

RECOMMENDATION ITU-R SM.853-1

NECESSARY BANDWIDTH

(Question ITU-R 77/1)

(1992-1997)

The ITU Radiocommunication Assembly,

considering

- a) that the concept of “necessary bandwidth” defined in No. 146 (S1.152) of the Radio Regulations, is useful for specifying the spectral properties of a given emission, or class of emission, in the simplest possible manner;
- b) that with regard to the efficient use of the radio-frequency (RF) spectrum, necessary bandwidths for individual classes of emission must be known, that in some cases the formulae listed in Recommendation ITU-R SM.1138 can only be used as a guide and that the necessary bandwidth for certain classes of emissions is to be evaluated corresponding to a specified transmission standard and required quality;
- c) that changes in technology have resulted in additions and variations in the modulations used for radiocommunication;
- d) that the numerical parameters used in the necessary bandwidth formulae may change with time due to changes in signal characteristics (e.g. average talker level),

recommends

that the necessary bandwidth formulae (contained in Recommendation ITU-R SM.1138) be supplemented with the following formulae.

1 Multi-channel frequency division multiplex – frequency modulation (FDM-FM) emissions

To account for changes in average talker level, which may occur over time, the formula for the necessary bandwidth B_n of multi-channel FDM emission is:

$$B_n = 2M + 2 \left[d \times 3.76 \times \text{antilog} \left(\frac{X + Y \log N_c}{20} \right) \right] K$$

where:

M : maximum modulating frequency (Hz)

d : per-channel deviation

N_c : number of circuits in the multiplexed message load

K : unity

$X = -2$ to $+2.6$ for $12 \leq N_c < 60$ and for $Y = 2$

$X = -5.6$ to -1.0 for $60 \leq N_c < 240$ and for $Y = 4$

$X = -19.6$ to -15.0 for $N_c \geq 240$ and for $Y = 10$.

The term enclosed in brackets is the peak deviation, D . The numerator $(X + Y \log N_c)$ of the fraction represents the average power of the composite signal delivered to the modulator input of the transmitter.

The basis for this formula is contained in § 1, Annex 1. In particular, Annex 1 shows how to determine the appropriate value for the variable X in the formula.

2 Unmodulated pulse emissions

The necessary bandwidth for unmodulated pulses with either a trapezoidal or rectangular pulse shape is given in Table 1.

TABLE 1
Unmodulated pulse emissions

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

Annex 2 contains the method used for determining the necessary bandwidth of the unmodulated pulses.

3 Digital modulation

The necessary bandwidth and example *K* values for several digital modulations are given in Table 2.

Annex 3 contains the methods used for determining the necessary bandwidths for digital modulation.

TABLE 2

Digital modulation

Modulation and conditions	Necessary bandwidth formula	Example K value	Percentage fractional power containment bandwidth ⁽¹⁾
2-PSK (unfiltered) $S = 2$ (computed)	$B_n = \frac{2RK}{\log_2 S}$	10.28 2.0	99 95
2-PSK (filtered, BER = 1×10^{-3}) $S = 2$ (computed)	$B_n = \frac{2RK}{\log_2 S}$	1.0 ⁽²⁾ 0.75 ⁽³⁾	100 100
MSK (unfiltered) $S = 2$ (computed) $D = 0.25 R$	$B_n = \frac{R}{\log_2 S} + 2 DK$	0.36 3.52	99 99.9
Gaussian filtered MSK (GMSK) 3 dB premodulation Gaussian filter bandwidth = $0.25 R$ $S = 2$ (computed) $D = 0.25 R$	$B_n = \frac{R}{\log_2 S} + 2 DK$	-0.28 0.18	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
m -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

BER: binary error ratio.

FSK: frequency shifting key.

MSK: minimum shifting key.

PSK: phase shift keying.

QAM: quadrature amplitude modulation.

- (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.