Appendix 1

Classification of Emission Designation and Necessary Bandwidths

I. Designation of Emission

Basic characteristics:

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 cases where 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

1.5.2.5which 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, tele-command D

3.6 Telephony (including audio 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

tr : 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: 100 Hz	100HA1AAN

Description of emission	Necessary bandwidth		Designation of emission
	Formula	Sample calculation	
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: 2100 Hz = 2.1 kHz	2K10A2AAN
Selective calling signal using sequential (single frequency code, single-sideband full carrier)	B_n = M	Maximum code frequency: 2110 Hz M = 2110 Bandwidth: 2100 Hz = 2.11 kHz	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 = $\frac{B}{2}$	B = 50 D = 35 Hz (70 Hz shift) K = 1.2 Bandwidth: 134 Hz	134HJ2BCN
Telegraphy, multi-channel with voice frequency, error correction. Some channels are time-division multiplexed, (single side-band, reduced carrier)	B_n = highest central frequency + M + DK M = $\frac{B}{2}$	15 channels; highest central frequency is: 2850 Hz B = 100 D = 42.5 Hz (85 Hz shift) K = 0.7 Bandwidth: 2885 Hz = 2.885 kHz	2K89R7BCW
2. Telephony (commercial quality)			
Telephony, double-sideband (single channel)	B_n = 2M	M = 3000 Bandwidth: 6000 Hz = 6 kHz	6K00A3EJN
Telephony, single-sideband full carrier (single channel)	B_n = M	M = 3000 Bandwidth: 3000 Hz = 3 kHz	3K00H3EJN
Telephony, single-sideband, suppressed carrier (single channel)	B_n = M − lowest modulation frequency	M = 3000 lowest modulation frequency is 300 Hz Bandwidth: 2700 = 2.7 kHz	2K70J3EJN

Description of emission	Necessary bandwidth		Designation of emission
	Formula	Sample calculation	
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 is 2990 Hz M＝2990 Bandwidth: 2990 Hz＝2.99 kHz	2K99R3ELN
Telephony with privacy, single sideband, suppressed carrier (two or more channels)	B_n＝N_cM－lowest modulation frequency in the lowest channel	N_c＝2 M＝3000 lowest modulation frequency is 250 Hz Bandwidth: 5750 Hz＝5.75 kHz	5K75J8EKF
Sound broadcasting, double-sideband	B_n＝sum of M for each sideband	2 channels M＝3000 Bandwidth: 6000 Hz＝6 kHz	6K00B8EJN
3. Audio broadcasting			
Audio broadcasting, double-sideband	B_n＝2M M may vary between 4000 and 10000 depending on the quality desired	Speech and music M＝4000 Bandwidth: 8000 Hz＝8 kHz	8K00A3EGN
Audio broadcasting, single-sideband, reduced carrier (single channel)	B_n＝M M may vary between 4000 and 10000 depending on the quality desired	Speech and music M＝4000 Bandwidth: 4000 Hz＝4 kHz	4K00R3EGN
Audio broadcasting, single-sideband, suppressed carrier	B_n＝M－lowest modulation frequency	Speech and music M＝4500 lowest modulation frequency is 50 Hz Bandwidth: 4450 Hz＝4.45 kHz	4K45J3EGN
4. Television			
Television, vision and sound	Refer to CNS 14972	Bandwidth of radio channel: 6 MHz	6M00G7W
5. Facsimile			

Description of emission	Necessary bandwidth		Designation of emission
	Formula	Sample calculation	
Analogue facsimile by sub-carrier frequency modulation of a single-sideband emission with reduced carrier monochrome	B_n= C + $\frac{N}{2}$ + DK K = 1.1 (typically)	N = 1100 Corresponding to an index of cooperation of 352 and a cycler rotation speed of 60 rpm. Index of cooperation is the product of the drum diameter and number of lines per unit length. C = 1900 D = 400 Hz Bandwidth: 2890 Hz = 2.89 kHz	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 = $\frac{N}{2}$ K = 1.1 (typically)	N = 1100 D = 400 Hz Bandwidth: 1980 Hz = 1.98 kHz	1K98J3C--
6. Composite emissions			
Double-sideband, television relay	B_n = 2C+2M+2D	Video limited to 5 MHz Audio on 6.5 MHz, frequency modulated sub-carrier = 50 kHz; C = 6.5×10^{6} D = 50×10^{3} Hz M = 15000 Bandwidth: 13.13×10^{6} Hz = 13.13 MHz	13M1A8W--
Double-sideband radio relay system, frequency division multiplex	B_n = 2M	10 voice channels occupying baseband between 1 kHz and 164 kHz; M = 164000 Bandwidth: 328000 Hz = 328 kHz	328KA8E--

Description of emission	Necessary bandwidth		Designation of emission
	Formula	Sample calculation	
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 Hz Bandwidth: 20940 Hz = 20.94 kHz	20K9A9WWF
Independent sidebands; several telegraph channels with error-correction together with several telephone channels with privacy; frequency division multiplex	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 telegraphy channels require the bandwidth: 12000 Hz = 12 kHz	12K0B9WWF
III. Frequency Modulation			
1. Signal with quantized or digital information			
Telegraphy without error correction device. (single channel)	B_n = 2M+2DK M=$\frac{B}{2}$ K = 1.2 (typically)	B = 100 D = 85 Hz (170 Hz shift) Bandwidth: 304 Hz	304HF1BBN
Telegraphy, narrowband direct-printing with error correction (single channel)	B_n = 2M+2DK M=$\frac{B}{2}$ K = 1.2 (typically)	B = 100 D = 85 Hz (170 Hz shift) Bandwidth: 304 Hz	304HF1BCN
Selective calling signal	B_n = 2M+2DK M=$\frac{B}{2}$ K = 1.2 (typically)	B = 100 D = 85 Hz (170 Hz shift) Bandwidth: 304 Hz	304HF1BCN

Description of emission	Necessary bandwidth		Designation of emission
	Formula	Sample calculation	
Four frequency duplex telegraphy	B_n = 2M+2DK B = modulation rate (Bd) of the faster channel. If the channels are synchronized: M = $\frac{B}{2}$ (otherwise M = 2B) K = 1.1 (typically)	Spacing between adjacent frequencies = 400 Hz, synchronized channels B = 100 M = 50 D = 600 Hz Bandwidth: 1420 Hz = 1.42 kHz	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: 16000 Hz = 16 kHz	16K0F3EJN
3. Audio broadcasting			
Audio Broadcasting	B_n = 2M+2DK K = 1 (typically)	Monaural D = 75000 Hz M = 15000 Bandwidth: 180000 Hz = 180 kHz	180KF3EGN
4. Facsimile			
Facsimile by direct frequency modulation of the carrier; black and white	B_n = 2M+2DK M = $\frac{N}{2}$ K = 1.1 (typically)	N = 1100 elements/sec D = 400 Hz Bandwidth: 1980 Hz = 1.98 kHz	1K98F1C--
Analogue facsimile	B_n = 2M+2DK M = $\frac{N}{2}$ K = 1.1 (typically)	N = 1100 elements/sec D = 400 Hz Bandwidth: 1980 Hz = 1.98 kHz	1K98F3C--
5. Composite emissions (see table III-B)			

Description of emission	Necessary bandwidth		Designation of emission
	Formula	Sample calculation	
Radio-relay system, frequency division multiplex	$B_n = 2f_p + 2DK$ K = 1 (typically)	60 telephone channels occupying baseband between 60 kHz and 300 kHz; rms per-channel deviation: 200 kHz; continuity pilot at 331 kHz produces 100 kHz 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 60 kHz and 4028 kHz; rms per- channel deviation: 200 kHz; continuity pilot at 4715 kHz produces 140 kHz rms deviation of main carrier. $D = 200 \times 10^3 \times 3.76 \times 5.5 = 4.13 \times 10^6$ Hz $M = 4.028 \times 10^6$; $f_p = 4.715 \times 10^6$; $(2M + 2DK) > 2f_p$ Bandwidth: 16.32×10^6 Hz = 16.32 MHz	16M3F8EJF

Description of emission	Necessary bandwidth		Designation of emission
	Formula	Sample calculation	
Radio relay systems, frequency division multiplex	$B_n = 2f_p$	600 telephone channels occupying baseband between 60 kHz and 2540 kHz. rms per- channel deviation: 200 kHz; continuity pilot at 8500 kHz produces with 140 kHz rms deviation of main carrier. $D = 200 \times 10^2 \times 3.76 \times 4.36 = 3.28 \times 10^6$ Hz; $M = 2.54 \times 10^6$; K = 1; $f_p = 8.5 \times 10^6$ Hz; $(2M+2DK) < 2f_p$ Bandwidth: 17×10^6 Hz = 17 MHz	17M0F8EJF
Stereophonic sound broadcasting with multiplexed telephony sub-carrier	$B_n = 2M+2DK$ K = 1 (typically)	Pilot tone systems; M = 75000 D = 75000 Hz Bandwidth: 300000 Hz = 300 kHz	300KF8EHF

III-B. Multiplying factors for use in computing D, peak frequency deviation, in FM frequency division multiplex (FM-FDM) multi-channel emissions

Necessary bandwidth for FM-FDM systems:

$$B_n = 2M+2DK$$

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:

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

whichever is greater.

Number of telephone channels N_c	Multiplying factor[1]
	(Peak factor) x $log^{1}\left(\frac{value\ in\ dB\ above\ modulation\ reference\ level}{20}\right)$
$3<N_c<12$	(Peak factor) x $\log^{1}\left(\frac{a\ value\ in\ dB\ specified\ by\ the\ equipment\ manufacturer\ or\ station\ licensee,\ subject\ to\ the\ competen}{20}\right)$
$12 \leqq N_c < 60$	3.76 x $log^{1}\left(\frac{2.6+2\ log\ N_c}{20}\right)$

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

Number of telephone channels N_c	Multiplying factor[1]
	(Peak factor) x $log^{-1}\left(\frac{value\ in\ dB\ above\ modulation\ reference\ level}{20}\right)$
$60 \leqq N_c < 240$	3.76 x $log^{-1}\left(\frac{-1+4\ log\ N_c}{20}\right)$
$N_c \geqq 240$	3.76 x $log^{-1}\left(\frac{-15+10\ log\ N_c}{20}\right)$

1. 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	$B_n = \frac{2K}{t}$ K depends upon the ratio of pulse duration to pulse rise time. Its value usually falls between 1 and 10 and in many cases it does not need to exceed 6.	Primary radar: range resolution = 150m K = 1.5 (triangular pulse when t ≅ tr, only components down to 27dB from the strongest are considered) Then: $t = \frac{2x(range\ resolution)}{velocity\ of\ light} = \frac{2\ x\ 150}{3\ x\ 10^8}$ Bandwidth: $3x10^6$ Hz = 3 MHz	3M00P0NAN
2. Composite emissions			
Radio-relay system	$B_n = \frac{2K}{t}$ K = 1.6	Pulse position modulated by 36 voice channel baseband; pulse width at half amplitude = 0.4μs Bandwidth: $8x10^6$ Hz = 8 MHz (Bandwidth independent of the number of voice channels)	8M00M7EJT