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-Frequency modulation	F	(8) Cases not otl
-Phase modulation	G	(e) Third Symb
NOTE: Whenever frequency modulation '	'F''	tion to be transm
is indicated, Phase modulation "G" is a acceptable.	also	(1) No informat
(4) Emission in which the main		tion
carrier is amplitude and angle-		(3) Telegraphy-
modulated either simultaneously		ception
or in a pre-established sequence .	D	(4) Facsimile
(5) Emission of pulses: ¹ .		(5) Data transm
-Sequence of unmodulated		telecommand
pulses	Р	(6) Telephony
—A sequence of pulses:		broadcasting)
-Modulated in amplitude	Κ	(7) Television (v
-Modulated in width/duration	\mathbf{L}	(8) Combination
-Modulated in position/phase	Μ	(9) Cases not ot
-In which the carrier is angle-		(f) Tuno Pomio
modulated during the period		(1) Type D enns
of the pulse	\mathbf{Q}	are symbolized
—Which is a combination of the		rulog and rogulat
foregoing or is produced by		gion The use of the
other means	V	hidden
(6) Cases not covered above, in		(g) Whenever t
which an emission consists of the		an emission is n
main carrier modulated, either		for that emission
simultaneously or in a pre-estab-		he preceded by
lished sequence, in a combination		width of the emi
of two or more of the following		82.202(h)(1)
modes: amplitude, angle, pulse	W	32.202(0)(1).
(7) Cases not otherwise covered	Х	[49 FR 48697, Dec. 14,
1 Florida and the state of the		

¹Emissions 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 (2) or (3).

(d) Second Symbol-nature of signal(s) modulating the main carrier:

(1) No modulating signal (2) A single channel containing quantized or digital information without the use of a modulating sub-carrier, excluding time-division muliplex (3) A single channel containing quantized or digital information with the use of a modulating subcarrier, excluding time-division multiplex (4) A single channel containing analogue information (5) Two or more channels containing quantized or digital information (6) Two or more channels containing analogue information (7) Composite system with one or more channels containing quantized or digital information, together with one or more channels containing analogue information

herwise covered ... X

bol—type of informaitted:2

(1) No information transmitted	Ν
(2) Telegraphy—for aural recep-	
tion	Α
(3) Telegraphy—for automatic re-	
ception	В
(4) Facsimile	С
(5) Data transmission, telemetry,	
telecommand	D
(6) Telephony (including sound	
broadcasting)	\mathbf{E}
(7) Television (video)	\mathbf{F}
(8) Combination of the above	W
(9) Cases not otherwise covered	Х

sion: As an exception nciples, damped waves in the Commission's tions as type B emisype B emissions is for-

he full designation of ecessary, the symbol , as given above, shall the necessary bandssion as indicated in

1984]

§2.202 Bandwidths.

(a) Occupied bandwidth. The frequency bandwidth such that, below its lower and above its upper frequency limits, the mean powers radiated are each equal to 0.5 percent of the total mean power radiated by a given emission. In some cases, for example multichannel frequency-division systems, the percentage of 0.5 percent may lead to certain difficulties in the practical application of the definitions of occupied and necessary bandwidth; in such cases a different percentage may prove useful.

(b) Necessary bandwidth. For a given class of emission, the minimum value of the occupied bandwidth sufficient to ensure the transmission of information at the rate and with the quality required for the system employed, under specified conditions. Emissions useful

0

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 $\mathbf{2}$

3

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²In 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.

for the good functioning of the receiving equipment as, for example, the emission corresponding to the carrier of reduced carrier systems, shall be included in the necessary bandwidth.

(1) The necessary bandwidth shall be expressed by three numerals and one letter. The letter occupies the position of the decimal point and represents the unit of bandwidth. The first character shall be neither zero nor K, M or G.

(2) Necessary bandwidths:

between 0.001 and 999 Hz shall be expressed in Hz (letter H);

between 1.00 and 999 kHz shall be expressed in kHz (letter K):

between 1.00 and 999 MHz shall be expressed in MHz (letter M);

between 1.00 and 999 GHz shall be expressed in GHz (letter G).

(3) Examples:

0.002 Hz—H002	180.5 kHz—181K
0.1 Hz—H100	180.7 kHz—181K
25.3 Hz—25H3	1.25 MHz—1M25
400 Hz—400H	2 MHz—2M00
2.4 kHz—2K40	10 MHz-10M0
6 kHz—6K00	202 MHz - 202 M
12.5 kHz—12K5	5 65 CHz 5C65
180.4 kHz—180K	9.09 GHZ-9G09

(c) The necessary bandwidth may be determined by one of the following methods:

(1) Use of the formulas included in the table, in paragraph (g) of this section, which also gives examples of necessary bandwidths and designation of corresponding emissions;

(2) For frequency modulated radio systems which have a substantially linear relationship between the value of input voltage to the modulator and the resulting frequency deviation of the carrier and which carry either single sideband suppressed carrier frequency division multiplex speech channels or television, computation in accordance with provisions of paragraph (f) of this section and formulas and methods indicated in the table, in paragraph (g) of this section;

(3) Computation in accordance with Recommendations of the International Radio Consultative Committee (C.C.I.R.); 47 CFR Ch. I (10–1–10 Edition)

(4) Measurement in cases not covered by paragraph (c) (1), (2), or (3) of this section.

(d) The value so determined should be used when the full designation of an emission is required. However, the necessary bandwidth so determined is not the only characteristic of an emission to be considered in evaluating the interference that may be caused by that emission.

(e) In the formulation of the table in paragraph (g) of this section, the following terms are employed:

 B_n = Necessary bandwidth in hertz

B = Modulation rate in bauds

- N = Maximum possible number of black plus white elements to be transmitted per second, in facsimile
- M = Maximum modulation frequency in hertz

C = Sub-carrier frequency in hertz

- D = Peak frequency deviation, i.e., half the difference between the maximum and minimum values of the instantaneous frequency. The instantaneous frequency in hertz is the time rate of change in phase in radians divided by 2
- t = Pulse duration in seconds at half-amplitude
- $t_{\rm r}$ = Pulse rise time in seconds between 10% and 90% of maximum 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 telephone channels in radio systems employing multichannel multiplexing
- P = Continuity pilot sub-carrier frequency (Hz) (continuous signal utilized to verify performance of frequency-division multiplex systems).

(f) Determination of values of D and B_n for systems specified in paragraph (c)(2) of this section:

(1) Determination of *D* in systems for multichannel telephony:

(i) The rms value of the per-channel deviation for the system shall be specified. (In the case of systems employing preemphasis or phase modulation, this value of per-channel deviation shall be specified at the characteristic baseband frequency.)

(ii) The value of D is then calculated by multiplying the rms value of the per-channel deviation by the appropriate factors, as follows:

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Number of message circuits	Multiplying factors	Limits of X (P_{avg} (dBmO))
More than 3, but less than 12	4.47×[a factor specified by the equipment manu- facturer or station licensee, subject to Com- mission approval].	
At least 12, but less than 60	3.76 antilog (X+2 log ₁₀ N _c) 20	X: -2 to +2.6.
At least 60, but less than 240	3.76 antilog (X+4 log ₁₀ N _c) 20	X: -5.6 to -1.0.
240 or more	3.76 antilog (X+10 log ₁₀ N _c) 20	X: -19.6 to -15.0.

Where X represents the average power in a message circuit in dBmO; N_c is the number of circuits in the multiplexed message load; 3.76 corresponds to a peak load factor of 11.5 dB.

(2) The necessary bandwidth (B_n) normally is considered to be numerically equal to:

(i) 2M+2DK, for systems having no continuity pilot subcarrier or having a continuity pilot subcarrier whose frequency is not the highest modulating the main carrier;

(ii) 2P+2DK, for systems having a continuity pilot subcarrier whose frequency exceeds that of any other signal modulating the main carrier, unless the conditions set forth in paragraph (f)(3) of this section are met.

(3) As an exception to paragraph (f)(2)(ii) of this section, the necessary bandwidth (B_n) for such systems is nu-

merically equal to 2P or 2M+2DK, whichever is greater, provided the following conditions are met:

(i) The modulation index of the main carrier due to the continuity pilot subcarrier does not exceed 0.25, and

(ii) In a radio system of multichannel telephony, the rms frequency deviation of the main carrier due to the continuity pilot subcarrier does not exceed 70 percent of the rms value of the perchannel deviation, or, in a radio system for television, the rms deviation of the main carrier due to the pilot does not exceed 3.55 percent of the peak deviation of the main carrier.

(g) Table of necessary bandwidths:

Description of emission	Necessary bandwidth		Designation of
	Formula	Sample calculation	emission
	I. NO MODUL	ATING SIGNAL	
Continuous wave emis- sion.			N0N (zero)
	II. AMPLITUD	E MODULATION	
	1. Signal With Quantiz	red or Digital Information	
Continuous wave teleg- raphy.	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	100HA1A
Telegraphy by on-off keying of a tone mod- ulated carrier.	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	2K10A2A
Selective calling signal, single-sideband full carrier.	B _n =M	Maximum code frequency is: 2110 Hz, M=2110, Bandwidth: 2110 Hz=2.11 kHz	2K11H2B
Direct-printing teleg- raphy using a fre- quency shifted modu- lating sub-carrier sin- gle-sideband sup- pressed carrier.	B _n =2M+2DK, M=B+2	B=50, D=35 Hz (70 Hz shift), K=1.2, Band- width: 134 Hz	134HJ2B
Telegraphy, single side- band reduced carrier.	B _n =central frequency+M+DK, M=B+2	15 channels; highest central frequency is: 2805 Hz, B=100, D=42.5 Hz (85 Hz shift), K=0.7 Bandwidth: 2.885 Hz=2.885 kHz	2K89R7B

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5	Necessary bandwidth		
Description of emission	Formula	Sample calculation	emission
2. Telephony (Commercial Quality)			
Telephony double-side- band.	B _n =2M	M=3000, Bandwidth=6000 Hz=6 kHz	6K00A3E
Telephony, single-side- band, full carrier.	B _n =2M	M=3000, Bandwidth: 3000 Hz=3 kHz	3K00H3E
Telephony, single-side- band suppressed car- rier.	B _n =M-lowest modulation fre- quency	M=3000, lowest modulation frequency is 3000 Hz, 2700 Hz Bandwidth: 2700Hz=2.7 kHz	2K70J3E
Telephony with separate frequency modulated signal to control the level of demodulated speech signal, single- sideband, reduced carrier.	B _n =M	Maximum control frequency is 2990 Hz, M=2990, Bandwidth: 2990 Hz=2.99 kHz	2K99R3E
Telephony with privacy, single-sideband, sup- pressed carrier (two or more channels).	$B_n=N_c M-lowest$ modulation frequency in the lowest channel	Nc=2, M=3000 lowest modulation frequency is 250 Hz, Bandwidth: 5750 Hz=5.75 kHz	5K75J8E
Telephony, independent sideband (two or more channels).	B_n =sum of M for each sideband	2 channels, M=3000, Bandwidth: 6000 Hz=6 kHz	6K00B8E
	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: 8000 Hz= 8 kHz	8K00A3E
Sound broadcasting, sin- gle-sideband reduced carrier (single chan- nel).	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	4K00R3E
Sound broadcasting, sin- gle-sideband, sup- pressed carrier.	B _n =M-lowest modulation fre- quency	Speech and music, M=4500, lowest modula- tion frequency=50 Hz, Bandwidth: 4450 Hz=4.45 kHz	4K45J3E
	4. Te	levision	
Television, vision and sound.	Refer to CCIR documents for the bandwidths of the commonly used television systems	Number of lines=525; Nominal video band- width: 4.2 MHz, Sound carrier relative to video carrier=4.5 MHz	5M75C3F
		Total vision bandwidth: 5.75 MHz; FM aural bandwidth including guardbands: 250,000 Hz	250KF3E
		Total bandwidth: 6 MHz	6M25C3F
	5. Fa	acsimile	1
Analogue facsimile by sub-carrier frequency modulation of a sin- gle-sideband emission with reduced carrier.	$B_n=C-N+2+DK$, K=1.1 (typically)	N=1100, corresponding to an index of co- operation of 352 and a cycler rotation speed of 60 rpm. Index of cooperation is the product of the drum diameter and num- ber of lines per unit length C=1900, D=400 Hz, Bandwidth=2.890 Hz=2.89 kHz	2K89R3C
Analogue facsimile; fre- quency modulation of an audio frequency sub-carrier which modulates the main carrier, single-side- band suppressed car- rier.	B _n =2M+2DK, M=N/ ₂ , K=1.1 (typi- cally)	N=1100, D=400 Hz, Bandwidth: 1980 Hz=1.98 kHz	1K98J3C
	6. Compos	ite Emissions	
Double-sideband, tele- vision relay.	B _n =2C+2M+2D	Video limited to 5 MHz, audio on 6.5 MHz fre- quency modulated subcarrier deviation=50 kHz: C=6.5×10° D=50×10° Hz, M=15,000, Bandwith: 13.13×10° Hz=13.13 MHz	13M2A8W

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Description of emission	Nece	essary bandwidth	Designation of	
	Formula	Sample calculation	emission	
Double-sideband radio relay system.	B _n =2M	10 voice channels occupying baseband be- tween 1 kHz and 164 kHz; M=164,000 bandwith=328,000 Hz=328 kHz	328KA8E	
Double-sideband emis- sion of VOR with voice (VOR=VHF ormidirectional radio range).	B_=2C_max+2M+2DK, K=1 (typi- cally)	The main carrier is modulated by: —a 30 Hz sub-carrier—a carrier resulting from a 9960 Hz tone frequency modulated by a 30 Hz tone—a telephone channel—a 1020 Hz keyed tone for continual Morse identification. C_{max} =9960, M=30, D=480 Hz, Bandwidth: 20,940 Hz=20.94 kHz	20K9A9W	
Independent sidebands; several telegraph channels together with several telephone channels.	B _n =sum of M for each sideband	Normally composite systems are operated in accordance with standardized channel ar- rangements, (e.g. CCIR Rec. 348–2) 3 tele- phone channels and 15 telegraphy chan- nels require the bandwidth 12,000 Hz=12 kHz	12K0B9W	
	III-A. FREQUEN	CY MODULATION		
	1. Signal With Quantiz	zed or Digital Information		
Telegraphy without error-correction (single channel).	$B_n=2M+2DK$, M=B+2, K=1.2 (typically)	B=100, D=85 Hz (170 Hz shift), Bandwidth: 304 Hz	304HF1B	
Four-frequency duplex telegraphy.	B _n 2M+2DK, B=Modulation rate in bands of the faster channel. If the channels are synchronized: M=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	1K42F7B	
	2. Telephony (C	ommercial Quality)		
Commercial telephony	B _n =2M+2DK, K=1 (typically, but under conditions a higher value may be necessary	For an average case of commercial teleph- ony, M=3,000, Bandwidth: 16,000 Hz=16 kHz	16K0F3E	
	3. Sound I	Broadcasting		
Sound broadcasting	B _n =2M+2DK, K=1 (typically)	Monaural, D=75,000 Hz, M=15,000, Band- width: 18,000 Hz=180 kHz	180KF3E	
	4. Fa	acsimile		
Facsimile by direct fre- quency modulation of the carrier; black and white.	B _n =2M+2DK, M=N+2, K=1.1 (typi- cally)	N=1100 elements/sec; D=400 Hz, Bandwidth: 1980 Hz=1.98 kHZ	1K98F1C	
Analogue facsimile	B _n =2M+2DK, M=N÷2, K=1.1 (typi- cally)	N=1100 elements/sec; D=400 Hz, Bandwidth: 1980 Hz=1.98 kHz	1K98F3C	
	5. Composite Emiss	sions (See Table III-B)		
Radio-relay system, fre- quency division multi- plex.	B _n =2P+2DK, K=1	Microwave radio relay system specifications: 60 telephone channels occupying baseband between 60 and 300 kHz; rms per-channel deviation 200 kHz; rms deviation of main car- rier. Computation of main car- rier. computation of B_:D=(200×10 ³ 3×3.76×1.19), Hz=0.895×10 ⁶ , P=0.331×10 ⁶ Hz; Band- width: 2.452×10 ⁶ Hz	2M45F8E	
Radio-relay system fre- quency division mul- tiple.	B _n =2M+2DK, K=1	Microwave radio relay relay systems speci- fications: 1200 telephone channels occu- pying baseband between 60 and 5564 kHz; rms per channel deviation 200 kHz; continunity pilot at 6199 kHz produces 140 kHz rms deviation of main carrier. Computa- tion of $B_n: D=(20^{\circ}\times10^3\times3.76\times3.63)=2.73\times10^6;$ $M=5.64\times10^6$ Hz; $P=6.2\times10^6$ Hz; $(2M+2DK<2P: Bandwidth 16.59\times10^6$ Hz;	16M6F8E	

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Description of emission	Necessary bandwidth		
	Formula	Sample calculation	emission
Radio-relay system, fre- quency division multi- plex.	B _n =2P	Microwave radio relay system specifications: Multiplex 600 telephone channels occupying baseband between 60 and 2540 kHz; con- tinuity pilot at 8500 kHz produces 140 kHz rms deviation of main carrier. Computation of Bn:D=(200×10 ³ ×3.76×2.565)=1.93×10 ⁶ Hz; M=2.54×10 ⁶ Hz; 2DK)≤2P Bandwidth: 17×10 ⁶ Hz	17M0F8E
Unmodulated pulse emission.	B _n =2K+t, K depends upon the ratio of 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: 150 m, K=1.5 (triangular pulse where t=tr, only components down to 27 dB from the strong- est are considered) Then t=2×range resolu- tion+velocity of light=2×150+3×10 ⁸ =1×10 ⁻⁶ seconds, Bandwidth: 3×10 ⁶ Hz=3 MHz	3M00P0N
	6. Compos	ite 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 us, Bandwidth: 8×10 ⁶ Hz=8 MHz (Band- width independent of the number of voice channels)	8M00M7E
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; B _n = 8×10 ⁶ Hz = 8 MHz (Bandwidth independent of the number of voice channels)	8M00M7E
Composite transmission digital modulation using DSB-AM (Micro- wave radio relay sys- tem).	$B_n = 2RK/log_2S$	Digital modulation used to send 5 megabits per second by use of amplitude modulation of the main carrier with 4 signaling states $R = 5 \times 10^6$ bits per second; K = 1; S = 4; B _n = 5 MHz	5M00K7
Binarý Frequency Shift Keying.	$\begin{array}{l} (0.03 < 2D/R < 1.0); \\ B_n = 3.86D + 0.27R \\ (1.0 < 2D/R < 2) \\ B_n = 2.4D + 1.0R \end{array}$	Digital modulation used to send 1 megabit per second by frequency shift keying with 2 sig- naling states and 0.75 MHz peak deviation of the carrier $R = 1 \times 10^6$ bps; D = 0.75×10 ⁶ Hz; B _n = 2.8 MHz	2M80F1D
Multilevel Frequency Shift Keying.	$B_n = (R/log_2S) + 2DK$	Digital modulation to send 10 megabits per second by use of frequency shift keying with four signaling states and 2 MHz peak deviation of the main carrier $R = 10 \times 10^6$ bps; D = 2 MHz; K = 1; S = 4; B _n = 9 MHz	9M00F7D
Phase Shift Keying	$B_n = 2RK/log_2S$	Digital modulation used to send 10 megabits per second by use of phase shift keying with 4 signaling states $R = 10 \times 10^6$ bps; $K = 1$; $S = 4$; $B_n = 10$ MHz	10M0G7D
Quadrature Amplitude Modulation (QAM).	$B_n = 2R/log_2S$	64 QAM used to send 135 Mbps has the same necessary bandwidth as 64–PSK used to send 135 Mbps; R = 135×10 [€] bps; S = 64; B _p = 45 MHz	45M0W
Minimum Shift Keying	2-ary: $B_n = R(1.18)$ 4-ary: $B_n = R(2.34)$	Digital modulation used to send 2 megabits per second using 2-ary minimum shift keying R = 2.36×10^{6} bps; B _n = 2.36 MHz	2M36G1D

 $[28\ {\rm FR}\ 12465,\ {\rm Nov.}\ 22,\ 1963,\ {\rm as}\ {\rm amended}\ {\rm at}\ 37\ {\rm FR}\ 8883,\ {\rm May}\ 2,\ 1972;\ 37\ {\rm FR}\ 9996,\ {\rm May}\ 18,\ 1972;\ 48\ {\rm FR}\ 16492,\ {\rm Apr.}\ 18,\ 1983;\ 49\ {\rm FR}\ 48698,\ {\rm Dec.}\ 14,\ 1984;\ 68\ {\rm FR}\ 68543,\ {\rm Dec.}\ 9,\ 2003]$