Classification of emissions and necessary bandwidths

I. Classification

The basic characteristics are:

1) first symbol - type of modulation of the main carrier;

2) second symbol - nature of signal(s) modulating the main carrier;

3) third symbol - type of information to be transmitted.

Modulation used only for short periods and for incidental purposes (such as, in many cases, for identification or calling) may be ignored provided that the necessary bandwidth as indicated is not thereby increased.

1. First Symbol - Type of modulation of the main carrier

1.1	Emission of an unmodulated carrier	N
1.2	Emission in which the main carrier is amplitude-modulated (including caseswhere sub-carriers are angle-modulated)	
1.2.1	Double-sideband	A
1.2.2	Single-sideband, full carrier	H
1.2.3	Single-sideband, reduced or variable level carrier	R
1.2.4	Single-sideband, suppressed carrier	J
1.2.5	Independent sidebands	B
1.2.6	Vestigial sideband	C
1.3	Emission in which the main carrier is angle-modulated	
1.3.1	Frequency modulation	F
1.3.2	Phase modulation	G
1.4	Emission in which the main carrier is amplitude-and angle-modulated either simultaneously or in a pre-established sequence	D
1.5	Emission of pulses(Emissions where the main carrier is directly modulated by a signal which has been coded into quantized form (e.g. pulse code modulation) should be designated under 1.2 or 1.3)	
1.5.1	Sequence of unmodulated pulses	P
1.5.2	A sequence of pulses	
1.5.2.1	modulated in amplitude	K
1.5.2.2	modulated in width/duration	L
1.5.2.3	modulated in position/phase	M
1.5.2.4	in which the carrier is angle-modulated during the angle-period of the pulse	Q
1.5.2.5	which is a combination of the foregoing or is produced by other means	V
1.6	Cases not covered above, in which an emission consists of the main carrier modulated, either	

simultaneously or in a pre-established sequence, in a combination of two or more of the following modes: amplitude, angle, pulse   W

    1.7   Cases not otherwise covered   X

2. Second Symbol - Nature of signal(s) modulating the main carrier

    2.1   No modulating signal   0

    2.2   A single channel containing quantized or digital information without the use of a modulating sub-carrier(except time-division multiplex)   1

    2.3   A single channel containing quantized or digital information with the use of a modulating sub-carrier (except time-division multiplex)   2

    2.4   A single channel containing analogue information   3

    2.5   Two or more channels containing quantized or digital information   7

    2.6   Two or more channels containing analogue information   8

    2.7   Composite system with one or more channels containing quantized or digital information, together with one or more channels containing analogue information   9

    2.8   Cases not otherwise covered   X

3. Third Symbol - Type of information to be transmitted

    3.1   No information transmitted   N

    3.2   Telegraphy – for aural reception   A

    3.3   Telegraphy – for automatic reception   B

    3.4   Facsimile   C

    3.5   Data transmission, telemetry, telecommand   D

    3.6   Telephony (including sound broadcasting)   E

    3.7   Television (video)   F

    3.8   Combination of the above   W

    3.9   Cases not otherwise covered   X

4. In this context the word "information" does not include information of a constant, unvarying nature such as is provided by standard frequency emissions, continuous wave and pulse radars, etc.

II. In the formulation of the table, the following terms have been employed:

B_n : necessary bandwidth (Hz)

B : modulation rate (Bd)

N : maximum possible number of black plus white elements to be transmitted per second，in facsimile

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

N_c: number of baseband channels in radio systems employing multi-channel multiplexing

f_p : continuity pilot sub-carrier frequency (Hz) (continuous signal utilized to verify performance of frequency-division multiplex systems)

Description of emission	Necessary bandwidth		Designation of emission
	Formula	Sample calculation	
I. NO MODULATING SIGNAL			
Continuous wave emission	-	-	NONE
II. AMPLITUDE MODULATION			
1.Signal with quantized or digital information			
Continuous wave telegraphy, Morse Code	$B_n = BK$ $K = 5$ for fading circuits $K = 3$ for non-fading circuits	25 words per minute $B = 20$, $K = 5$ Bandwidth: 100Hz	100HA1AAN
Telegraph by on-off keying of a tone modulated carrier, Morse Code	$B_n = BK + 2M$ $K = 5$ for fading circuits $K = 3$ for non-fading circuits	25 words per minute; $B = 20$, $M = 1000$, $K = 5$ Bandwidth: 2100Hz =2.1kHz	2K10A2AAN
Selective calling signal using sequential single frequency code ,single-sideband full carrier	$B_n = M$	Maximum code frequency is 2110Hz ,M=2110 Bandwidth: 2110Hz=2.11kHz	2K11H2BFN
Direct-printing telegraphy using a frequency shifted modulating sub-carrier, with error-correction, single-sideband, suppressed carrier (single channel)	$B_n = 2M + 2DK$ $M = B/2$	$B = 50$ $D = 35$Hz (70Hz shift) $K = 1.2$ Bandwidth : 134Hz	134HJ2BCN
Telegraphy, multi-channel with voice frequency, error	$B_n =$ highest central frequency $+ M + DK$	15 channels; highest central frequency is	

| Description of emission | Necessary bandwidth | | Designation of emission |
	Formula	Sample calculation	
correction. Some channels are time-division multiplexed, single side-band, reduced carrier	$M = B/2$	2850Hz, $B = 100$ $D = 42.5$Hz (85Hz shift) $K = 0.7$ Bandwidth:2885Hz=2.885kHz	2K89R7BCW
2.Telephone (commercial quality)			
Telephony, double- sideband (single channel)	$B_n = 2M$	$M = 3000$ Bandwidth: 6000Hz = 6kHz	6K00A3EJN
Telephony, single- sideband full carrier (single channel)	$B_n = M$	$M = 3000$ Bandwidth: 3000Hz = 3kHz	3K00H3EJN
Telephony, single- sideband, suppressed carrier (single channel)	$B_n = M$-lowest modulation frequency	$M = 3000$ lowest modulation frequency = 300Hz Bandwidth: 2700Hz = 2.7kHz	2K70J3EJN
Telephony with separate frequency modulated signal to control the level of demodulated speech signal, single-sideband, reduced carrier (Lincompex) (single channel)	$B_n = M$	Maximum control frequency = 2990Hz. $M = 2990$ Bandwidth: 2990Hz = 2.99kHz	2K99R3ELN
Telephony with privacy, single sideband, suppressed carrier (two or more channels)	$B_n = N_c M$ -lowest modulation frequency in the lowest channel	$N_c = 2$ $M = 3000$ lowest modulation frequency = 250Hz Bandwidth: 5750Hz = 5.75kHz	5K75J8EKF
Telephony, independent sideband (two or more channels)	$B_n =$ sum of M for each sideband	2 channels $M = 3000$ Bandwidth: 6000Hz = 6kHz	6K00B8EJN
3.Sound broadcasting			
Sound broadcasting, double-sideband	$B_n = 2M$ M may vary between 4000 and 10000 depending on the quality desired	Speech and music $M = 4000$ Bandwidth: 8000Hz = 8kHz	8K00A3EGN
Sound broadcasting,	$B_n = M$	Speech and music	4K00R3EGN

Description of emission	Necessary bandwidth		Designation of emission
	Formula	Sample calculation	
single-sideband, reduced carrier (single channel)	M may vary between 4000 and 10000 depending on the quality desired	$M = 4000$ Bandwidth: 4000Hz = 4kHz	
Sound broadcasting, single-sideband, suppressed carrier	$B_n = M$ -lowest modulation frequency	Speech and music $M = 4500$ lowest modulation frequency = 50Hz. Bandwidth: 4450Hz = 4.45kHz	4K45J3EGN
4. Television			
Television, vision and sound	Refer to the relevant CCIR documents for the bandwidths of the commonly used television systems	Number of lines = 625 Nominal video bandwidth: 5MHz Sound carrier relative to video carrier= 5.5MHz Total vision bandwidth: 6.25MHz FM sound bandwidth including guard bands:750kHz RF channel bandwidth: 7MHz	6M25C3F-- 750KF3EGN
5. Facsimile			
Analogue facsimile by sub-carrier frequency modulation of a single-sideband emission with reduced carrier monochrome	$B_n = C + N/2 + DK$ $K = 1.1$ (typically)	$N = 1100$ corresponding to an index of cooperation of 352 and a cycler rotation speed of 60rpm. Index of cooperation is the product of the drum diameter and number of lines per unit length. $C = 1900, D = 400Hz$ Bandwidth: 2890Hz = 2.89kHz	2K89R3CMN
Analogue facsimile; frequency modulation of an audio frequency sub- carrier which modulates the main carrier, single- sideband suppressed carrier	$B_n = 2M + 2DK$ $M = N/2$ $K = 1.1$ (typically)	$N = 1100$ $D = 400Hz$ Bandwidth:1980Hz = 1.98kHz	1K98J3C--

| Description of emission | Necessary bandwidth | | Designation of emission |
	Formula	Sample calculation	
6. Composite emissions			
Double-sideband, television relay	$B_n = 2C + 2M + 2D$	Video limited to 5MHz, audio on 6.5MHz, frequency modulated sub-carrier, sub-carrier deviation = 50kHz: $C = 6.5 \times 10^6$ $D = 50 \times 10^3 \text{Hz}$ $M = 15000$ Bandwidth: $13.13 \times 10^6 \text{Hz} =$ 13.13MHz	13M1A8W--
Double-sideband radio relay system, frequency division multiplex	$B_n = 2M$	10 voice channels occupying baseband between 1kHz and 164kHz $M = 164000$ Bandwidth: 328000Hz = 328kHz	328KA8E--
Double-sideband emission of VOR with voice (VOR =VHF omnidirectional radio range)	$B_n = 2C_{max} + 2M + 2DK$ $K = 1$ (typically)	The main carrier is modulated by : - a 30Hz sub-carrier - a carrier resulting from a 9960Hz tone frequency modulated by a 30 Hz tone - a telephone channel - a 1020Hz keyed tone for continual Morse identification $C_{max} = 9960$ $M = 30$ $D = 480 \text{Hz}$ Bandwidth: 20940Hz = 20.94kHz	20K9A9WWF
Independent sidebands; several telegraph channels with error-correction together with several telephone channels with privacy; frequency division	B_n = sum of M for each sideband	Normally composite systems are operated in accordance with standardized channel arrangements (e.g. Rec. ITU-R F.348). 3 telephone channels and 15	12K0B9WWF

Description of emission	Necessary bandwidth		Designation of emission
	Formula	Sample calculation	
multiplex		telegraphy channels require the bandwidth: 12000Hz = 12kHz	
III. FREQUENCY MODULATION			
1. Signal with Quantized or Digital Information			
Telegraphy without error correction device. (single channel)	$B_n = 2M + 2DK$ $M = B/2$ $K = 1.2$ (typically)	$B = 100$ $D = 85$Hz (170Hz shift) Bandwidth: 304Hz	304HF1BBN
Telegraphy, narrowband direct-printing with error correction (single channel)	$B_n = 2M + 2DK$ $M = B/2$ $K = 1.2$ (typically)	$B = 100$ $D = 85$Hz (170Hz shift) Bandwidth: 304Hz	304HF1BCN
Selective calling signal	$B_n = 2M + 2DK$ $M = B/2$ $K = 1.2$ (typically)	$B = 100$ $D = 85$Hz (170Hz shift) Bandwidth: 304Hz	304HF1BCN
Four frequency duplex telegraphy	$B_n = 2M + 2DK$ B: modulation rate (Bd) of the faster channel. If the channels are synchronized: $M = B/2$(otherwise M = 2B) $K = 1.1$ (typically)	Spacing between adjacent frequencies = 400Hz, Synchronized channels $B = 100$ $M = 50$ $D = 600$Hz Bandwidth: 1420Hz = 1.42kHz	1K42F7BDX
2. Telephony (commercial quality)			
Commercial telephony	$B_n = 2M + 2DK$ $K = 1$ (typically, but under certain conditions a higher value may be necessary)	For an average case of commercial telephony, $D = 5000$Hz $M = 3000$ Bandwidth: 16000Hz = 16kHz	16K0F3EJN
Sound Broadcasting	$B_n = 2M + 2DK$ $K = 1$ (typically)	Monaural $D = 75000$Hz $M = 15000$ Bandwidth:180000Hz=180kHz	180KF3EGN
3. Sound broadcasting			
Sound Broadcasting	$B_n = 2M + 2DK$ $K = 1$	Monaural $D = 75000$Hz	180KF3EGN

Description of emission	Necessary bandwidth		Designation of emission
	Formula	Sample calculation	
	(typically)	$M = 15000$ Bandwidth: 180000Hz = 180kHz	
4. Facsimile			
Facsimile by direct frequency modulation of the carrier; black and white	$B_n = 2M + 2DK$ $M = N/2$ $K = 1.1$ (typically)	$N = 1100$ elements/sec $D = 400$Hz Bandwidth: 1980Hz = 1.98kHz	1K98F1C--
Analogue facsimile	$B_n = 2M + 2DK$ $M = N/2$ $K = 1.1$ (typically)	$N = 1100$ elements /sec $D = 400$Hz Bandwidth: 1980Hz = 1.98kHz	1K98F3C--
5. Composite emissions (see Table III-B)			
Radio-relay system, frequency division multiplex	$B_n = 2f_p + 2DK$ $K = 1$ (typically)	60 telephone channels occupying baseband between 60kHz and 300kHz; rms per-channel deviation: 200kHz; continuity pilot at 331kHz produces 100kHz rms deviation of main carrier. $D = 200 \times 10^3 \times 3.76 \times 2.02 = 1.52 \times 10^6$ Hz $f_p = 0.331 \times 10^6$ Hz Bandwidth: 3.702×10^6 Hz = 3.702 MHz	3M70F8EJF
Radio-relay system, frequency division multiplex	$B_n = 2M + 2DK$ $K = 1$ (typically)	960 telephone channels occupying baseband between 60kHz and 4028kHz; rms per-channel deviation: 200kHz; continuity pilot at 4715kHz produces 140kHz rms deviation of main carrier. $D = 200 \times 10^3 \times 3.76 \times 5.5 = 4.13 \times 10^6$ Hz $M = 4.028 \times 10^6$ $f_p = 4.715 \times 10^6$ $(2M + 2DK) > 2f_p$	16M3F8EJF

Description of emission	Necessary bandwidth		Designation of emission
	Formula	Sample calculation	
		Bandwidth: 16.32×10^6 Hz = 16.32MHz	
Radio relay systems, frequency division multiplex	$B_n = 2 f_p$	600 telephone channels occupying baseband between 60kHz and 2540kHz. rms per-channel deviation: 200kHz; continuity pilot at 8500kHz produces with 140kHz rms deviation of main carrier. $D = 200 \times 10^3 \times 3.76 \times 4.36 = 3.28 \times 10^6$ Hz $M = 2.54 \times 10^6$ $K = 1$ $f_p = 8.5 \times 10^6$ $(2M + 2DK) < 2 f_p$ Bandwidth: 17×10^6 Hz = 17MHz	17M0F8EFJ
Stereophonic sound broadcasting with multiplexed telephony sub-carrier	$B_n = 2M + 2DK$ $K = 1$ (typically)	Pilot tone systems; $M = 75000$ $D = 75000$Hz Bandwidth: 300000Hz = 300kHz	300KF8EHF

III-B. MULTIPLYING FACTORS FOR USE IN COMPUTING D, PEAK FREQUENCY DEVIATION, IN FM FREQUENCY DIVISION MULTIPLEX (FM-FDM) MULTI-CHANNEL EMISSSIONS

For FM-FDM systems the necessary bandwidth is:

$$B_n = 2M + 2DK$$

The value of D, or peak frequency deviation, in these formulae for B_n is calculated by multiplying the rms value of per-channel deviation by the appropriate "multiplying factor" shown below.

In the case where a continuity pilot of frequency f_p exists above the maximum modulation frequency M, the general formula becomes:

$$B_n = 2f_p + 2DK$$

In the case where the modulation index of the main carrier produced by the pilot is less than 0.25, and the rms frequency deviation of the main carrier produced by the pilot is less than or equal to 70% of the rms value of per-channel deviation, the general formula becomes either:

$$B_n = 2f_p \quad \text{or} \quad B_n = 2M + 2DK$$

whichever if greater.

Number of telephone channels N_c	Multiplying factor [1]
	$(\text{Peak factor}) \times \text{antilog} \left[\dfrac{\text{value in dB above modulation reference level}}{20} \right]$
$3 < N_c < 12$	$4.47 \times \text{antilog} \left[\dfrac{\text{a value in dB specified by the equipment manufacturer or station licensee, subject to administration approval}}{20} \right]$
$12 \leqq N_c < 60$	$3.76 \times \text{antilog} \left[\dfrac{2.6 + 2 \log N_c}{20} \right]$
	Multiplying factor [2]
Number of telephone channels N_c	$(\text{Peak factor}) \times \text{antilog} \left[\dfrac{\text{value in dB above modulation reference level}}{20} \right]$
$60 \leqq N_c < 240$	$3.76 \times \text{antilog} \left[\dfrac{-1 + 4 \log N_c}{20} \right]$
$N_c \geqq 240$	$3.76 \times \text{antilog} \left[\dfrac{-15 + 10 \log N_c}{20} \right]$

[1] In the above chart, the multipliers 3.76 and 4.47 correspond to peak factors of 11.5 and 13.0 dB, respectively.

[2] In the above chart, the multipliers 3.76 correspond to peak factors of 11.5 dB.

Description of emission	Necessary bandwidth		Designation of emission
	Formula	Sample calculation	
IV. PULSE MODULATION			
1. Radar			
Unmodulated pulse emission	$B_n = 2K/t$ 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.	Primary radar: range resolution = 150m $K = 1.5$ (triangular pulse when $t \cong t_r$, only components down to 27dB 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 = 3MHz	3M00P0NAN
2. Composite emissions			
Radio-relay system	$B_n = 2K/t$ $K = 1.6$	Pulse position modulated by 36 voice channel baseband; pulse width at half amplitude = 0.4 μ s Bandwidth: 8×10^6 Hz = 8MHz (Bandwidth independent of the number of voice channels)	8M00M7EJT