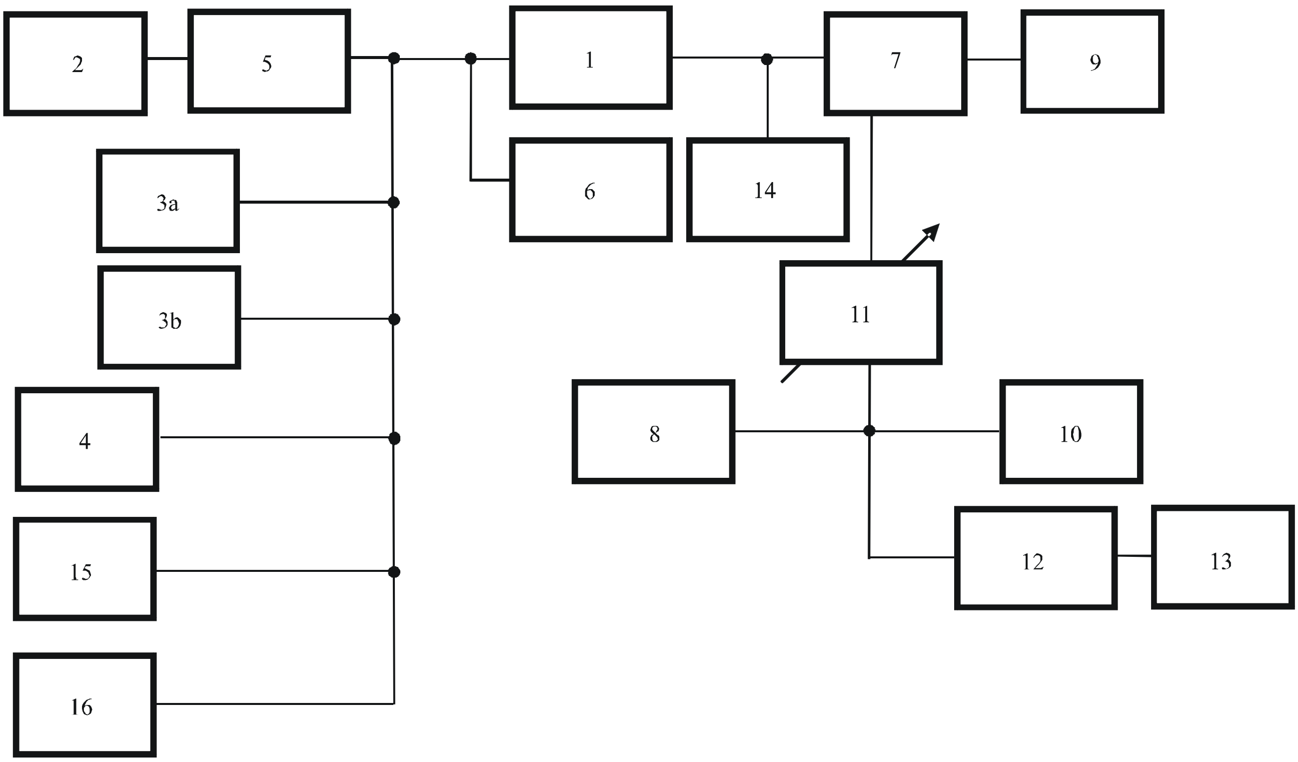
5.6 Measurement of the –30 dB bandwidth and bandwidths of OoB spectra of transmitters is conducted using the set-up depicted (in simplified form) in Fig. 1.

Parts of the set-up apply only to the specific measurement methods used for particular classes of emissions, and are not used for the others.

Concerning transmitters operating in the classes of emissions F9B, F9E and F9D, measurements are conducted in each channel with a different type of transmitted information, using the methods applicable for that type of information.

FIGURE 1

Measurement set-up for obtaining transmitter bandwidth and OoB emissions



1 transmitter
2 noise generator . . . .
3a, 3b audio generator
4 telegraph signal simulator
5 shaping filter
6 r.m.s. voltmeter
7 connector (directional coupler)
8 modulometer
9 dummy antenna
10 deviometer
11 attenuator
12 spectrum analyser
13 frequency meter
14 power meter
15 transmitter element of crosstalk analyser
16 television test signal generator

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5.7 If the specifications for a particular radio system specify OoB bandwidth on the basis of an OoB measurement level other than –30 dB, the bandwidth is to be converted to the B_c (B_{-30}) level by means of Table 4.

TABLE 4

Level used in specification (dB)	–24	–26	–28	–35	–40
Conversion factor to B_c	$B_c = 1.25B_{-24}$ $B_{-24} = 0.8B_c$	$B_c = 1.15B_{-26}$ $B_{-26} = 0.87B_c$	$B_c = 1.07B_{-28}$ $B_{-28} = 0.93B_c$	$B_c = 0.86B_{-35}$ $B_{-35} = 1.17B_c$	$B_c = 0.73B_{-40}$ $B_{-40} = 1.37B_c$

NOTE 1 – This conversion is based on the assumption that the mean slope of the OoB spectrum envelope is 12 dB per octave.

The B_n/B_c conversion factors for a given (notified) class of emission can be used to determine the necessary bandwidth of emission and verify its compliance with the notified bandwidth set out in the requirements.

Example: A notice for the G1B class of emission specifies that the bandwidth for OoB spectra at –28 dB is 23 kHz, i.e. B_{-28} = 23 kHz.

From Table 4 we get the conversion formula $B_c = 1.07B_{-28}$, so B_c = 23 kHz × 1.07 = 24.6 kHz.

The present requirements specify that, for G1B, $B_c = 1.4B_n$. For that notice, the necessary bandwidth is therefore B_n = 24.6/1.4 = 17.6 kHz.

Test signals for measurement of transmitter bandwidths

5.8 In application to transmitters operating in the classes of emissions A1AAN, A1BBN, A2AAN, H2BBN, J2BBN, F1BCN, G1BCN, FID, FIE, F2B, F7E, AIBBN, F7B, F8B, GIB, GIE, GIF, GIW, G2B, G2D, G7D, G7E, G7F and G7W, measurements are performed while the transmitter is being modulated with a test signal of orthogonal telegraph dots.

For transmitters operating in the classes of emissions A1AAN, A1BBN, A2AAN, H2BBN, J2BBN, F1BCN, G1BCN, G1D, G2B, G1E, G1F, G1W, G2D, G7D, G7E, G7F and G7W, measurements are performed at the maximum modulation speed stipulated in the technical specifications for the transmitter under test.

For transmitters of the maritime mobile service operating in the G1BCN class of emission in a transmission regime of narrow-band phase-shift keying, measurements are performed at a modulation rate of $B = 0.88\ B_{max}$, where B_{max} is the maximum modulation rate in the channel.

For transmitters operating in the F1BCN, FID, FIE and F2B classes of emissions, measurements are performed at the maximum rated values of frequency deviation at the maximum modulation rate and using the most frequently occurring combinations of deviation and modulation rate.

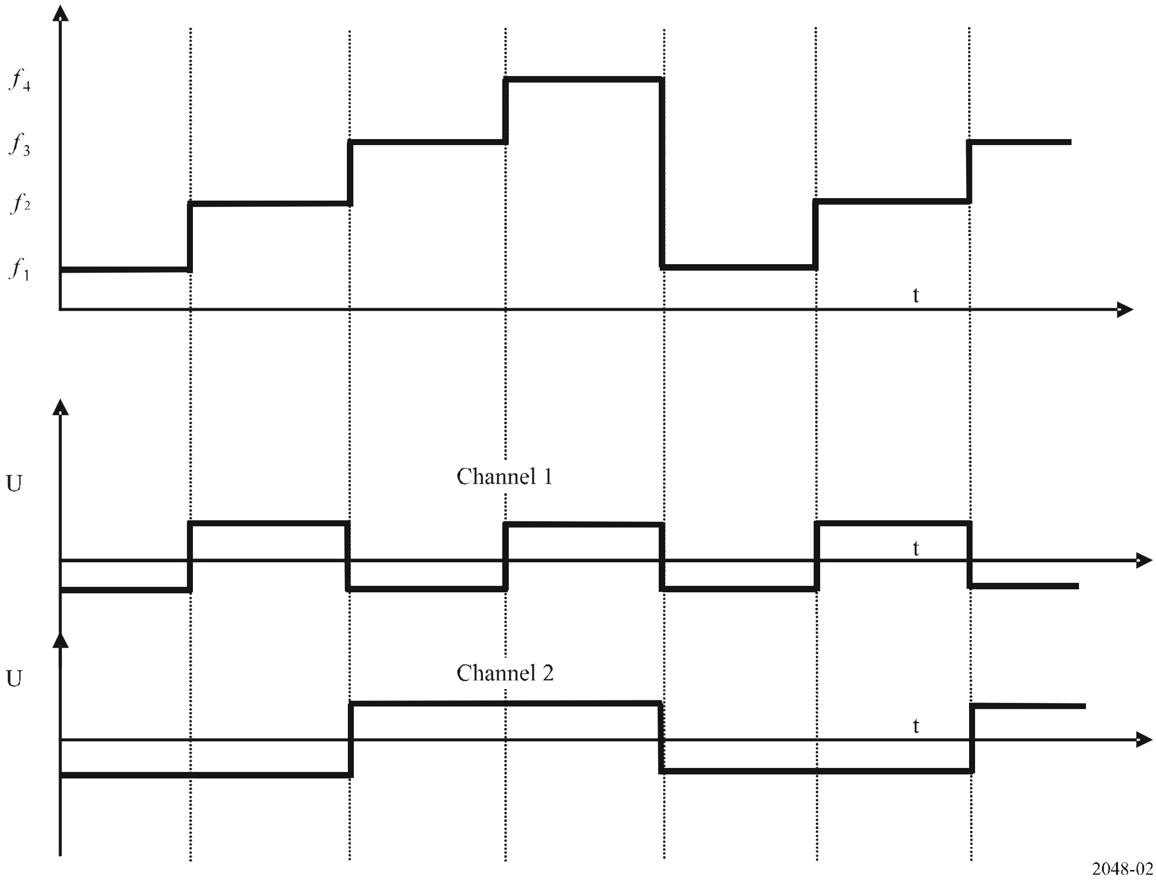
5.9 In application to transmitters operating in the classes of emissions F7BDX, F7D, F7E and F8B, the test signal is generated by modulating both channels of the transmitter with telegraph dots, the speed and synchronization of which shall be selected such that the instantaneous frequency (phase) of the transmitter goes through all four values at regular time intervals (see Fig. 2).

For transmitters operating in the F7BDX class of emission, measurements are performed at maximum frequency separation and maximum modulation speed (on one of the channels).

NOTE 1 – If measurement with the modulation signals described shows the transmitter to satisfy the requirements (see § 4) for synchronous operation of the channels, it is considered also to satisfy the requirements for asynchronous operation.

FIGURE 2

Shape of test signal for transmitters operating in the F7BDX class of emission



f_1: frequency that corresponds to "key raised" in both channels

f_2: frequency that corresponds to "key depressed" in the first and "key raised" in the second channel

f_3: frequency that corresponds to "key raised" in the first and "key depressed" in the second channel

f_4: frequency that corresponds to "key depressed" in both channels

U: modulating potential

t: time.

5.10 In application to transmitters operating in the F1C-- or F3C-- classes of emissions, the test signal is a 1.9 kHz sinusoidal signal amplitude-modulated with a coefficient of modulation of 90% and a frequency of 1.1 kHz. Measurements of bandwidth are performed with a frequency deviation of 1 500 Hz at the transmitter output.

5.11 In application to transmitters operating in the classes of emissions A3C-- or R3C--, the test signal is a 1.9 kHz sinusoidal signal frequency-modulated with a 550 Hz sinusoidal signal at a deviation of 400 Hz (simulating transmission of black and white bars). Modulation depth at the transmitter output is set at 90%.

5.12 In application to transmitters operating in the F3EGN class of emission, the test signal is sinusoidal with a frequency equal to the maximum value of the modulating frequency, with a coefficient of non-linear distortion of 1% maximum. Measurements are performed at peak frequency deviation. Deviation uncertainty must not exceed 5%.

NOTE 1 – The requirements for the –30 dB occupied bandwidth of emission frequencies of broadcast transmitters with a broadband linear modulation stage are considered to have been met if the peak frequency deviation specified in the technical specifications is not exceeded and there is compliance with the non-linear distortion, noise and transmitter noise requirements.

5.13 In transmitters operating in the classes of emissions A3EJN, A3EGN, H3EJN, J3EJN, R3EJN, R3EGN, R7BCF, J7BCF, F3EJN, B8EJN and B9WWX, measurements are performed using filter-shaped noise test signals.

For transmitters operating in the classes of emissions A3EGN or R3EGN, a broadcast signal shaping filter is used (see Annex 3, § 12).

For transmitters operating in the classes of emissions R7BCF, J7BCF or B9WWX, and transmitters of the mobile service operating in the classes of emissions A3EJN, R3EJN, H3EJN, J3EJN or F3EJN, the shaping filter may be any filter having the passband of the telephony channel used in that service.

In all other cases a conventional telephone signal shaping filter (see Annex 3, § 11) is used. For transmitters operating in the B8EJN or B9WWX classes of emissions, a noise test signal is fed via shaping filters into each of the channels.

5.14 In application to transmitters operating in the F8EJF class of emission, the noise signal generated by a crosstalk analyser is used as the test signal.

5.15 In application to transmitters operating in the D7W class of emission, the test signal is provided from a pseudo-random sequence pulse generator.

5.16 In application to transmitters operating in the F3F or F8WWN classes of emissions, the test signal is provided from a television test signal generator.

5.17 In application to transmitters operating in the M7E, PONAN, K1B-- or Q1B-- classes of emissions, measurements are performed in a regime of transmitter modulation using non-coded pulses that are as short as possible under the technical specifications for the transmitter under test. If the transmitter is incapable of operation under a regime of exclusively short pulses, measurement may be performed in a working or test modulation regime.

5.18 Concerning those classes of emissions for which the given standards do not specify rules for measuring the –30 dB bandwidth and bandwidths of OoB spectra, the general rules provided in the ITU-R Recommendations are used.

Determining test signal levels

5.19 For application to transmitters operating in the classes of emissions A1AAN, A1BBN, A2AAN, H2BBN, J2BBN, F1BCN, G1BCN, FID, FIE, F2B, F7E, AIBBN, F7B, F8B, GIB, GIE, GIF, GIW, G2B, G2D, G7D, G7E, G7F and G7W, the level of the test signal is that of the unmediated (unshifted) carrier, or of the subcarrier, for the R3C-- class of emission.

5.20 In application to transmitters operating in classes of emissions A3EJN, A3EGN, R3EJN, R3EGN, B8EJN, H3EJN, J3EJN, R7BCF, J7BCF, B9WWX and F3EJN, the level of the noise test signal is determined by the following method.

Using a low-frequency generator, the transmitter input is modulated with a sinusoidal signal having a frequency of 600 Hz if a telephone signal shaping filter is being used, 1 000 Hz if a filter with a telephone-type channel passband is used, or 300 Hz if a broadcast signal shaping filter is used.

The level of the sinusoidal input signal is adjusted to provide 100% modulation for transmitters operating in the A3EJN and A3EGN class of emission, nominal peak power for transmitters operating in classes R3EGN, R3EJN, B8EJN, H3EJN, J3EJN, R7BCF, J7BCF and B9WWX, and nominal frequency deviation for those operating in the F3EJN class.

The r.m.s. value of that signal voltage, U_{sin}, is noted. In the case of transmitters operating in the classes of emissions A3EJN, A3EGN, R3EGN, R3EJN, H3EJN, J3EJN, R7BCF, J7BCF, B8EJN or B9WWX, a noise signal is then fed through the same shaping filter, its level being adjusted so as to give an effective noise voltage, measured by the same meter, of $U_N = K_s U_{sin}$.

If it is not possible to achieve a modulation factor of 100% (class A3EJN or A3EGN emissions), the r.m.s. value of the noise voltage may be adjusted using the formula $U_N = 2K_s U'_{sin}$, where U'_{sin} is the effective signal level giving a factor of modulation of 50%. The value of K_s for the various cases described is given in Table 5.

In the case of classes of emissions R3EJN, R3EGN, J3EJN, B8EJN and J7BCF, the necessary level of the noise signal can be adjusted via the transmitter output power, in such a way that when the noise signal is fed in, the mean output power of the transmitter is exactly 0.25 of its rated peak power.

TABLE 5

Value of the coefficient K_s

Class of emission	Description	K_s
A3EGN, A3EJN	Radio broadcasting and telephony Aircraft transmitters in the aeronautical mobile service	0.35 0.47
H3EJN, R3EJN, R3EGN, J3EJN, J7BGF, F3EJN, R7BCF	Radio broadcasting and telephony, including transmitters in the mobile service, multichannel voice-frequency telegraphy	0.47
B8EJN	Second-channel telephony Fourth-channel telephony	0.33 0.23

For transmitters that operate only with specific types of electroacoustic transducers (such as microphones or laryngophones) and use dynamic range limiting on the input signal, the level of the noise signal at the transmitter input is adjusted so that $U_N = K_s U_{sin\ nom}$, where $U_{sin\ nom}$ is the r.m.s. value of the nominal output voltage given in the transducer specifications and K_s is the value of the coefficient in Table 5.

For transmitters with r.m.s.-normalized modulation input voltage, the noise signal r.m.s. must be adjusted so that it equals that value.

5.21 In application to transmitters operating in the F8EJF class of emission, the level of the noise test signal applied to the telephone channel terminal input is adjusted so that $P_{n.test} = P_{ch.in} + P_{load}$, where $P_{ch.in}$ is the nominal power at the input of the terminal equipment of the TF group channel for one voice-frequency channel and P_{load} is the mean power level of the multiplex message, determined in accordance with Table 1A.

5.22 In application to transmitters operating in the F8WWN class of emission, the test signal level (amplitude of the brightness signal applied to the input of the terminal equipment of the television radio relay link) must be one 1 W.

5.23 In application to transmitters operating in the D7D or D7W class of emission, test signal parameters are established as per § 5.18.

Measurements of –30 dB occupied bandwidth and bandwidths of OoB spectra

5.24 Measurements of the –30 dB occupied bandwidth and bandwidths of OoB spectra of transmitters are performed using the set-up depicted in Fig. 1.

If necessary, the spectrum analyser can also be used for indirect (field) measurement of the transmitter. In this case, antennas must be used that meet the broadband requirements for these measurements.

If necessary, the measuring apparatus is positioned inside a shielded chamber.

It is permissible to measure the –30 dB occupied bandwidth and OoB spectra levels by means of the pfd parameters of the electromagnetic field, as long as this does not increase the uncertainty associated with the measurement method.

5.25 The measuring apparatus in the set-up depicted in Fig. 1 must meet the requirements laid out in Annex 3.

5.26 Spectrum analyser settings are adjusted using the following criteria.

The resolution bandwidth of the spectrum analyser at –3 dB (Δf) is set at one third of the modulation rate for periodic test signals, or approximately 1/10τ, for pulsed emissions in application to pulsed emission classes, the frequency response of the spectrum analyser's IF stage must be approximately bell-shaped.

In using noise test signals, Δf must not exceed 0.05 B_c.

The span of the spectrum analyser (and the receiver passband, if the analyser is connected to the receiver's IF stage) is adjusted to 1.5 to 2 times the bandwidth obtained from the data in Table 1.

The time constant of the video filter and the spectrum analyser sweep time depend on the class of emission of the transmitter:

– for measurement of emissions of the classes A1AAN, A1BBN, A2AAN, H2BBN, J2BBN, F1BCN, G1BCN, F3EGN, F1C--, F3C--, F7BDX, FIE, FID, F7D, F7E, F8B, F9B, GID, GIE, GIF, GIW, G7D, G7E, G7F, G2B and G2D, the time constant must be set to the smallest value possible with the spectrum analyser, and the sweep time, T, must meet the condition:

$$T \geq SPAN/\Delta f_2 \qquad (1)$$

– spectrum analysers with either a linear or a logarithmic detector may be used;

– for measurement of emissions of the classes A3EJN, A3EGN, R3EJN, R3EGN, B8EJN, H3EJN, J3EJN, R7BCF, J7BCF, B9WWX, F3EJN, F8EJF and D7W, spectrum analysers may be used with linear, quadratic or logarithmic detectors, with the time constant, τ', satisfying the condition

$$\tau' \geq 16/\Delta f \qquad (2)$$

The sweep time is selected on the basis of the following conditions: if Q, the slope of the spectrum envelope at the measurement point, is less than 30 dB/octave, then, depending on whether the instrument is fitted with a linear, quadratic or logarithmic detector, respectively, the sweep time is calculated using one of the formulae in (3):

$$\left.\begin{array}{c} T_{lin} \geq 8.3\tau'\, SPAN[3.4(1+3/Q)]^{-2}/B_c \\ T_{quad} \geq 11.8\tau'\, SPAN[3.4(1+3/Q)]^{-2}/B_c \\ T_{log} \geq 11.8\tau'\, SPAN[0.1(Q)]^{-2}/B_c \end{array}\right\} \qquad (3)$$

If the slope at the measurement point, Q, is greater than 30 dB/octave, then the sweep time is calculated using one of the formulae in (4):

$$\left.\begin{array}{l} T_{lin} \geq 2.3\, SPAN\, \tau' \left|X_{spec}\right| / B_c \\ T_{quad} \geq 4.6\, SPAN\, \tau' \left|X_{spec}\right| / B_c \\ T_{log} \geq 4.6\, SPAN\, \tau' \log\left[\upsilon / \left(\upsilon - \left|X_{spec}\right| + 1\right)\right] / B_c \end{array}\right\} \qquad (4)$$

If the sweep time obtained using formulae (3) and (4) is greater than the maximum sweep time of the spectrum analyser, then measurement must be performed in manual sweep mode.

To determine the value of Q in preparation for precise measurement of the –30 dB occupied bandwidth, the following procedure is used.

The span of the spectrum analyser is set some three to four times wider than B_c, and Q is then either read directly off the analyser display (if it is fitted with a logarithmic detector) as shown in Fig. 3, or calculated from the difference in the 0 dB attenuator readings at B_c and at $2B_c$.

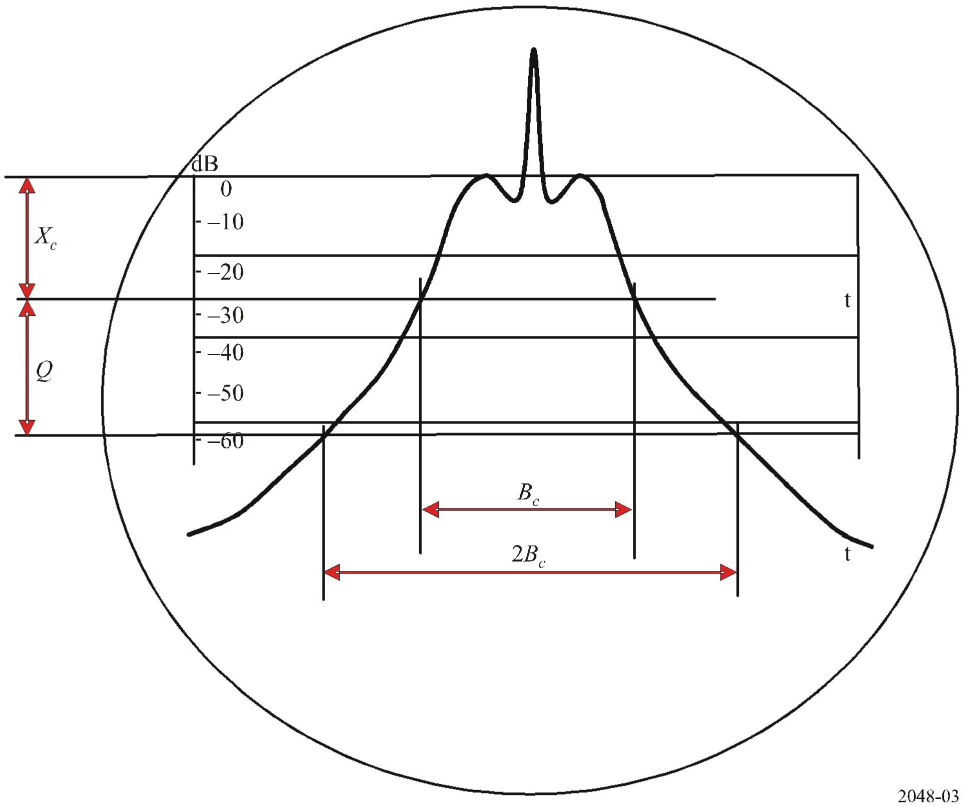
For measurement of emissions of the classes PONAN, K1B-- and Q1B--, the time constant of the video filter must be set to the smallest value possible with the spectrum analyser.

The sweep time is selected using the condition $T \geq 50/F_{rep}$, where F_{rep} is the pulse repetition frequency.

NOTE 1 – Q may also be estimated from Q', the difference in the levels between B_c and $1.5B_c$. In that case Q is obtained using the formula $Q = 1.7\ Q'$.

FIGURE 3

Estimating the slope of the envelope



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5.27 The zero decibel level, which is the reference against which x dB measurements are taken with the spectrum analyser, is determined in the following manner:

– for measurement of emissions of the classes A1AAN, A1BBN, A2AAN, H2BBN, H2BFN, J2A, J2BBN, J2BCN, F1B, F1BCN, G1BCN, F3EGN, F1C--, F3C--, F7BDX, FID, FIE, F2B, F7E, F7B, F7D, F8B, F8D, GIB, GIE, GIF, GIW, G2B, G2D, G7D, G7E, G7F and G7W: level of unmodulated (unkeyed) carrier;

– for measurement of emissions of the classes A3C-- and R3C--: level of unmodulated subcarrier;

– for measurement of emissions of the classes PONAN, K1B-- and Q1B--: level of strongest spectral component of the transmitter's output stage under modulation with the test signal;

– for measurement of emissions of the classes A3EJN, A3EGN, R3EJN, R3EGN, B8EJN, B8EGN, D7W, H3EJN, J3EJN, R7BCF, J7BCF, B9WWX, F3EJN, F3EHN, F3F, F8EJF, F8WWN, F9D and F9E: maximum level of the spectral envelope (in determining zero level) within the sideband domain, i.e. the portion of the spectrum analyser's response corresponding to the carrier frequency is not taken into account;

NOTE 1 – When measuring A3EGN class of emission, if the maximum spectral power density in the sideband domain is masked by the carrier response, the spectrum envelope at the analyser display is adjusted so that the emission bandwidth at –10 dB level has a width of 4 kHz.

The amplitude of the corresponding spectral component is lined up with the 0 dB mark on the display. If this is not possible, it may be lined up with any fixed horizontal line in the upper third of the spectrum analyser display screen. This becomes the reference from which the other standard levels can be measured: –30, –40, –50 and –60 dB.

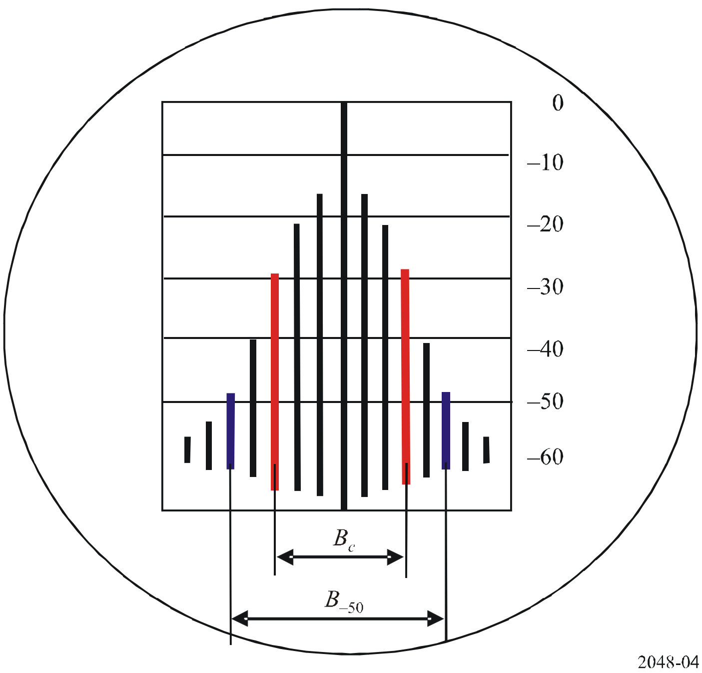
In between setting the zero level and actually measuring the –30 dB occupied bandwidth and bandwidths of OoB spectra, the settings of the spectrum analyser, i.e. the resolution bandwidth, the sweep time and the video filter time constant must not be changed.

5.28 Once the zero level has been established, the next step is to measure the –30 dB occupied bandwidth and bandwidths of OoB spectra.

If the spectrum analyser has a logarithmic detector, the –30 dB occupied bandwidth and bandwidths of OoB spectra can be read directly off the spectrum analyser's scale, by taking the difference in frequencies between the highest and lowest spectral components that just exceed the given level (see Fig. 4). This requires that the uncertainty of the spectrum analyser on the logarithmic scale be no more than 2 dB. If such is not the case, then the reading is obtained using the linear detector.

FIGURE 4

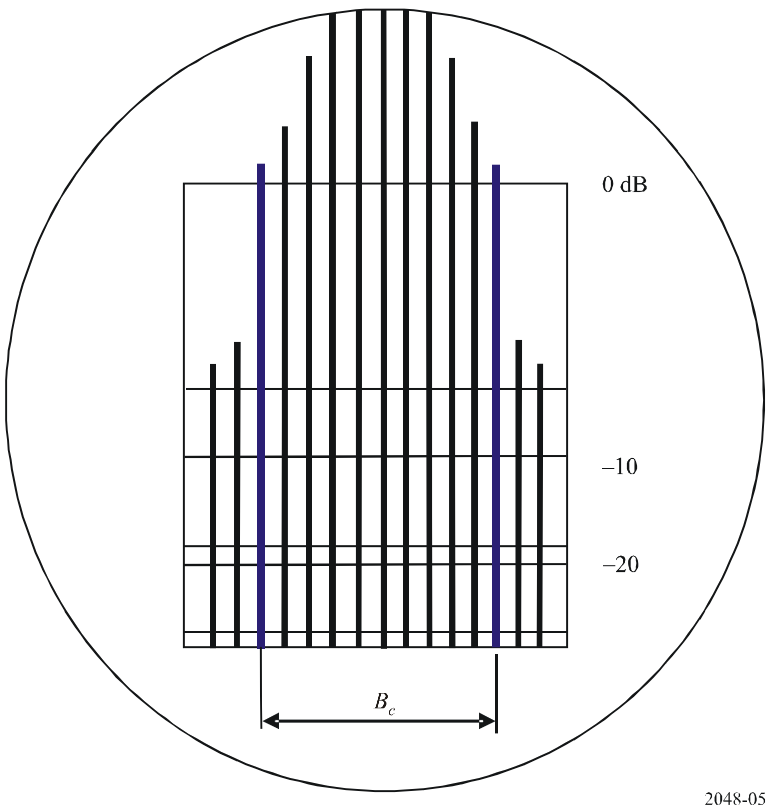
Obtaining a reading for the –30 dB occupied bandwidth and bandwidths of OoB spectra using a spectrum analyser with a logarithmic detector



To calibrate a spectrum analyser with a linear detector (i.e. to establish the zero decibel level as per § 5.27), the attenuation setting of the analyser's attenuators (at the input and/or in its IF stage, depending on the type of analyser used) or the external attenuator shown in Fig. 1 must be adjusted to a level that is higher than the measured *x* dB level (–30 dB to measure the –30 dB occupied bandwidth and –40, –50 and –60 dB respectively for measuring bandwidths of OoB spectra). After applying the modulating signal to the transmitter, and without changing the spectrum analyser's resolution bandwidth or span, attenuation is decreased by *x* dB. The required bandwidth can now be read off at the zero decibel line, between the spectral components at the extreme upper and lower end of the emission spectrum (see Fig. 5).

FIGURE 5

Obtaining a reading for the *x* dB bandwidth (B_c, B_x) using a spectrum analyser with a linear or quadratic detector



If measurement is being performed with a linear detector and the spectrum analyser in manual mode, the IF filter is tuned between the lower and upper limit of the span, and the frequency meter connected to the output of the analyser's IF stage is used to read off the two frequencies at which the spectrum analyser response crosses the 0 dB level (as shown in Fig. 5). The difference between those frequencies gives the –30 dB occupied bandwidth.

If the measured emission bandwidth is off the spectrum analyser's scale, so that it is necessary to increase the span, calibration of the analyser will have to be repeated for the unmodulated carrier (to establish the zero level as described in § 5.27). Once this has been done, the above procedure can be repeated.

6 Method of measuring of OoB emissions of transmitters in the marine mobile service in the classes of emissions R3EJN, H3EJN, H2BBN, J3EJN

6.1 The levels of discrete spectral components of the output signal in the out-of-band domain, for a transmitter being modulated with a dual-tone test signal that produces modulation up to the rated peak envelope power, must not exceed the limits given in Table 3.

6.2 Measurement of OoB spectra of transmitters working in a J3EJN regime are performed using the set-up shown in Fig. 1.

6.3 One of the generators is used to apply to the transmitter input a signal having a frequency of 470 Hz and an amplitude such that the transmitter output power is equal to:

$$P'_{mean} = P'_{peak} = 0.25\ P_{p.r..}$$

where:

$P_{p.r..}$: rated peak envelope power.

Without disconnecting the signal from the first LF generator, another LF generator is used to apply a second signal to the transmitter at a frequency of 2 550 Hz, adjusting the signal level to give transmitter output power equal to:

$$P''_{mean} = 0.5\ P_{p.r..} \qquad (6)$$

$$P''_{peak} = P_{p.r..}$$

6.4 The span of the spectrum analyser is adjusted to at least 20 kHz and the IF bandwidth to 50-150 Hz. The speed (sweep time) is determined as described in § 5.26.

6.5 The spectral components of the modulating signal are adjusted along the horizontal axis so that they are centred in the scale of the spectrum analyser.

If the spectral components corresponding to the modulated signal are equal in magnitude, the transmission coefficient of the spectrum analyser is adjusted to align them with the 0 dB mark, or with some other mark in the upper third of the spectrum analyser's scale. If the levels of the components are not the same, the modulating signal levels are adjusted slightly to make them equal, without going beyond equation (6). Then they are aligned with the 0 dB or other mark on the spectrum analyser's scale.

6.6 The levels of combined third-ninth degree components and any other components falling in the bandwidth shown in Table 3 can be read off directly if a spectrum analyser with a logarithmic scale is being used. If the spectrum analyser has a linear scale, this must be done with the aid of the attenuators of the spectrum analyser, in accordance with the analyser instructions. The level measurements should be attenuated with respect to the spectral components of the modulated signal by at least the amounts indicated in Table 3. The attenuation figures thus obtained for the spectral components in the band $f_{tx} \pm 7.5$ kHz are used to calculate the power levels. The power of any one component must not exceed 50 mW, in accordance with Table 3.

6.7 Measurement of OoB spectra of transmitters working in a H3EJN regime are performed using the set-up depicted in Fig. 1.

The transmitter's carrier level is adjusted so that the power at the output is as specified in equation (5). An LF generator is then used to apply a signal to the transmitter at a frequency of 2 000 Hz and a signal level such that the transmitter power at the output is as specified in equation (6).

The level readings are then taken in accordance with the instructions in § 6.4 to 6.6.

6.8 Measurement of OoB spectra of transmitters working in a H2BBN regime are performed with the transmitter in "depressed key" mode following the procedure described in § 6.7.

6.9 Measurement of OoB spectra of transmitters working in a R3EJN regime are performed with the transmitter set up for regime J3EJN or H3EJN. Measurement is performed by the procedure in § 6.2-6.4 or 6.7 respectively.

7 Method of measuring bandwidths of OoB spectra of aircraft transmitters in the aeronautical mobile service

7.1 The levels of the components of the spectral power density of OoB spectra supplied to the antenna or dummy antenna, with the transmitter modulated by a noise test signal to give rated peak power, should not exceed the limits indicated in Table 2.

7.2 Measurement of bandwidths of OoB spectra of transmitters are performed only in the class of emission J3EJN, using the set-up depicted in Fig. 1.

7.3 LF signal generators 3a and 3b are used to apply to the input of the transmitter two sinusoidal signals of 1 100 and 1 500 Hz respectively; both signals have the same level, U_s, which is adjusted to give nominal peak power to the dummy antenna 9.

Using the spectrum analyser 12, the LF levels of the two modulation components are fine-adjusted so as to make the components equal, and the input or IF stage attenuators of the spectrum analyser or the external attenuator 11 are adjusted to bring that level to –6 dB. In this configuration the 0 dB level corresponds to peak emission power for a transmitter of the class of emission J3EJN.

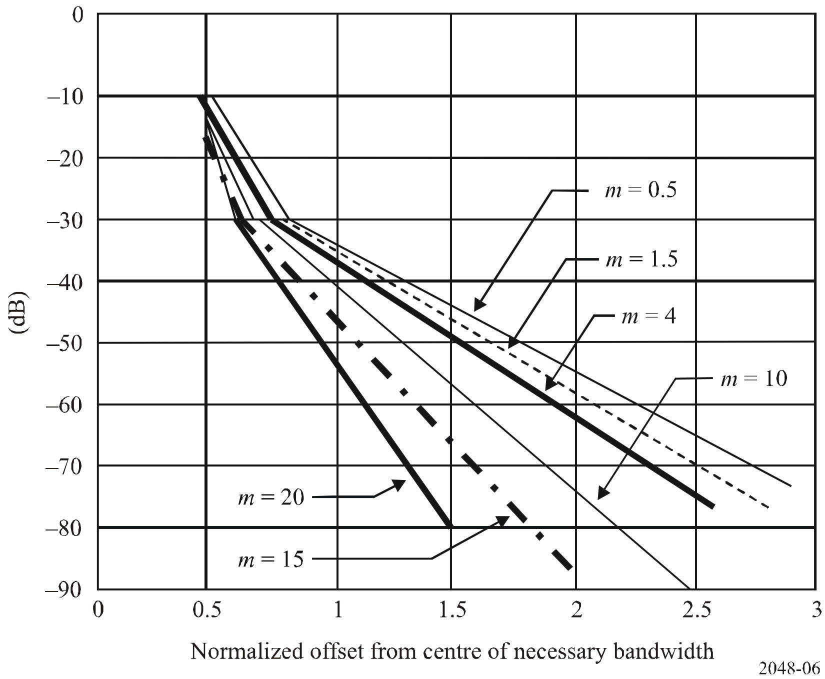
7.4 Next, LF generators 3a and 3b are disconnected, and noise generator 2 is connected to the transmitter via telephone signal shaping filter 5. The signal from noise generator 2 is adjusted to give 0.47 U_s on the r.m.s. voltmeter 6. The –30 dB occupied bandwidth and bandwidths of OoB spectra at levels –38 and –43 dB are measured, with respect to the zero level established in 7.3. The bandwidths should not exceed the limits given in Table 2.

Annex 1

Converting transmitter OoB spectra data expressed in terms of offset from the centre of the necessary bandwidth

FIGURE 6

Graph illustrating the relation between the OoB envelope and the modulation index for the classes of emissions F1B, F1D, F1W, F7B, F7D and F7W



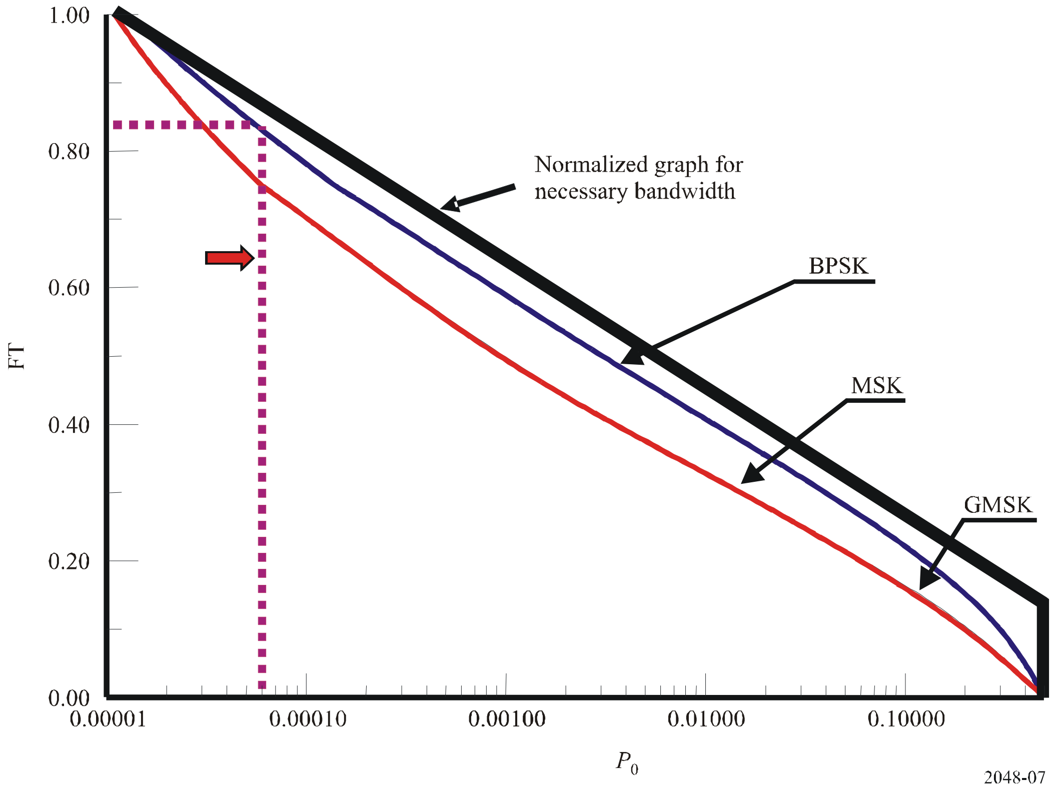
Example: For the class of emissions F7D, assuming m = 0.5 and D = 5 kHz, the graph gives B_c ($B_{–30}$) ≈ 47 kHz, corresponding to an offset of 0.7 with the mask method of calculation.

Annex 2

Adjusting necessary bandwidth for reduced communication channel error coefficient

FIGURE 7

Relation, under the Nyquist criterion, between the necessary bandwidth, FT, and the reliability adequacy of the received digital information, P_0, independently of information coding and code redundancy



Example: For a BPSK system, error correction reduces the requirements for information reliability for the channel to 5×10^{-4}. In that case, the necessary bandwidth requirements calculated as per Table 1 may be reduced to 82%.

1 In the case of severely congested frequency bands, and for radio systems that are particularly susceptible to interference or have very demanding requirements in terms of reliability of information, necessary bandwidth must be calculated taking into account the quality of message transfer.

2 For digital communication systems, transfer quality is characterized by the probability P_{err} that corresponds to the bit-error ratio. If the desired error probability is known, it is possible to determine the necessary bandwidth for the wanted signal that will provide the needed reliability of information transfer, i.e. the bandwidth necessary to achieve that probability throughout the entire radiocommunication system. The figures thus obtained may differ significantly from the value of necessary bandwidth calculated on the basis of the modulation parameters and, accordingly, the –30 dB occupied bandwidth at the –30 dB level.

Annex 3

General requirements for measuring equipment

Spectrum analysers

1 The frequency range of the spectrum analyser used must cover the operating spectrum of the transmitter being tested.

Different types of spectrum analyser may be used to take measurements of different portions of the operating spectrum.

2 The spectrum analyser must be capable of spanning the full signal spectrum envelope in the frequency band corresponding to the lowest measurement level.

NOTE 1 – If no spectrum analyser is available with the necessary span, the spectrum envelope may be determined in segments.

3 At the –3 dB level the spectrum analyser must have a passband of:

– one third of the keying frequency, if periodic test signals are being used;

– $0.1/\tau$ for pulse emissions;

– $0.05B_c$ if noise test signals are being used.

In this case the spectrum analyser must have a post-detector averaging stage having as time constant $\tau' \geq 16/\Delta f$.

4 The dynamic range of the spectrum analyser must provide for measurement accuracy of ±2 dB at the lowest measured level, i.e. –60 dB.

5 The frequency response of the spectrum analyser in the given frequency band must be flat to within 3 dB.

6 Maximum total uncertainty for level measurement is 10%.

Noise generators

7 The noise power spectral density in the measured frequency band must be flat to within 2 dB.

8 The noise power level at the generator output must be adequate for normal modulation. If the generator output is too weak, it may be used in conjunction with an amplifier. In that case the frequency response function of the amplifier must be flat to within 1 dB (in the band between $0.9F_{lc}$ and $1.2F_{uc}$, where F_{lc} and F_{uc} are the lower and upper frequency of modulating signal, respectively).

The coefficient of non-linear distortion of the amplifier must not exceed 3% (with sinusoidal signals of 300, 600 and 1 000 Hz being successively applied to the amplifier input).

9 Maximum uncertainty for the output setting is 6%.

Telegraph signal sources

10 The maximum content of telegraph dots is 3%. The maximum relative pulse rise time is 2%. Standard keying speed must be supported (from 47 to 2 400 baud) at a maximum relative error rate of 10^{-5}. The signal source must have two channels providing the level of output signal voltage needed for normal transmitter operation.

Shaping filters

11 An electrical diagram and a graph depicting the frequency response of a shaping filter used to generate telephone signals from white noise may be found in § 5.2 of Recommendation ITU-R SM.328.

12 An electrical diagram and a graph depicting the frequency response of a shaping filter used to generate broadcast signals from white noise may be found in § 6.2 of Recommendation ITU-R SM.328.

13 The frequency response functions of actual filters may, for portions of the range, deviate by up to 2 dB from the curves shown in § 5.2 and 6.2 of Recommendation ITU-R SM.328.

14 Shaping filters used must be officially calibrated.

Attenuators

15 Attenuators are required to provide *a* dB of attenuation throughout the monitored spectrum. The value of *a* must be $P_0 - P_{LL} - |X| \geq a \geq P_0 - P_{UL}$, and the permitted dissipation power P_{aTT} must be $P_{aTT} \geq P_0$, where P_0 is the mean power (dB/μW) at the attenuator input, and P_{UL} and P_{LL} are, respectively, the upper and the lower limit (dB/μW) for mean power measurements with the instrument.

16 The standing wave ratio (SWR) for the attenuator input (output) must not exceed 1.4.

17 Maximum uncertainty for the attenuator setting is 1 dB.

18 The SWR for voltage for any individual ancillary element within the HF stage must not exceed 1.5.

Other instrumentation

19 Power measuring instruments must have a measurement accuracy of ±5% or better for the given frequency band and type of power.

20 Digital frequency meters must provide frequency readings with a maximum uncertainty of 10^{-9} (at least an order of magnitude better than the frequency tolerance for the radio system being tested).

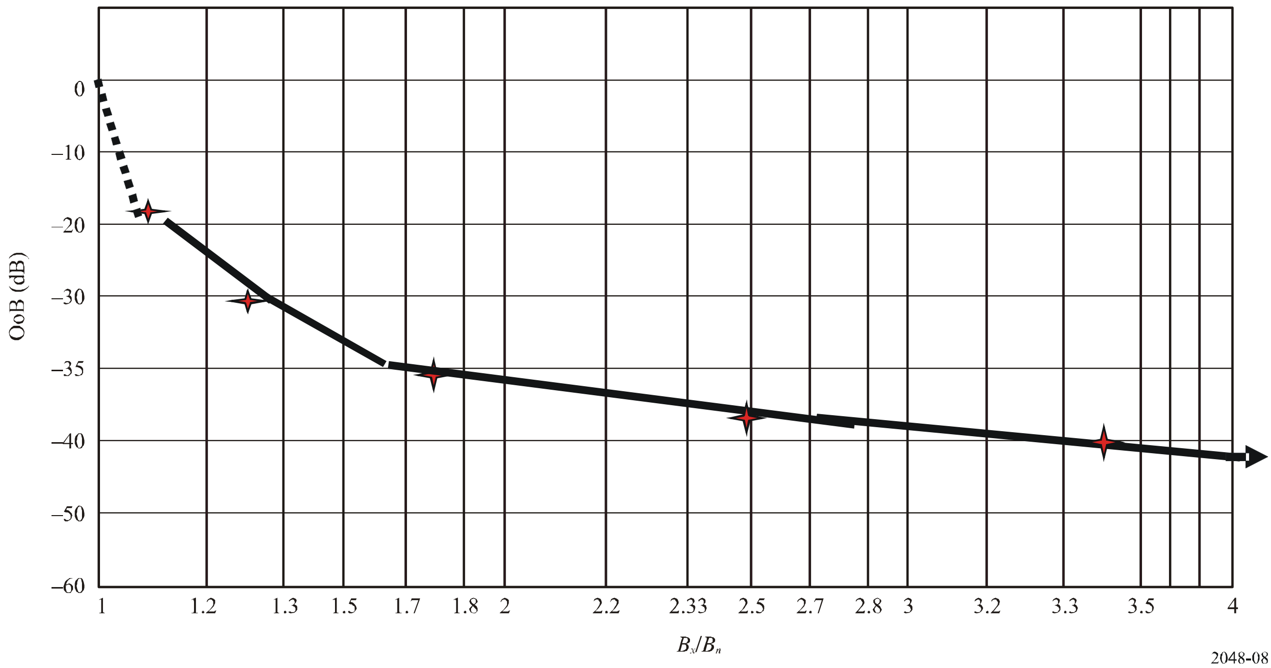
Annex 4

Example OoB emission limits drawing for checking of emissions

In Fig. 8, stars indicate data points obtained by measurement: $B_{–26}$ = 1.15B_n; $B_{–38}$ = 1.4B_n; $B_{–43}$ = 1.94B_n; $B_{–50}$ = 2.75B_n; $B_{–55}$ = 3.6B_n. The heavy line indicates the limits established above (Table 1, Telephony, single sideband, suppressed carrier, transmitters of the fixed service.)

FIGURE 8

Comparing OoB measurements with specified limits for class J3EJN (transmitter of the fixed service)



Remarks: Comparison of the measurements obtained with the applicable limits shows that the transmitter's –30 dB bandwidth and bandwidths of its OoB spectra meet the requirements.

Annex 5

Symbols and abbreviations

1 Parameters and variables

B	Modulation rate (Bd)
B_{ch}	Overall channel speed (Bd)
B_n	Necessary bandwidth (Hz[2])
B_c	–30 dB occupied bandwidth (Hz)
B_s	Maximum carrier frequency shift (Hz)
BT	normalized filter bandwidth, given as the product of the –3 dB bandwidth and the time to transmit one coded element (sub-impulse)
D	peak frequency deviation (half the difference between the maximum and minimum values of instantaneous frequency) (Hz)
$D_{\text{MAX.TV}}$	Peak frequency deviation created by video signal (Hz)
F_0	Nominal carrier frequency (Hz)
F_U	Maximum modulation frequency, maximum voice frequency (Hz)
F_{uc}	Channel upper frequency
F_{lc}	Channel lower frequency
F_{um}	Upper middle frequency
F_L	Minimum voice frequency, minimum modulation frequency (Hz)
F_{max}	Maximum frequency of sinusoid signal modulating the pulse peak in the K1D class of emission (Hz)
F_{sc}	Subcarrier frequency (Hz)
F_{PS}	Pilot signal frequency (Hz)
f_{tx}	Assigned transmitter frequency
f_r	Continuity pilot signal frequency
φ	Gaussian filter function
K	Working coefficient used for calculation purposes in Table 1
K_G, K_α, K_β	In digital communication systems, these are coefficients determined by the filters and filtering methods used. In general, α is for a cosine root filter and β is a raised cosine filter
K_d	Coefficient equal to the relative instability of the carrier frequency
K_{fade}	Coefficient that characterizes the effect of fading on the transmission line
K_f	Phase change parameters
K_S	Coefficient for r.m.s. voltage measurements
K_R	Coefficient for coding redundancy with error correction, equal to the ratio of the number of code elements at the coder output to those at the input ($K_R > 1$). If redundancy ψ is specified in %, then the coefficient is given by $K_R = 1 + \psi/100$

(2) Where units of hertz are indicated, kHz, MHz and GHz may also be used.

$\Delta\varphi$	Phase shift (degrees)
m	Frequency modulation index
m_p	Frequency modulation index taking into account the characteristics of a given system, including the peak factor
N_c	Number of channels
N_f	Number of subcarrier frequencies
N_p	Number of independent frequency bands
Δf	Width of static passband of the spectrum analyser's IF stage at the –3 dB level (Hz)
ΔF	Subcarrier separation (Hz)
ΔF_G	Passband of Gaussian filter
ΔF_{ch}	Effective value of frequency deviation created by the measured level of one channel (MHz)
T	Sweep time (duration of forward sweep) (s)
τ_d	Sample length
τ_r	Length of pulse leading edge (μs)
τ_f	Length of pulse trailing edge (μs)
τ	Length of pulse (s or μs)
τ'	Time constant of video filter (s) coefficient characterizing pulse shape asymmetry: $\delta = 2\ \tau_r\ \tau_f/(\tau_f + \tau_r)$
δ_d	Coefficient characterizing asymmetric sample shape: $\delta_d = (2\ \delta_{dr}\ \delta_{df})/(\delta_{df} + \delta_{dr})$
Θ (α)	Relative settling time for signal (pulse), pulse rounding coefficient
P	Emitted power (dBW)
P_{load}	Mean power of multichannel message (dBW)
$P_{ch.mean}$	Mean power of one voice-frequency channel (dBW)
P_0	Information reliability
R	Digital data transmission speed (bit/s, kbit/s, Mbit/s or Gbit/s)
Q	Slope of spectral envelope in the OoB domain (dB/octave)
S	Number of states in phase-shift keying; if the *N*-ary parameter ⊕ is used, the conversion used is $S = \oplus^2$. (NOTE – Multi-position phase-shift keying is frequently specified in the form *M*-ary.)
U_N	Voltage of noise signal
U_{sin}	Signal r.m.s. voltage
Z	Maximum number of black and white code elements per second.

NOTE 1 – Throughout this list, parameters for which the units are indicated as "Hz" may also be given in kHz, MHz and GHz.

2 List of abbreviations designating types of modulation as used in this Report

Abbreviation	Type of signal modulation
π/4 DQPSK	Differential π/4 quaternary phase shift keying
π/4 QPSK	Quaternary π/4 phase shift keying
APSK, 32 APSK	Amplitude phase shift keying
BCFSK	Binary code frequency shift keying
BCM	Block code modulation
BDM	Binary delta modulation
BDPSK	Binary differential phase shift keying
BFSK	Binary frequency shift keying
BFSK	Binary frequency shift keying, duo-binary frequency shift keying
CPFSK (4CPFSK)	Controlled PFSK
CPM	Continuous phase modulation
FDM-FM	FM frequency division multiplex
FFSK	Filtered FSK
GMSK	Gaussian filtered minimum shift keying or Gaussian minimum shift keying
FM	Frequency modulation
FMSK	Filtered minimum shift keying
FSK	Frequency shift keying
GFPM	Gated frequency position modulation
LFM	Linear frequency or space frequency modulation
M-ary QAM	*M*-ary quadrature amplitude modulation
MFSK	Multiple or multilevel FSK
MLCM	Multi-level code modulation
MSK ≡ FFSK	Unfiltered minimum shift keying or fast frequency shift keying
MPSK	Multiple PSK
MSK	Minimum shift keying
NBPM	Narrow-band phase modulation
PCM	Pulse code modulation
PDM	Pulse duration modulation
PFM	Pulse frequency modulation
PM	Phase modulation
PNM	Pulse number modulation

Abbreviation	Type of signal modulation
PPM	Pulse phase modulation
PSK	Phase shift keying
QAM	Quadrature amplitude modulation
QPR, QPR-AZD	Quadrature partial response, QPR with ambiguity zone detection
QPSK	Quadrature phase shift keying
RPSK	Relative phase shift keying
SFM	Swept frequency or space frequency modulation
TCM	Trellis code modulation
TFM	Tamed frequency modulation
WBFM	Wideband frequency modulation