Chapter 5
Spectrum Standards

5.1 GENERAL

5.1.1 Introduction

This chapter contains Radio Frequency Spectrum Standards applicable to Federal radio stations and systems.

A radio frequency spectrum standard is a principle, rule, or criterion that bounds the spectrum-related parameters, and characteristics, of a radio station or system for the purpose of managing the Radio Frequency Spectrum. Application of spectrum standards include:

1. assisting consideration of telecommunications systems for the National spectrum review process (Chapter 10),
2. systems planning, design, and procurement,
3. consideration of protection devices for the transmission of classified, and/or sensitive but unclassified information, and their spectrum needs.

The standards contained herein are those associated with the potential impact of any system or station on the normal operation of other systems or stations.

If spectrum standards are not specified in this chapter, the appropriate provisions of the ITU Radio Regulations normally shall apply. If spectrum standards are not specified in this chapter or in the ITU Radio Regulations, the appropriate criteria contained in current Recommendations of the ITU-R shall be used as guidelines.

Compliance with standards contained in this chapter may not preclude the occurrence of interference. Therefore, compliance with the standards does not obviate the need for cooperation in resolving and implementing engineering solutions to harmful interference problems (see Section 2.3.7).

5.1.2 Consequences of Non-conformance with the Provisions of this Chapter

In any instance of harmful interference caused by nonconformance with the provisions of this chapter, the responsibility for eliminating the harmful interference normally shall rest with the agency operating in nonconformance.

5.1.3 Agency Procurement Specifications

Procurement specifications shall, as a minimum, assure compliance with the appropriate requirements of this chapter. Agencies may promulgate more stringent criteria for their own use.

5.1.4 Measurement Methods

Spectrum standards for this chapter are referenced to measurement methods in Annex M. Measurement methods referenced in the annex are provided only for clarification and uniform interpretation of the standards. In cases of harmful interference, the agencies involved are expected to utilize these or equivalent, mutually agreed upon, methods of measurement for resolution of any disagreement concerning compliance with the standards. Agencies may, at their discretion, use these measurement methods as minimum qualification test procedures, e.g., as part of factory test procedures.

5.1.5 Terminology

Definitions of Special Terms, Services, and Stations are contained in Chapter 6.

Desired Relationship of Occupied Bandwidth to Necessary Bandwidth

The emission designator(s) associated in the authorization for any particular frequency assignment specifies the value of the necessary bandwidth of emission for the particular type(s) of transmission permitted. The values of necessary bandwidth are generally idealized. All reasonable effort shall be made in equipment design and operation by Federal agencies to maintain the occupied bandwidth of the emission of any authorized transmission as close to the necessary bandwidth as is reasonably practicable. (See Annex J for additional information concerning the method of calculating necessary bandwidth.)

Authorized Bandwidth

For purposes of this Manual, the term "authorized bandwidth" is defined as the necessary bandwidth (bandwidth required for the transmission and reception of intelligence) and does not include allowance for transmitter drift or doppler shift. See, in addition, Chapter 6 for the definitions of special terms including authorized bandwidth and mean power.

Resolution Bandwidth

Resolution bandwidth is the 3 dB bandwidth of the measurement system used, e.g., in power spectral density measurements. The appropriate resolution bandwidth of the measurement system varies depending on the modulation type and frequency band but should not be greater than the necessary bandwidth of the transmitter being measured.

Power (RR)

Power is designated as:
- peak envelope power (PX or pX)
- mean power (PY or pY)
- carrier power (PZ or pZ)

p denotes power expressed in watts
P denotes power in dB relative to a reference level

Logarithm

In this chapter, Log=Log_{10}

5.2 FREQUENCY TOLERANCES AND UNWANTED EMISSIONS

5.2.1 Table of Frequency Tolerances

Frequency tolerance standards applicable to Federal stations are specified in Table 5.2.1. The table specifies standards for station types arranged within frequency bands.

Transmitter frequency tolerance is the maximum permissible departure from the assigned frequency by the center frequency of the frequency band occupied by an emission.

Receiver frequency tolerance is the maximum permissible departure of the center frequency of the IF passband from the desired center frequency of the IF passband.

In Table 5.2.1 the units for frequency tolerance are expressed in (±) parts per million (ppm) unless otherwise stated. For the purpose of this Manual, the "±" symbol will always be implied. For example, ± 10 ppm will appear as 10 ppm.

The power shown for the various categories of stations is the peak envelope power for single sideband transmitters and the mean power for all other transmitters, unless otherwise indicated. (RR)

Table 5.2.1 Table of Frequency Tolerances

Frequency Band 9 kHz to 535 kHz	Frequency Tolerance
I. Fixed Stations	
A. 9 - 50 kHz	100
B. 50 - 535 kHz	50
II. Mobile Stations	
A. Aeronautical Stations	
1. Aeronautical	50
2. Aircraft	50
3. Survival craft	500
B. Land Mobile Stations	
1. Base (TIS) (530 kHz)	100 Hz
2. Land Mobile	20
3. Direct Printing telegraph and data.	10 Hz
C. Maritime Mobile Stations	
1. Coast	100
2. Ship a. Direct printing telegraph and data. b. Other that above	 10 Hz 200
3. Ship Emergency Transmitters	500 (a)
4. Survival Craft	500
III. Radiodetermination Stations	100

Frequency Band 535 kHz to 1605 kHz	Frequency Tolerance
I. Broadcasting Stations	10 Hz (b)

Frequency Band 1605 kHz to 4000 kHz	Frequency Tolerance
I. Fixed Stations	
A. All, except SSB	10
B. SSB radiotelephone	20 Hz
II. Mobile (Aeronautical, Land, Maritime) Stations	
A. Aeronautical Mobile Stations	
1. Aeronautical a. pY ≤ 200W b. pY > 200W c. SSB radiotelephone	 20 10 10 Hz (c)
2. Aircraft a. All except SSB b. SSB radiotelephone	 20 20 Hz (d)
B. Land Mobile Stations	
1. Base a. pY ≤ 200W, except SSB b. pY > 200W, except SSB c. SSB radiotelephone	 20 (e) 10 20 Hz
2. Land Mobile a. All except SSB b. SSB radiotelephone	 50 20 Hz
C. Maritime Mobile Stations	
1. Coast a. pY ≤ 200W, except c and d below b. pY > 200W, except c and d below c. SSB Radiotelephone d. Direct printing telegraph and data	 100 50 20 Hz 10 Hz
2. Ship a. All except below b. SSB radiotelephone c. Direct printing telephony and data	 40 (f) 40 Hz 40 Hz
3. Survival Craft a. EPIRB	 100
D. Radiodetermination Stations	
1. Radionavigation a. pY ≤ 200W b. pY > 200W	 20 10
2. Radiolocation	10
E. Broadcasting Stations	10 Hz

Frequency Band 4 to 29.7 MHz	**Frequency Tolerance**
I. Fixed Stations	
A. pY ≤ 500W, except C and D below	20
B. pY > 500W, except C and D below	10
C. SSB/ISB Radiotelephone	20 Hz
D. Class F1B emissions	10 Hz
II. Mobile (Aeronautical, Land, Maritime) Stations	
A. Aeronautical mobile stations	
1. Aeronautical a. pY ≤ 500W, except SSB b. pY > 500W, except SSB c. SSB Radiotelephone	 30 10 10 Hz (c)
2. Aircraft a. All except SSB b. SSB Radiotelephone	 30 20 Hz
B. Land mobile stations	
1. Base a. pY ≤ 500W, except SSB b. pY > 500W, except SSB c. SSB Radiotelephone	 20 10 20 Hz
2. Land Mobile a. All except SSB b. SSB Radiotelephone	 30 20 Hz
C. Maritime mobile stations	
1. Coast a. SSB radiotelegraph b. Direct printing telegraph and data c. Other than above	 20 Hz 10 Hz 20 Hz (g)
2. Ship a. Class A1A emission b. Other than A1A emissions (1) SSB Radiotelephone (2) Direct printing, telegraphy and data (3) Other than above	 10 50 Hz 10 Hz 50 Hz (h)
3. Survival craft	50
III. Broadcasting stations	2
IV. Space and earth stations	20

Frequency Band 29.7 to 108 MHz	**Frequency Tolerance**
I. Fixed stations	
A. 29.7-50 MHz, single-channel analog/digital FM/PM	5 (i)
B. Other than above	
1. pY ≤ 10W	20
2. pY > 10W	5
II. Mobile (Aeronautical, Land, Maritime) Stations	
A. 29.7- 50 MHz, analog and digital FM/PM	
1. Land and mobile	5 (i)
2. Portables	20 (i)
B. Other than above	
1 pY ≤ 10W	20 (j)
2. pY > 10W	5
III. Aeronautical Radionavigation stations (Marker beacons on 75 MHz)	50
IV. Broadcasting stations	
A. TV sound and vision	500 Hz (k)(l)
B. Other than TV	
1. pY ≤ 10 W	3000 Hz
2. pY > 10 W	2000 Hz
V. Space and earth stations	20

Frequency Band 108 to 470 MHz	**Frequency Tolerance**
I. Fixed stations.	
A. 108 - 406.1 MHz, all except below.	5
B. 138 - 150.8 and 162 - 174 MHz, narrowband analog/digital FM/ PM except C below	1.5
C. 162 - 174 MHz, low power and splinter channels 1. pY ≤ 10W 2. pY ≤ 10W	 5 2
D. 406-470 MHz	
1. 406.1-420 MHz a. Multi-Channel b. Analog/Digital FM/PM (1) Wideband (2) Narrowband	 2.5 (m)(n) 2.5 (i) 1.0 (i)
2. Other than above a. pY ≤ 10 W b. pY > 10 W	 5 2.5
II. Mobile (Aeronautical, Land, Maritime) Stations	
A. Aeronautical mobile stations	
1. Aeronautical	
a. Analog/digital FM/PM (1) 162-174 MHz (a) Wideband (b) Narrowband (2) 406.1-420 MHz (a) Wideband (b) Narrowband b. Other than above	 5(i) 1.5(o) 2.5 (i) 1.0 (o) 20
2. Aircraft	
a. 156-174 and 406.1-420 MHz (1) 162-174 MHz analog/digital FM/PM (a) Wideband (b) Narrowband	5 5(i) 2.5 (o)

(2) 406.1-420 MHz analog/digital FM/PM	
(a) Wideband	5(i)
(b) Narrowband	2.5(o)
b. Other than above	20
B. Land mobile stations	
1. Base	
a. 108 - 406.1 MHz, all except below	5
b. 138-150.8 and 162 - 174 MHz analog/digital FM/PM	
(1) Wideband	5(i)
(2) Narrowband	1.5(o)(v)
c. 162 - 174 MHz, splinter channel	
(1) pY ≤ 10 W	5
(2) pY > 10 W	2
d. 220 - 222 MHz, single-channel, narrowband	0.1
e. 406.1 - 470 MHz	
(1) 406.1 - 420 MHz analog/digital FM/PM	
(a) Wideband	2.5 (i)
(b) Narrowband	1.0 (o)
(2) Other than above	
(a) pY ≤ 10 W	5
(b) pY > 10 W	2.5
2. Land Mobile	
a. 138-150.8 and 162-174 MHz, all except below	5 (j)
b. 138-150.8 and 162-174 MHz, analog/digital FM/PM	
(1) Wideband	5 (i)
(2) Narrowband	2.5 (o)
c. 162 - 174 MHz (splinter channels)	
(1) pY ≤ 10 W	5
(2) pY > 10 W	2
d. 220 - 222 MHz (single channel, narrowband)	1.5 (p)
e. 406.1- 420 MHz analog/digital FM/PM	
(1) Wideband	5 (i)
(2) Narrowband	
(a) portable (pY = 5 watts)	2.5 (o)(w)
(b) all others	2 (o)
f. Other than above	15
C. Maritime mobile stations	
1. Coast	
a. 150.8 - 162.0125 MHz	
(1) FM	
(a) pY < 3 W	100 (q)
(b) 3 W ≤ pY ≤ 50 W	50 (q)
(2) Other than above	
(a) pY < 3 W	10
(b) 3 W ≤ pY < 100 W	5
(c) pY ≥ 100 W	2.5
b. Outside of 150.8 - 162.0125 MHz	
(1)162 - 174 MHz, analog/digital FM/PM	
(a) Wideband	5 (i)
(b) Narrowband	1.5 (o)
(2) 406.1 - 420 MHz, analog/digital FM/PM	
(a) Wideband	2.5 (i)
(b) Narrowband	1.0 (o)
(3) Other than above	10
2. Ship	
a. 150.8 - 162.0125 MHz (FM, pY < 25 W)	100 (q)(r)
b. 156 - 162 MHz	10
c. 162 - 174 MHz, analog/digital FM/PM	
(1) Wideband	5 (i)
(2) Narrowband	2.5 (o)
d. 406.1 - 420 MHz, analog/digital FM/PM	
(1) Wideband	5 (i)
(2) Narrowband	2 (o)
(3) Other than above	5
e. 450 - 470 MHz	5
f. Outside above bands	20 (r)
3. Survival craft	
a. 156 - 174 MHz	10 (r)
b. Other than above	20 (s)
III. Radiodetermination Stations	
A. Radionavigation stations	
1. Radar	50
2. Other than radar	20
B. Radiolocation stations	
1. Radar	50 (t)
2. Other than radar	50
IV. Broadcasting Stations	
A. TV sound and vision	500 Hz (k)(o)
B. Other than TV	2000 Hz
V. Space and Earth Stations	20

Frequency Band 470 to 960 MHz	Frequency Tolerance
I. Fixed Stations	
A. Point-to-Multipoint (932 - 932.5, 941 - 941.5MHz)	1.5 (n)
B. Point-to-Point (932.5 - 935, 941.5 - 944 MHz)	2.5 (n)
C. Other than above	5
II. Mobile (Aeronautical, Land, Maritime) Stations	
A. Land (Aeronautical, Base, Coast)	5
B. Mobile (Aircraft, Land Mobile, Ship)	
1. pY ≤ 3 W	20
2. pY > 3 W	5
III. Radiolocation Stations	400
IV. Broadcasting Stations	
A. TV Broadcasting	500 Hz (k)(i)
B. TV Broadcasting Translators	200
V. Space and Earth Stations	20

Frequency Band 960 to 1215 MHz	Frequency Tolerance
I. Aeronautical Radionavigation Stations	
A. Aeronautical and Ship Stations	10
B. Aircraft	50
II. IFF/ATCRBS of similar type station	
A. Interrogators 1030 MHz	200 kHz
B. Transponders 1090 MHz	3 MHz

Frequency Band 1215 to 10500 MHz	Frequency Tolerance
I. Fixed Stations	
A. pY ≤ 100 W	
1. 1215 to 4000 MHz	30 (n)
2. 4 to 10500 MHz	50 (n)
B. pY > 100 W	10 (n)
II. Mobile (Aeronautical, Land, Maritime) Stations	
A. 1215 to 2450 MHz	20
B. 2450 to 4000 MHz	30
C. 4000 to 10500 MHz	50
III. Radiodetermination Stations	
A. 1215 to 2450 MHz	500
B. 2450 to 4000 MHz	800
C. 4000 to 10500 MHz	1250
IV. Space and Earth Stations	20

Frequency Band 10.5 to 30 GHz	Frequency Tolerance
I. Fixed Stations	
A. 21.2 - 23.6 GHz	300
B. 21.8 – 22.075 GHz and 23 -23.275 GHz	500 (u)
C. Other than above	50 (n)
II. Mobile (Aeronautical, Land, Maritime) Stations	100
III. Radiodetermination Stations	2500
IV. Space and Earth Stations	50

Frequency Band Greater than 30 GHz	Frequency Tolerance
I. Fixed Stations	75
II. Mobile (Aeronautical, Land, Maritime) Stations	150
III. Radiodetermination Stations	5000
IV. Space and Earth Stations	75

Notes For Frequency Tolerances

(a) If the emergency transmitter is used as the reserve transmitter for the main transmitter, the tolerance for ship station transmitters applies.

(b) In the area covered by the North American Regional Broadcasting Agreement (NARBA), the tolerance of 20 Hz may continue to be applied.

(c) 20 Hz is applicable to other than Aeronautical Mobile (R) frequencies.

(d) The tolerance for aeronautical stations in the Aeronautical Mobile (R) service is 10 Hz.

(e) Travelers Information Stations (TIS) on 1610 kHz have a tolerance of 100 Hz.

(f) For A1A emissions the tolerance is 50 ppm.

(g) For A1A emissions the tolerance is 10 ppm.

(h) For ship station transmitters in the band 26.175-27.5 MHz, on board small craft, with a carrier power not exceeding 5 W operating in or near coastal waters and utilizing A3E or F3E and G3E emissions, the frequency tolerance is 40 ppm.

(i) This tolerance is based on emissions with an analog input and a necessary bandwidth of 16 kHz. Stations with digital inputs may require a different necessary bandwidth, but still must meet all other standards. It does not apply to military equipment used for tactical and/or training operations, FM wireless microphone systems whose pY<0.1 watts, equipment on splinter channels, and fixed stations with multichannel emissions. Also, in the band 162-174 MHz, it does not apply to equipment operating on channels designated for low power systems as set forth in Sections 4.3.8 and 5.3.6, or NOAA Weather Radio Transmitters. The measurement method for the receiver frequency tolerance is contained in paragraph 2.1.2.E.1 of Annex M.

(j) 50 ppm applies to wildlife telemetry with mean power output less than 0.5 W.

(k) In the case of television stations of:

(1) 50 W (vision peak envelope power) or less in the band 29.7-100 MHz;

(2) 100 W (vision peak envelope power) or less in the band 100-965 MHz and which receive their input from other television stations or which serve small isolated communities. It may not, for operational reasons, be possible to maintain this tolerance. For such stations, this tolerance is 1000 Hz.

(l) For transmitters for system M(NTSC) the tolerance is 1000 Hz. However, for low power transmitters using this system note (m) applies.

(m) The receiver frequency tolerance shall be maintained within 10 ppm.

(n) See Annex M, paragraph 2.1.2.C.1.(a), for the measurement method of (1) multichannel equipment in the 406.1-420 MHz band, (2) point-to-point and point-to-multipoint equipment in the bands 932-935/941-944 MHz, or (3) point-to-point and transportable type equipment operating between 1710 MHz and 15.35 GHz (except for systems designed to use scatter techniques).

(o) This tolerance is for stations with emissions having a necessary bandwidth of 11 kHz or less. It does not apply to military equipment used for tactical and/or training operations, FM wireless microphone systems whose mean output power does not exceed 0.1 watt, equipment operating on channels designated for low power systems as set forth in Sections 4.3.8 and 5.3.6, and NOAA Weather Radio Transmitter.

(p) This standard is for narrowband operations with a necessary bandwidth of 4 kHz or less.

(q) The frequency tolerance standard is for maritime mobile stations using FM emissions in the band 150.8-162.0125 MHz with a necessary bandwidth of less than or equal to 16 kHz. See Annex M, paragraph 2.1.2.B, for the measurement method.

(r) Outside band 156-174 MHz, for transmitters used by on-board communications stations, a tolerance of 5 ppm shall apply.

(s) For transmitters used by on-board communications stations, a tolerance of 5 ppm applies.

(t) A frequency tolerance of 10 ppm applies to wind profiler radars operating on the frequency 449 MHz.

(u) Applies to frequency pairs 21.825 GHz, 23.025 GHz; 21.875, 23.075 GHz; 21.925, 23.125 GHz, 21.975 GHz, 23.175 GHz, 22.025 GHz, 23.225 GHz, 22.075 GHz, and 23.275 GHz only.

(v) This tolerance is for new narrowband stations which will become effective on 1 January 2006. Stations already operational, procured prior to 1 January 2006 or have been approved by NTIA/SPS shall conform to a 2.5ppm tolerance standard.

(w) This tolerance is for new narrowband stations which will become effective on 1 January 2006.

5.2.2 Location of Standards for Levels of Unwanted Emissions

5.2.2.1 Location of Specific Standards

The location of levels of unwanted emission standards are provided in Table 5.2.2.1 below. The table specifies the section number for each standard by station type.

Table 5.2.2.1

Station Type: FIXED STATIONS	Location of Standards
Single Sideband and Independent Sideband Equipment (2-29.7 MHz)	5.3.1
Multichannel (406.1-420 MHz) Point-to-point and point-to-multipoint (932-935/941-944 MHz) Point-to-point and transportable, except for systems using scatter techniques (1.71-15.35 GHz)	5.3.3
Analog or Digital FM/PM Wideband Operations (29.7-50, 162-174, and 406.1-420 MHz)	5.3.5.1
Analog or Digital FM/PM Narrowband Operations (138-150.8,162-174, and 406.1-420 MHz)	5.3.5.2
Low Power Channels and Splinter Channels (162-174 MHz and 406.1-420 MHz)	5.3.6
Telemetry, Terrestrial (1435-1525, 2200-2290, 2310-2320 and 2345-2390 MHz)	5.3.7
Analog Transmissions and Low Power Transmit (21.2-23.6 GHz)	5.3.9
Other than above	5.2.2.2

Station Type: LAND and MOBILE STATIONS	Location of Standards
Single Sideband and Independent Sideband Equipment (2-29.7 MHz)	5.3.1
Maritime Mobile Stations using FM (150.8-162.0125 MHz)	5.3.2
Land Mobile, Single Channel Narrowband Operations (220-222 MHz)	5.3.4
Analog or Digital FM/PM Wideband Operations (29.7-50, 162-174, and 406.1-420 MHz)	5.3.5.1
Analog or Digital FM/PM Narrowband Operations (138-150.8, 162-174 MHz and 406.1-420. MHz)	5.3.5.2
Low Power Channels and Splinter Channels (162-174 MHz and 406.1-420 MHz)	5.3.6
Telemetry, Terrestrial (1435-1525, 2200-2290, 2310-2320 and 2345-2390 MHz)	5.3.7
Other than above	5.2.2.2

Station Type: RADIODETERMINATION STATIONS	Location of Standards
Primary radars including spacebased radars on a case-by-case bases (100 MHz to 40 GHz)	Part 5.5
Other than above	5.2.2.2

Station Type: BROADCASTING STATIONS	Location of Standards
All bands	5.2.2.2

Station Type: EARTH and SPACE STATIONS (excluding spacebased radars)	Location of Standards
Below 470 MHz	5.2.2.2
470 MHz and above	Part 5.6

5.2.2.2 General Standards

Below 29.7 MHz, the following standard applies when no other standard applies:

The mean power of any unwanted emissions supplied to the antenna transmission line, as compared with the mean power of the fundamental, shall be in accordance with the following:

1. On any frequency removed from the assigned frequency by more than 100 percent, up to and including 150 percent of the authorized bandwidth, at least 25 decibels attenuation;

2. On any frequency removed from the assigned frequency by more than 150 percent, up to and including 300 percent of the authorized bandwidth, at least 35 decibels attenuation; and

3. On any frequency removed from the assigned frequency by more than 300 percent of the authorized bandwidth, for transmitters with mean power of 5 kilowatts or greater, at least 80 decibels attenuation; and for transmitters with mean power less than 5 kilowatts, at least 43+10 log (pY) decibels attenuation (i.e., 50 microwatts absolute level), except that:

a. For transmitters of mean power of 50 kilowatts or greater and which operate over a frequency range approaching an octave or more, a minimum attenuation of 60 decibels shall be provided and every effort should be made to attain at least 80 decibels attenuation.

b. For hand portable equipment of mean power less that 5 watts, the attenuation shall be at least 30 decibels, but every effort should be made to attain 43+10 log(pY) decibels attenuation (i.e., 50 microwatts absolute level).

c. For mobile transmitters, any unwanted emissions shall be at least 40 decibels below the fundamental without exceeding the value of 200 milliwatts, but every effort should be made to attain 43+10 log(pY) decibels attenuation (i.e., 50 microwatts absolute level).

d. When A1A, F1B, or similar types of narrowband emissions are generated in an SSB transmitter, the suppressed carrier may fall more than 300 percent of the authorized bandwidth from the assigned frequency. Under these conditions, the suppressed carrier shall be reduced as much as practicable and shall be at least 50 decibels below the power of the fundamental emission.

29.7 MHz and above, the following standard applies when no other standard applies:

The mean power of any emission supplied to the antenna transmission line, as compared with the mean power of the fundamental, shall be in accordance with the following (above 40 GHz these are design objectives pending further experience at these orders of frequency):

1. On any frequency removed from the assigned frequency by more than 75 percent, up to and including 150 percent, of the authorized bandwidth, at least 25 decibels attenuation;

2. On any frequency removed from the assigned frequency by more than 150 percent, up to and including 300 percent, of the authorized bandwidth, at least 35 decibels attenuation; and

3. On any frequency removed from the assigned frequency by more than 300 percent of the authorized bandwidth:

a. For transmitters with mean power of 5 kilowatts or greater, attenuation shall be at least 80 decibels.

b. For transmitters with mean power less than 5 kilowatts, spurious output shall not exceed 50 microwatts (i.e., 43+10 log(pY)) decibels attenuation except for frequency modulated maritime mobile radiotelephone equipment above 30 MHz as follows:

(1) The mean power of modulation products falling in any other international maritime mobile channel shall not exceed 10 microwatts for mean transmitter power 20 watts or less.

(2) The mean power of any other unwanted emission on any discrete frequency within the international maritime mobile band shall not exceed 2.5 microwatts for transmitters with mean power of 20 watts or less.

(3) For maritime mobile transmitters of mean power above 20 watts, these 2.5 and 10 microwatt limits may be increased in proportion to the increase of the mean power of the transmitters above this 20 watts.

5.3 FIXED AND MOBILE STATIONS

5.3.1 HF Single Sideband and Independent Sideband Equipment (2-29.7 MHz)

This standard specifies that spectrum standards for single sideband equipment for single channel voice, direct printing telegraphy and data, in the Fixed and Mobile services between 2 and 29.7 MHz (Except in the bands allocated exclusively to the Aeronautical Mobile (R) service.) In using the spectrum standards indicated below, it should be recognized that they do not prohibit an agency from making improvements thereon.

A. Transmitter Standards

1. For unwanted emissions for fixed and mobile services (except the land mobile service), the peak power of any emission on any frequency removed from the center of the authorized bandwidth[1] (BW) by a displacement frequency (fd in kHz) shall be attenuated below the peak envelope power (pX) of the transmitter in accordance with the following schedule:

fd in kHz	Attenuation in dB
$50\%BW < f_d < 150\%BW$	26
$150\%BW < f_d \leq 250\%BW$	35
$f_d > 250\%$ BW	40 + 10 log(pX) or 80 whichever is the lesser attenuation.

Figure 5.3.1 below provides an example of HF SSB emission plotted using the measurement method described in Annex M. The figure also shows the standard superimposed on the plot to show conformance.

For the land mobile service, the peak power of any emission on any frequency removed from the center of the authorized bandwidth[1] (BW) by a displacement frequency (f_d in kHz) shall be attenuated below the peak envelope power (pX) of the transmitter in accordance with the following schedule:

fd in kHz	Attenuation in dB
1.75 kHz $f_d \leq$ 5.25 kHz	28
5.25 kHz $f_d \leq$ 8.75 kHz	38
$f_d >$ 8.75 kHz	43+10 log (pX)

2. Where suppressed carrier operation is employed, transmitters shall be capable of operation with the emitted carrier power attenuated at least 40 dB below peak envelope power.

3. Where interoperability with conventional double sideband AM receivers is required, single sideband transmitters shall have the capability to transmit the carrier at a level within 6 dB of the peak envelope power.

4. The upper sideband mode shall be employed where there is need for working among international services.

B. Receiver Standards

1. Selectivity. The passband[2] shall be no greater than the authorized bandwidth of emission and the slope of the selectivity characteristic outside the passband shall be 100 dB/kHz.

---

[1] In other than exceptional cases the practice is to authorize 3 kHz as the necessary bandwidth for normal voice intelligibility. This is specified by the emission designator. In the practical case, to meet the minimum performance requirements of this paragraph the roll-off of the emission curve will begin at a value somewhat less than 1.5 kHz from the assigned frequency.

[2] Passband--The passband is the band of frequencies limited by the two frequencies for which the voltage is attenuated to one-half of the voltage of the most favored frequency.

2. Tunability. The equipment shall be capable of operation on any frequency within its tuning range. However, where a synthesizer is employed as the frequency controlling element, the receiver shall be capable of operation on any frequency which is an integral multiple of 0.1 kHz.

C. Antenna Standards [3]

Fixed Station

1. Directive antennas are not required below 4 MHz. Directive antennas shall be employed above 4 MHz unless in specific cases they are shown to be impracticable.

2. Minimum forward power gain over an isotropic radiator located at the same height over the same earth as directive antenna shall be 10 dB in the range 4 to 10 MHz and 15 dB in the range 10 to 30 MHz.[4] The gain of any reference antenna used in an actual measurement must be specified relative to an isotropic antenna.

3. The antenna gain in the desired direction over that of a lobe in any other direction shall be greater than 6 dB.

Mobile Station

To the extent practicable, land stations shall use antennas designed so as to reduce their radiation and/or their susceptibility to interference in those directions where service is not required.

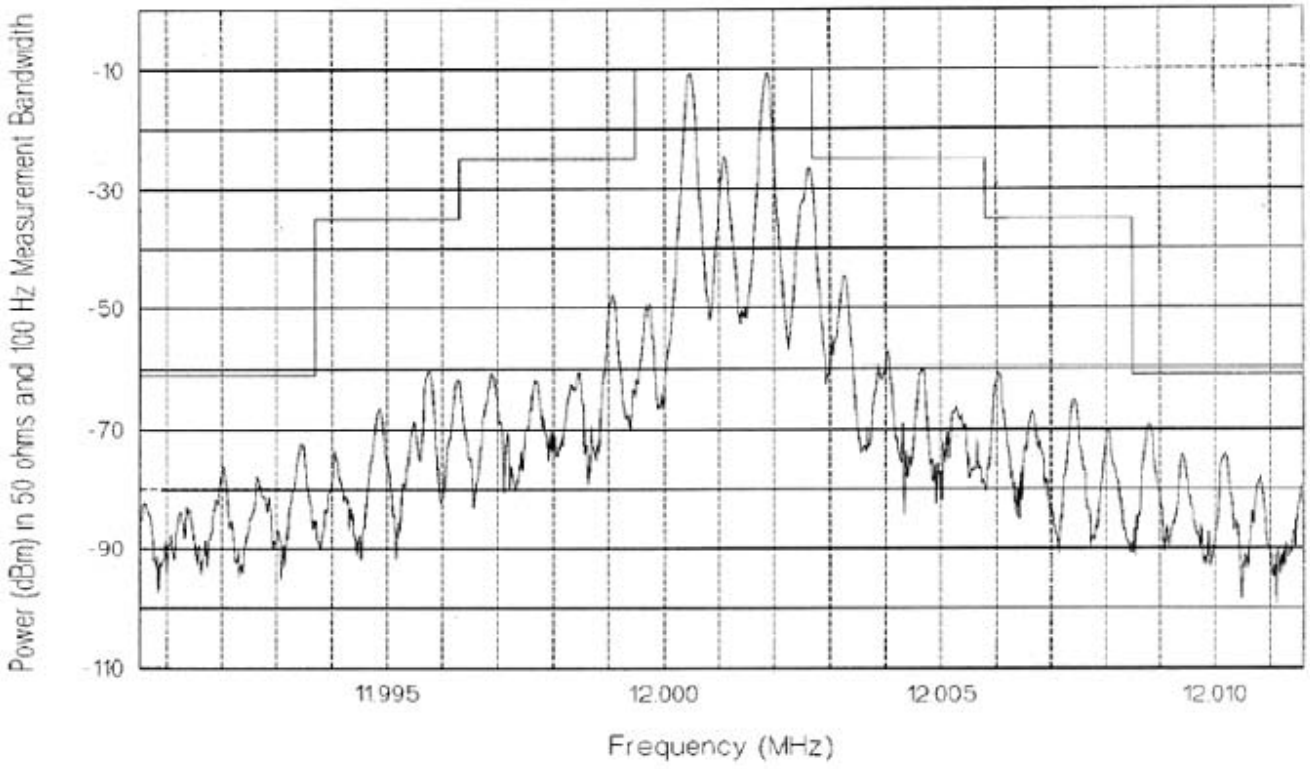


Figure 5.3.1 RSL (dBm) vs. Frequency (MHz)
Example of measured Emission for HF SSB Transmitter Fundamental with NTIA Standard in Section 5.3.1.
Modulation Tones = 400 Hz and 1800 Hz, Resolution BW = 100 Hz, Span = 21.1 kHz

---

[3] Applies to both transmitting and receiving antennas, but to the latter only when protection from harmful interference is required.

[4] These gain figures would be approximately 6 dB greater if the gain were to be expressed relative to an isotropic antenna in free space, in order to account for ground reflection.

5.3.2 Maritime Mobile Stations using FM (150.8-162.0125 MHz)

This standard is for maritime mobile stations using FM emissions in the band 150.8-162.0125 MHz with a necessary bandwidth of less than or equal to 16 kHz.

After January 21, 1997, ship station transmitters, except portable ship station transmitter, must be capable of automatically reducing power to 1 watt or less when tuned to the frequency 156.375 MHz or 156.650 MHz. A manual override will permit full carrier power operation on these channels.

5.3.3 Fixed Services (406.1-420 MHz Band, the 932-935/941-944 MHz Bands, and the 1710 MHz-15.35 GHz Frequency Range)

The following standard is for Federal Government Fixed Services employing: (a) multichannel equipment in the 406.1-420 MHz band, (b) point-to-point and point-to-multipoint equipment in the bands 932-935/941-944 MHz, or (c) point-to-point and transportable type equipment operating between 1710 MHz and 15.35 GHz (except for systems designed to use scatter techniques).

This standard became effective on August 28, 1990, for fixed operations (point-to-point and point-to-multipoint) in the bands 932-935/941-944 MHz. These bands are partially allocated for Federal and non-Federal fixed service use on a co-primary basis. Standards for receivers operating in the bands 932-935/941-944 MHz, are not mandatory and are presented herein to provide guidelines to promote efficient and effective use of these shared frequencies.

This standard became effective on January 1, 1987, for multichannel equipment operating in the 406.1-420 MHz band. Such equipment placed in operation or contracted for prior to January 1, 1987, may continue to operate without regard to the requirements of this standard.

This standard became effective on January 1, 1979, for fixed equipment operating in the 1710 MHz - 15.35 GHz frequency range. Such equipment placed in operation or contracted for prior to January 1, 1979 may continue to operate without regard to the requirements of this standard until January 1, 1994.

A. Transmitter Standards

Unwanted Emissions. The mean power of any emission on any frequency removed from the center of the authorized bandwidth (BW) by a displacement frequency (fd in kHz) shall be attenuated below the mean output power (pY) of the transmitter in accordance with the following schedule. For cases where a resolution bandwidth is not specified, use 100 kHz for center frequencies less than 1 GHz and 1 MHz for center frequencies greater than or equal to 1 GHz:

(a) For transmission other than those employing digital modulation techniques:

fd in kHz	**Attenuation in dB**
$50\%BW < f_d \leq 100\%BW$	25
$100\%BW < f_d \leq 250\%BW$	35
$f_d > 250\%$ BW	43 + 10log (pY) or 80 whichever is the lesser attenuation

(see Figure 5.3.3a for a sample application of this standard)

(b) For transmissions employing digital modulation techniques:[5]

[5] Relatively narrowband digital radio systems may be unduly restricted by this standard. Work is in progress to define appropriate limitations for such narrowband systems. This standard will be modified in accordance with the findings and experience with such narrowband systems.

In any 4 kHz band, the center frequency of which is removed from the assigned frequency by more than 50 percent, up to and including 250 percent, of the authorized bandwidth as specified by the following equation but at least 50 decibels:

$$A = 35 + .8(\% - 50) + 10\log(BW)$$

where:

A = attenuation (in decibels) below the mean output power level, % = percent of the authorized bandwidth removed from the assigned frequency.

and BW = authorized bandwidth in MHz.

Attenuation greater than 80 decibels is not required.

In any 4 kHz band, the center frequency of which is removed from the assigned frequency by more than 250 percent of the authorized bandwidth: At least 43 + 10 log(pY) decibels, or 80 decibels, whichever is the lesser attenuation. The Measurement Method is in paragraph 2.1.1.C.1.(b) of Annex M. (see Figure 5.3.3b for a sample application of this standard)

(c) In the bands 932-935 and 941-944 MHz, fixed point-to-multipoint stations using transmissions employing digital modulation techniques with a bandwidth of 12.5 kHz or less, the power of any emission shall be attenuated below the unmodulated carrier power (mean power can be used) of the transmitter (pY) in accordance with the following schedule:

(1) On any frequency removed from the center of the authorized bandwidth by a displacement frequency (fd in kHz) of more than 2.5 kHz up to and including 6.25 kHz: At least 53 log(f_d/2.5) decibels;

(2) On any frequency removed from the center of the authorized bandwidth by a displacement frequency (fd in kHz) of more than 6.25 kHz up to and including 9.5 kHz: At least 103 log(fd/3.9) decibels;

(3) On any frequency removed from the center of the authorized bandwidth by a displacement frequency (fd in kHz) of more than 9.5 kHz up to and including 15 kHz: At least 157 log(f_d/5.3) decibels;

(4) On any frequency removed from the center of the authorized bandwidth by a displacement frequency greater that 15 kHz: At least 50+10 log(pY) or 70 decibels, whichever is the lesser attenuation.

(d) In the bands 932-935 and 941-944 MHz, fixed point-to-multipoint stations using transmissions employing digital modulation techniques with a bandwidth greater than 12.5 kHz, the power of any emission shall be attenuated below the unmodulated carrier power (mean power can be used) (pY) of the transmitter in accordance with the following schedule;

(1) On any frequency removed from the center of the authorized bandwidth by a displacement frequency (fd in kHz) of more than 5 kHz up to and including 10 kHz: At least 83 log (fd/5) decibels;

(2) On any frequency removed from the center of the authorized bandwidth by a displacement frequency (fd in kHz) of more than 10 kHz up to and including 250 percent of the authorized bandwidth: At least 116 log(fd/6.1) or 50+10 log(pY) or 70 decibels, whichever is the lesser attenuation;

(3) On any frequency removed from the center of the authorized bandwidth by more than 250 percent of the authorized bandwidth: At least 43+10 log(pY) decibels or 80 decibels, whichever is the lesser attenuation.

2. The maximum equivalent isotropic radiated power (EIRP) shall not exceed the values specified below. However, the additional constraints of Section 8.2.34 of this manual apply.

Frequency Band (MHz)	Maximum Allowable EIRP (dBm)
406.1-420	80
932-932.5	47
932.5-935	70
941-941.5	60
941.5-944	70
1710-4990	80
7125-15350	85

B. Receiver Standards

1. The receiver unwanted signals shall be attenuated at least 60 dB relative to the receiver sensitivity at the center of the passband. The Measurement Method is in paragraph 2.1.1.C.2.(b) of Annex M.

2. Selectivity. Receiver selectivity is the degree to which a receiver is able to discriminate against the effects of undesired signals primarily outside the authorized emission bandwidth that arrive at its RF input terminals.

The –3 dB receiver bandwidth should be commensurate with the authorized emission bandwidth plus twice the frequency tolerance of the transmitter specified in Section 5.2.1. The –60 dB receiver bandwidth shall not exceed five times the –3 dB receiver bandwidth.

3. Conducted Undesired Emissions are those undesired signals generated in the receiver and leaving the receiver by way of the receiving transmission line.

Conducted emissions from the receiver on any frequency, as measured at the radio frequency interface point to the antenna system, shall not exceed –85 dBW. For the bands 406.1-420 MHz and 932-935/941-944 MHz, conducted emissions shall not exceed –57 dB.

4. Noise Figure. The noise figure of a receiver is the ratio expressed in dB of (1) the output noise power to (2) the portion of noise power attributable to thermal noise in the input termination at 290 kelvins.

The receiver noise figure including preamplifier should be 9 dB or less for frequencies below 4400 MHz, 12 dB or less for frequencies between 4400 MHz, and 10 GHz, and 14 dB or less for higher frequencies (up to 15.35 GHz).

C. Antenna Standards

The following limitations do not apply to transportable antenna systems when used in tactical and training operations. Additionally, the following limitations do not apply to multipoint distribution systems (point-to-multipoint) operating in the bands 406.1-420, 932-932.5 and 941-941.5 MHz.

1. Each station shall employ directional antennas with the major lobe of radiation directed toward the receiving station with which it communicates, or toward any passive repeater that may be used.

2. Antenna Radiation Pattern. The antenna radiation pattern is the relative power gain as a function of direction for the specified polarization.

Directional antennas shall meet the performance standards indicated in Table 5.3.3. For assignments in bands shared with satellite-space services, determination on additional beamwidth limitations shall be made on a case-by-case basis if mutual interference problems are likely to be involved.

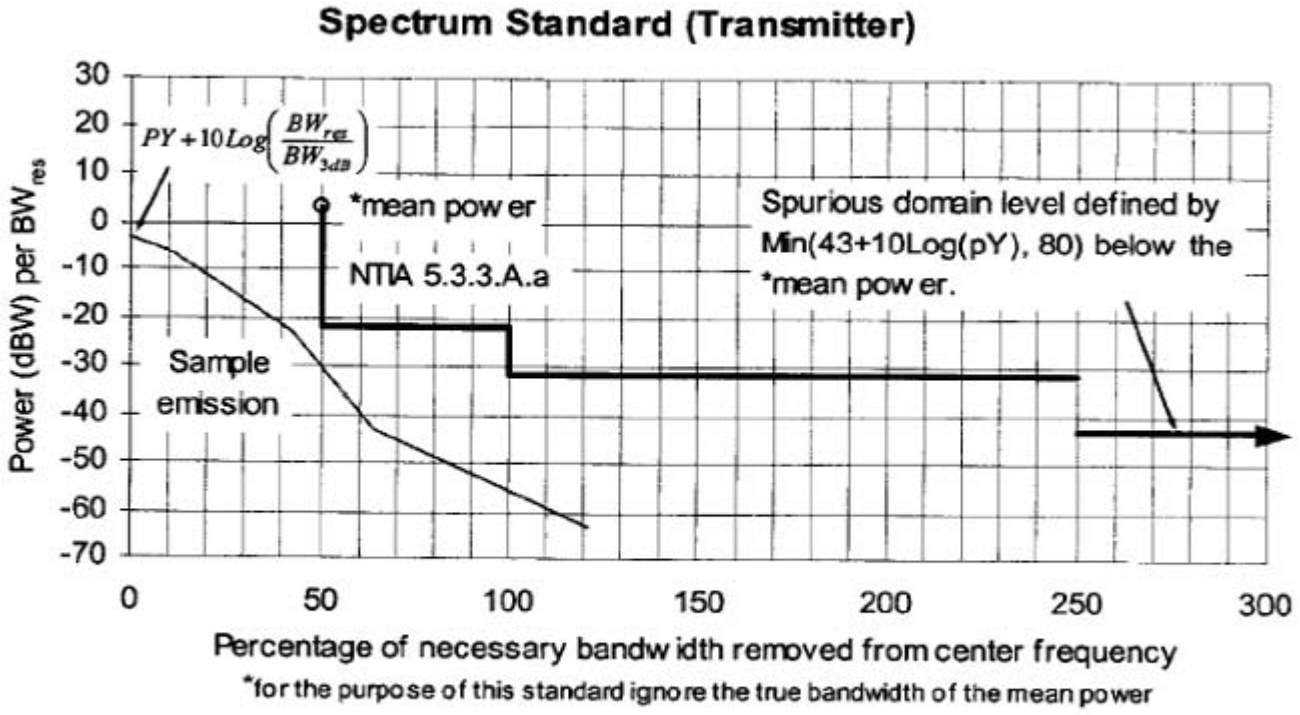


Figure 5.3.3a

Figure 5.3.3a shows a sample analog emission whose center frequency is 7.135 GHz, necessary bandwidth is 19.8 MHz, -3 dB bandwidth is 4 MHz, and mean output is 2 watts (3 dBW), plotted against the standard. The emission complies with the standard.

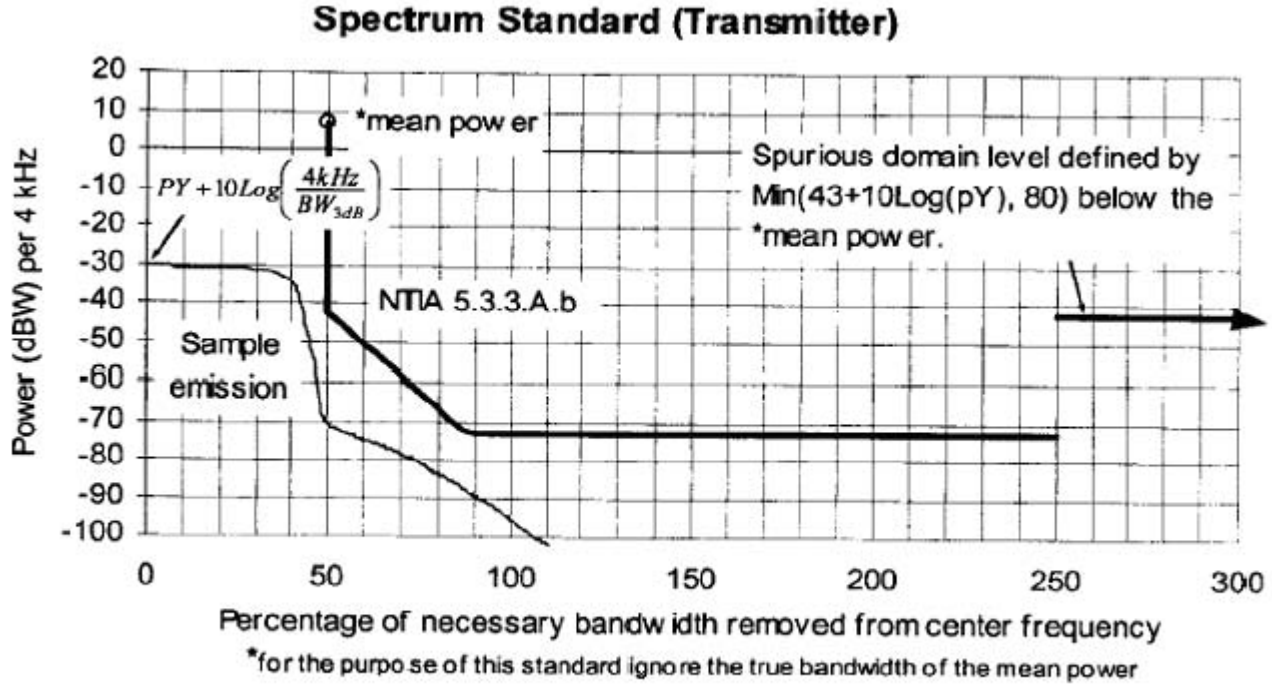


Figure 5.3.3b

Figure 5.3.3b shows a sample digital emission whose necessary bandwidth is 30 MHz, -3 dB bandwidth is 22 MHz, and mean output power is 5 watts (7 dBW), plotted against the standard. The emission complies with the standard.

TABLE 5.3.3

Frequency Band	Maximum beamwidth (3 dB point)	Minimum suppression at angle in degrees from center line of main beam (dB)						
		5-10	10-15	15-20	20-30	30-100	100-140	140-180
406.1-420 MHz[1]	80	-	-	-	-	10	10	10
a) 932.5-935 MHz 941.5-944 MHz[2]	14	-	6	11	14	17	20	24
b) 932.5-935 MHz 941.5-944 MHz[2]	20	-	-	6	10	13	15	20
1710-1850 MHz[3]	10	-	14	16	18	23	24	30
1710-1850 MHz[4]	8	5	18	20	20	25	28	36
2200-2400 MHz	8.5	4	12	16	16	24	25	30
4.4-4.99 GHz	4	13	20	23	24	29	31	31
7.125-8.5 GHz	2.5	19	23	28	30	34	35	43
14.4-15.35 GHz	1.5	21	26	31	35	37	41	48
21.8 – 22.075 GHz and 23 -23.275 GHz	3.3	18	26	26	33	33	55	55

1 - Any secondary lobe.

2 - Stations in this service must employ an antenna that meets the performance standard except that, in areas not subject to frequency congestion, subject to frequency coordination along the borders of the U.S., antennas meeting standards for category B may be employed. Note, however, the use of a high performance antenna may be required where interference problems can be resolved by the use of such antennas.

3 - These suppression levels could be met, e.g., by a 1.2 meter (4 foot) diameter parabolic antenna.

4 - This standard is applicable to new stations in the 1710-1850 MHz band placed in service after January 1, 1985, except for those located on the military test ranges specified in Section 7.17.1 and those limitations noted in paragraph 5.3.3.C. These suppression levels could be met, e.g., by a 1.83 meter (6 foot) diameter parabolic antenna.

Note: It is recognized that relatively narrowband systems may be unduly restricted by this standard. Work is in progress to define appropriate limitations for such narrowband systems. This standard will be modified in accordance with findings and experience with such narrowband systems.

5.3.4 Land Mobile, Single Channel Narrowband Operations (220-222 MHz Band)

The 220-222 MHz band was reallocated on September 6, 1988 to the land mobile service for shared Federal and non-Federal operations. The operations are limited to single channel, narrowband equipment. The 2 MHz available in this band are allocated in 400 channels each 5 kHz wide and paired to create 200 narrowband channel pairs. See Section 4.3.15 for the channeling plan. This standard became effective on January 1, 1992.

A. Transmitter Standards

1. Bandwidth Limitations: The maximum authorized bandwidth shall be 4 kHz.

2. Unwanted Emissions: On any frequency removed from the center of the authorized bandwidth by a displacement frequency (fd in kHz), the power of any emission shall be attenuated below the peak envelope power (pX) watts in accordance with the following schedule:

f_d in kHz		Attenuation in dB
$2 < f_d \leq 3.75$	the lesser of	$30 + 20(f_d-2)$ or $55 + 10\log(pX)$ or 65
$3.75 < f_d$	at least	$55 + 10\log(pX)$

The Measurement Method is in paragraph 2.1.1.D of Annex M.

B. Geographic Separation of Sub-Band A Base Station Receivers and Sub-Band B Base Station Transmitters

1. Base station receivers utilizing channels assigned for sub-band A as designated in Chapter 4 will be geographically separated from those base station transmitters utilizing channels removed 200 kHz or less and assigned from sub-band B as follows:

Separation Distances (Kilometers)	Effective Radiated Power (Watts)*
0.0 - 0.3	**
0.3 - 0.5	5
0.5 - 0.6	10
0.6 - 0.8	20
0.8 - 2.0	25
2.0 - 4.0	50
4.0 - 5.0	100
5.0 - 6.0	200
over 6.0	500

* Transmitter peak envelope power shall be used to determine effective radiated power.
** Stations separated by 0.3 km or less shall not be authorized. This table does not apply to the low-power mobile data channels 196-200. (See Section C.)

2. Except for nationwide assignments, the separation of co-channel base stations shall be 120 kilometers. Shorter separations will be considered on a case-by-case basis upon submission of a technical analysis indicating that at least a 10 dB protection will be provided to an existing station's 39 dB signal level contour.

C. Limitations on Power and Antenna Height:

1. The permissible effective radiated power (ERP) with respect to antenna heights shall be determined from the following table. These are maximum values and applications are required to justify power levels requested.

Table. ERP vs. Antenna Height

Antenna Height above Average Terrain (HAAT) Meters	Effective Radiated Power (ERP) Watts*
Up to 150	500
150 to 225	250
225 to 300	125
300 to 450	60
450 to 600	30
600 to 750	20
750 to 900	15
900 to 1050	10
Above 1050	5

* Transmitter PEP shall be used to determine ERP.

2. The maximum permissible ERP for mobile units is 50 watts. Portable units are considered as mobile units.

3. Channels 196-200 are limited to 2 watts ERP and a maximum antenna height of 6.1 meters (20 feet) above ground.

5.3.5 Standards for Fixed and Mobile Analog or Digital FM/PM Operations (29.7-50, 138-150.8, 162-174, and 406.1-420 MHz Bands)[6]

5.3.5.1 Standard for Fixed and Mobile Analog or Digital FM/PM Wideband Operations (29.7-50, 162-174, and 406.1-420 MHz Bands)

Standards in this section related specifically to digital systems became effective on October 1, 1990.

These standards do not apply to:

- Military equipment used for tactical and/or training operations.
- FM wireless microphone systems whose mean output power does not exceed 0.1 watt.
- Equipment operating on splinter channels. (See Section 5.3.6).
- Fixed stations equipment with multichannel emissions (see Section 5.3.3).

The following is for fixed and mobile/land mobile service employing fixed, land, mobile and portable stations using analog or digital FM or PM emissions in the bands 29.7-50, 162-174, and 406.1-420 MHz. These standards are based upon emissions with analog input and a necessary bandwidth of 16 kHz.[7]

Stations with digital input may require a different necessary bandwidth but still must meet all other standards.

A. Transmitter

1. Unwanted Emissions: The power of any unwanted emission on any frequency removed from the center of the authorized bandwidth (BW) by a displacement frequency (fd in kHz) shall be attenuated below the unmodulated carrier power (pZ) in accordance with the following and Figure 5.3.5.1.

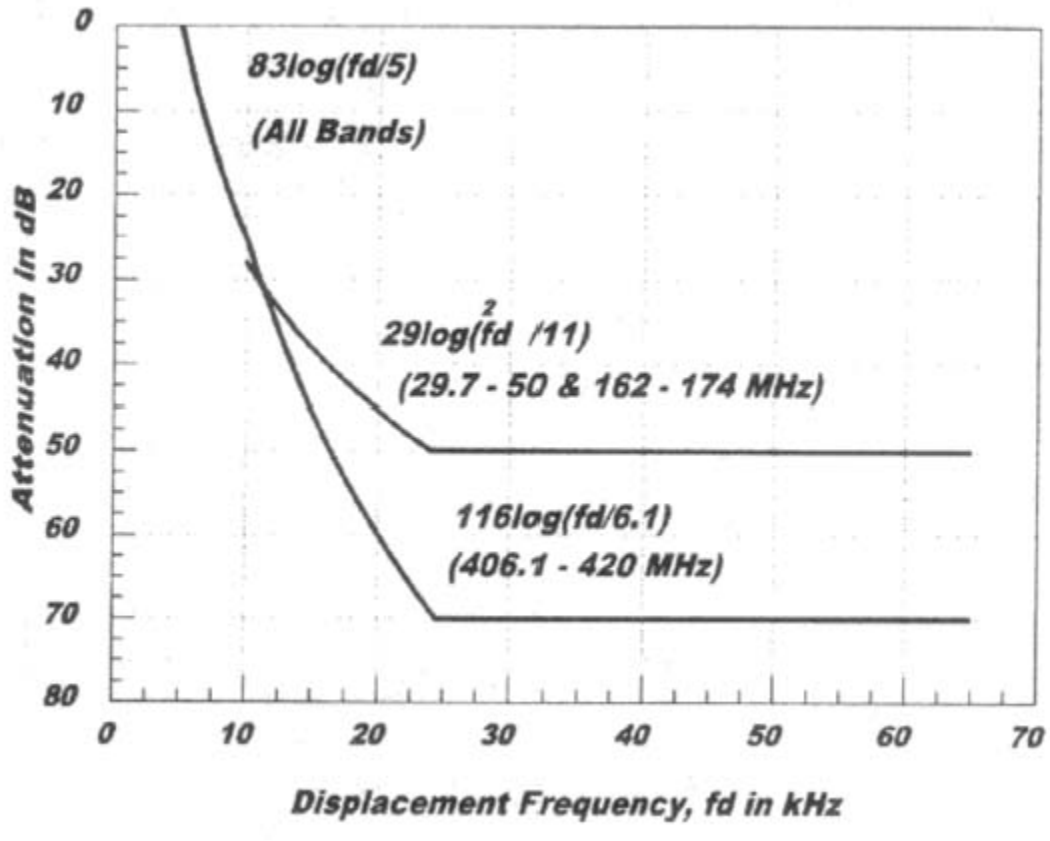
---

[6] In the band 406.1 - 410 MHz, power is limited to a maximum of 7 W/kHz of necessary bandwidth as specified in footnote US117 to the Tables of Frequency Allocations (Chapter 4).

[7] The spacing of channels (adjacent channel spacing) is 20 kHz in the 30-50 MHz band and 25 kHz in the 162-174 and 406.1 - 420 MHz bands.

fd in kHz	**Attenuation in dB**
5 kHz < f_d ≤ 10 kHz	All bands: 83log (f_d/5)
10 kHz < f_d ≤ 250% BW	29.7-50 MHz & 162-174 MHz: 29log (f_d^2/11) or 50 whichever is the lesser attenuation

Figure 5.3.5.1



406.1-420 MHz: 116log (f_d/6.1) or 50 + 10log (pZ) or 70 whichever is the lesser attenuation.

fd > 250% BW	All bands: 50 + 10log (pZ) (i.e. 10 microwatts absolute) Portable 43 + 10log (pZ) (i.e. 50 microwatts absolute)

Figure 5.3.5.1 shows the mask for a fixed or mobile station operating in the bands 29.7-50, 162-174 and 406.1- 420 MHz with an authorized bandwidth of 25 kHz and a mean power of 100 watts.

2. Frequency Deviation for all station classes and frequency bands shall not exceed 5 kHz. The Measurement Method is in paragraph 2.1.E.1 of Annex M.

B. Receiver

1. Spurious Response Attenuation:

Station Class	Band (MHz)		
	29.7-50	162-174	406.1-420
Land, Fixed, Mobile	85 dB	85 dB	85 dB
Portable	60 dB	60 dB	50 dB

2. Adjacent Channel Selectivity:

ANALOG			
Station Class	Band (MHz)		
	29.7-50	162-174	406.1-420
Land, Fixed, Mobile	80 dB	80 dB	80 dB
Portable	50 dB	70 dB	60 dB

DIGITAL			
Station Class	Band (MHz)		
	29.7-50	162-174	406.1-420
Land, Fixed, Mobile	50 dB	55 dB	55 dB
Portable	50 dB	50 dB	50 dB

3. Intermodulation Attenuation:

Station Class	Band (MHz)		
	29.7-50	162-174	406.1-420
Land, Fixed, Mobile	60 dB	70 dB	70 dB
Portable	50 dB	50 dB	50 dB

4. Conducted Spurious Emissions: All station classes and all bands –57 dBm.
5. The Measurement Method is in paragraph 2.1.1.E.1 of Annex M.

5.3.5.2 Standards for Fixed and Mobile Analog or Digital FM/PM Narrowband Operations in the 138-150.8, 162-174 and 406.1-420 MHz Bands

The standards outlined in this section apply to narrowband systems in the 138-150.8, 162-174 and 406.1-420 MHz bands. These standards do not apply to:

- Military equipment used for tactical and/or training operations in the 138-150.8 MHz band.
- FM wireless microphone systems whose mean output power does not exceed 0.1 watt.
- Equipment operating on channels designated for low-power systems as set forth in Sections 4.3.8, 4.3.10, 4.3.10a and 5.3.6.
- NOAA Weather Radio Transmitters.

Standards

The following standards apply to fixed and mobile/land mobile services employing fixed, land, mobile, and portable stations using analog or digital emissions in the 138-150.8, 162-174 and 406.1-420 MHz bands with a necessary bandwidth of 11 kHz or less. These standards are based upon either TIA/EIA 603-C for narrowband analog or TIA-102.CAAB-B for narrowband digital transmitters and receivers. Additionally, the receiver standards listed below are based upon Class A receiver limits as specified in the appropriate TIA publication.

Effective Dates

These standards for new narrowband stations operating within the subject frequency bands shall become effective on 1 January 2008. Stations already operational, procured prior to 1 January 2008 or have been approved by NTIA/SPS will be allowed to operate in accordance with existing standards and without modification until the end of the life cycle of the equipment.

Waivers

Waivers of the requirements herein may be requested when supported by reasonable justification. Waiver requests should be accompanied by technical data in support of the waiver and an explanation of the non-conforming parameters. Waivers granted will be subject to the provisions of Section 5.1.2.

A. Transmitter

1. Unwanted Emissions: The power of any unwanted emission on any frequency removed from the center of the authorized bandwidth (BW) by a displacement frequency (fd) shall be attenuated below the unmodulated carrier power (pZ) in accordance with the following and the emission mask in Figure 5.3.5.2.

Displacement Freq (fd)	**Attenuation (dB)**
$0 < f_d \leq 2.5$ kHz	0
2.5 kHz < f_d < 12.5 kHz	$7(f_d-2.5)$
12.5 kHz < f_d	50 + 10log (pZ) or 70 whichever is the smaller

2. Frequency Deviation for all FM or PM station classes shall not exceed 2.5 kHz for analog emissions, and 3.11 kHz for digital emissions

3. The Measurement Method is in paragraph 2.1.E.2 of Annex M.

B. Receiver

1. Spurious Response Attenuation (all bands):

Station Class	**Digital**	**Analog**
Land, Fixed	90 dB	75 dB
Mobile	80 dB	75 dB
Portable	70 dB	70 dB

2. Adjacent Channel Selectivity (all bands):

Station Class	**Digital**	**Analog**
Land, Fixed	60 dB	45 dB
Mobile	60 dB	45 dB
Portable	60 dB	45 dB

3. Intermodulation Rejection (all bands):

Station Class	**Digital**	**Analog**
Land, Fixed	80 dB	75 dB
Mobile	75 dB	75 dB
Portable	70 dB	70 dB

4. Conducted Spurious Emissions for all station classes and all bands: -57 dBm.

5. The Measurement Method is in paragraph 2.1.E.2 of Annex M.

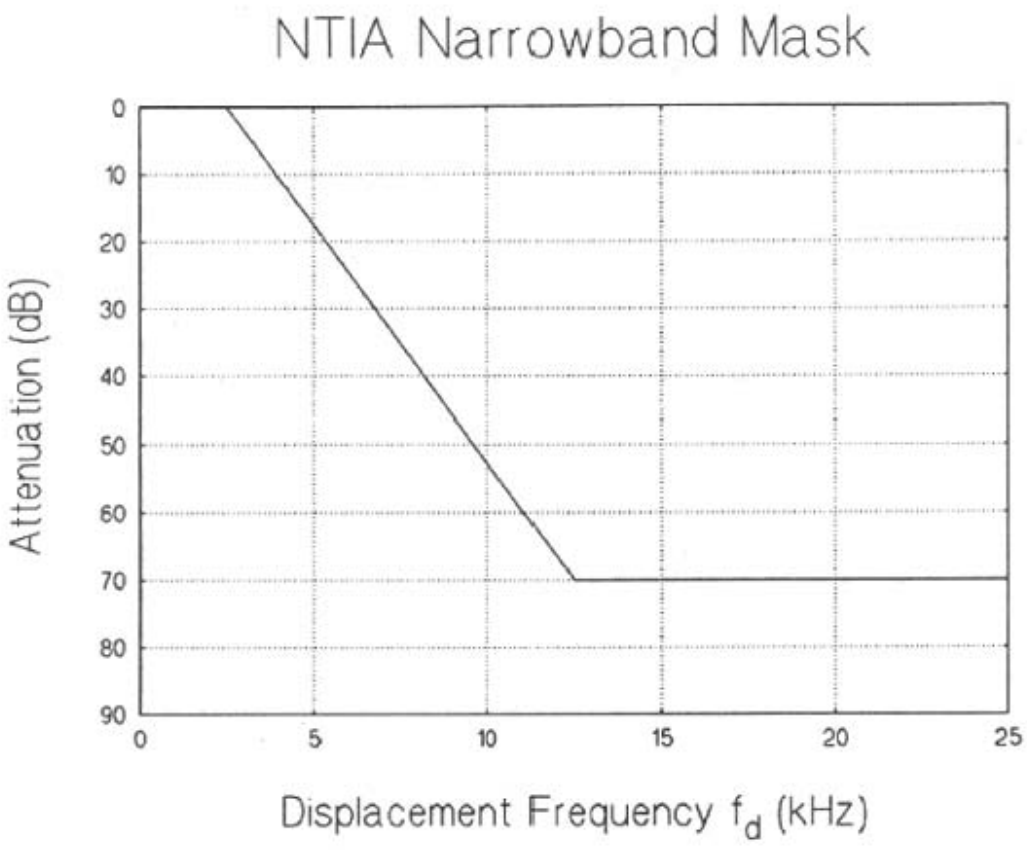


Figure 5.3.5.2 LEVELS OF UNWANTED EMISSIONS

Note: This emission mask represents the Telecommunications Industry Association (TIA) emission mask developed for narrowband FM and Digital systems designed to operate in 12.5 kHz channels in the 138-150.8 MHz, 162-174 MHz, and 406.1-420 MHz bands. (The mask assumes pZ=100 watts.)

5.3.6 Low Power Channels and Splinter Channels (162-174 MHz Band)

1. The following transmitter standards are for the use of fixed and mobile low power channels identified in Section 4.3.8 and splinter channels identified in Section 4.3.10.

2. Emission--For FM or PM emission the maximum frequency deviation plus the highest audio tone shall not exceed 0.5 times the authorized bandwidth (authorized bandwidth is equal to 2D + 2M).

3. Unwanted emission levels at the equipment antenna terminals on any frequency removed from the center of the authorized bandwidth (BW) by a displacement frequency (fd in kHz) shall be attenuated below the mean power (pY) of the unmodulated carrier output as specified by the following:

fd in kHz	**Attenuation in dB**
$50\%BW < f_d \leq 100\%$ BW	25
$100\%BW < f_d \leq 250\%$ BW	35
$f_d > 250\%$ BW	43 dB + 10 log (pY)

4. Power output--The maximum mean power of the unmodulated carrier output for operations on splinter channels in the 406-420 MHz band shall be limited to 30 watts.

5.3.7 Telemetry, Terrestrial (1435-1525, 2200-2290, 2310-2320 and 2345-2390 MHz Bands)

This standard is applicable to terrestrial telemetering stations, authorized for operation in the bands 1435-1525, 2200-2290, 2310-2320 and 2345-2390 MHz. The details of this standard can be found in Chapter 2 of the Range Commanders Council Telemetery IRIG Standard TG 106-## Part 1. This document can be found at http://www.ntia.doc.gov/osmhome/106.pdf or http://www.ntia.doc.gov/osmhome/106.doc. Subsequent revisions of this document will be reviewed by the Technical Subcommittee prior to adoption.

5.3.8 Low Power Transmit (21.8-22.075 and 23.0-23.275 GHz Band Segments)[8]

These standards apply to the following six frequency pairs within the above two band segments:

21.825 GHz	23.025 GHz
21.875 GHz	23.075 GHz
21.925 GHz	23.125 GHz
21.975 GHz	23.175 GHz
22.025 GHz	23.225 GHz
22.075 GHz	23.275 GHz

1. Unwanted Emissions.

When using transmissions other than those employing digital modulation techniques: the mean power of any emission supplied to the antenna transmission line, as compared with the mean power of the fundamental, shall be in accordance with the following (above 40 GHz these are design objectives pending further experience at these orders of frequency):

a. On any frequency removed from the assigned frequency by more than 50 percent, up to and including 100 percent of the authorized bandwidth, at least 25 decibels attenuation;

b. On any frequency removed from the assigned frequency by more than 100 percent, up to and including 250 percent of the authorized bandwidth, at least 35 decibels attenuation; and

c. On any frequency removed from the assigned frequency by more than 250 percent of the authorized bandwidth, at least 43 + 10 log(pY) decibels or 80 decibels, whichever is the lesser attenuation.

2. Maximum equivalent isotropically radiated power (EIRP) shall be 55 dBm.

3. The rated transmitter output power shall not exceed 0.100 watts.

4. Upon showing need, a maximum bandwidth of 50 MHz may be authorized per frequency assigned.

5. These radio systems shall have no more than five hops in tandem, except upon showing of need, but in any event the maximum tandem length shall not exceed 40 km (25 miles).

6. Interfering signals at the antenna terminals of stations authorized shall not exceed -90 dBm and -70 dBm, respectively, for co-channel and adjacent channel interfering signals.

7. Antennas employing circular polarization may be used with these systems.

8. Maximum beamwidth shall not exceed 4 with a minimum front-to-back ratio of 38 dB.

---

[8] These frequency pairs are shared between Federal and non-Federal users. Power constraints placed on the frequency pairs facilitate coordination due to the decreased interference potential.

5.4 DISTRESS AND SAFETY COMMUNICATIONS

1. Global Maritime Distress and Safety System (GMDSS):

Stations in the maritime and other radio services employing frequencies and techniques used in the GMDSS shall comply with the relevant ITU-R recommendations with respect to the technical characteristics of:

a. Digital selective calling (DSC) distress call formats (RR **32.9.3** and **34.2**);

b. DSC on VHF channel 70 (156.525 MHz):

(1) Capability of sensing the presence of a signal on channel 70, and

(2) Automatic prevention of transmitting a DSC call on channel 70, except for a distress and safety call by DSC, when the channel is occupied by calls (Volume 4, Rec. ITU-R M.489-2);

c. Other aspects of DSC equipment (RR **54.2**);

d. Narrowband direct printing (NBDP) message formats (Volume 4, Rec. ITU-R M.492-6) and error correction for distress, urgency, and safety messages (RR **32.43**, **33.17**, and **33.37**, respectively);

e. Transmissions from satellite emergency position-indicating radio beacons (EPIRBs) operating in the bands 406-406.1 MHz and 1645.5-1646.5 MHz (RR Appendix **13** Part A5, Section I(c) and RR **34.1**);

f. Transmissions from search and rescue radar transponders operating in the band 9200-9500 MHz (RR **5.474**); and

g. Broadcasts on 518 (NAVTEX) and other broadcasts of maritime safety information using NBDP in the bands 4-27.5 MHz (RR **33.41**).

Additionally, such stations when using DSC shall conform to the calling, acknowledgement, and operating procedures for DSC contained in the Radio Regulations (Article **32**) and the relevant ITU-R recommendation(s).

2. 121.5/243 MHz EPIRBs:

EPIRBs operating at 121.5 MHz and/or 243 MHz shall conform to the requirements of Volume 4, Rec. ITU-R M.690.1 and Annex 10 to the Convention on International Civil Aviation, to the extent that each provision is applicable.

5.5 RADAR SPECTRUM ENGINEERING CRITERIA (RSEC)

5.5.1 General Including RSEC-A

The wide application of radar for various functions makes large demands on the electromagnetic spectrum, and requires the application of effective frequency management measures for the equipment and systems involved. Criteria for certain equipment characteristics are specified herein to ensure an acceptable degree of electromagnetic compatibility among radar systems, and between such systems and those of other radio services sharing the frequency spectrum.

These criteria are concerned with promoting efficient use of the spectrum, and in specifying them there is no intent to require particular numerical values from the standpoint of the radar's mission. For example, characteristics such as power, sensitivity, pulse repetition rate, pulse duration, pulse rise and fall times, and the range of radio frequency emission are closely related to operational requirements. Accordingly, where limits for some of these characteristics are specified herein, the criteria have been chosen to avoid undue degradation of operational effectiveness. Moreover, the specification of these criteria is compatible with the policy of encouraging a free and unrestricted approach in further research looking toward more effective radars. Nevertheless, any proposals for new approaches and new system concepts involving radar must be reviewed from a frequency management viewpoint prior to development of new equipment.

Useful receiver techniques are available for reduction of the susceptibility of radars to low-duty-cycle pulse interference. The applicability of such devices as video integrators, correlators, PRF and pulse width discriminators varies with factors such as cost, availability, and their adaptability to specific equipment and environmental situations. While the mandatory incorporation of such devices is not specified herein, their application is recommended for low duty-cycle radars intended for operation in congested frequency bands and geographic areas.

All primary radars[9] shall be classified in one of five groups as shown in the following table and shall come under the criteria indicated for that group.

Applicability of RSEC [10, 11]

Radar Description	Applicable Criteria
Group A Non-pulsed radars of 40 watts or less rated average power; or Pulsed radars of 1 kW or less rated peak power; or Radars with an operating frequency above 40 GHz; or Man-portable10 radars; or Man-transportable11 radars; or Radionavigation radars in the band 9300-9500 MHz; as described above; or Expendable, non-recoverable radars on missiles	Criteria A Presently exempt from any RSEC
Group B Radars having a rated peak power of more than 1 kW but not more than 100 kW and operating between 2900 MHz and 40 GHz	Criteria B See 5.5.2
Group C All radars not included in Group A, B, D or E	Criteria C See 5.5.3
Group D All fixed radars in the 2700-2900 MHz band	Criteria D See 5.5.4
Group E Wind Profiler Radar (WPR) operating on 449 MHz	Criteria E See 5.5.5

For radars employing more than a single emitter, including phased array radars, variable PRF radars, radars whose modulation changes from pulse to pulse, and other special types of radars for which any of the following criteria cannot be directly applied, special methods may be required in establishing appropriate criteria. Pending adoption of technical criteria for such radars, values submitted for these parameters shall be accompanied by an explanation of their derivation.

The provisions of Section 5.5.2, Criteria B, are applicable to Class 1 spacebased radar systems[12] on a case-by-case basis. The provisions of Section 5.5.2 or Section 5.5.3 (i.e. Criteria B or C as appropriate) are applicable to Class 2 spacebased radar systems[13] and active spaceborne sensors[14] on a case-by-case basis.

---

[9] Primary Radar: A radiodetermination system based on the comparison of reference signals with radio signals reflected from the position to be determined. (No. 1.101 of the ITU Radio Regulations, 2004 Edition.)

[10] Man-portable: Items which are designed to be carried as a component part of individual, crew-served or team equipment in conjunction with assigned duties. These items are nominally less than 15 kilograms (32 pounds).

[11] Man-transportable: items which are usually transported on wheeled, tracked or air vehicles but have integral provisions to allow periodic handling by one or more individuals for limited distances (i.e., 100-500 meters). These items are nominally less than 30 kilograms (65 pounds).

[12] Spacebased Radiolocation System--Class 1: a radiolocation system in space the primary function of which is the detection and location of objects on or near the surface of the Earth.

[13] Spacebased Radiolocation System--Class 2: a radiolocation system installed aboard a spacecraft for the purpose of determining the relative positions or velocities of one or more extravehicular objects.

[14] Active Spaceborne Sensor-- a measuring instrument in the earth exploration-satellite service, or in the space research service, by means of which physical measurement of various phenormena are obtained through transmission and reception of radio waves.

In the special case where Federal radionavigation radars operate in the shared Federal/non-Federal band 9300-9500 MHz, an acceptable degree of electromagnetic compatibility is deemed to be that degree of compatibility associated with the radar equipment commercially available to the non-Federal community of users. The vast preponderance of the use of this band by non-Federal domestic and foreign ships and aircraft creates a situation where relatively inexpensive commercial equipment is available "off the shelf" and at the same time equipment improvements which might be incorporated unilaterally by small numbers of Federal stations would have little effect on the band as a whole. Accordingly, Federal radionavigation radars to be operated in this band having a rated peak power of 100 kW or less are placed in Group A with the understanding that Federal agencies would procure equipment that are acceptable for non-Federal use and that this exemption will be re-examined should the situation in this band change. Measurement procedures for RSEC may be found in Annex M, paragraph 2.1.2.A RSEC.

Waivers

Waiver of the requirements herein may be requested when supported by reasonable justification. When technical and engineering data are supplied in support of a request for waiver or in evaluating the performance of equipment, an explanation of the non-conforming parameters and measurement methods employed shall be furnished. Manufacturer's data may be used where deemed appropriate and adequate.

Pulse Characteristics and Emissions Mask

Figure 1 shows a radar pulse and where the pulse rise time (t_r) and pulse width (t) are calculated. Figure 2 shows the radar emission bandwidth and emission levels for Criteria B, C, and D.

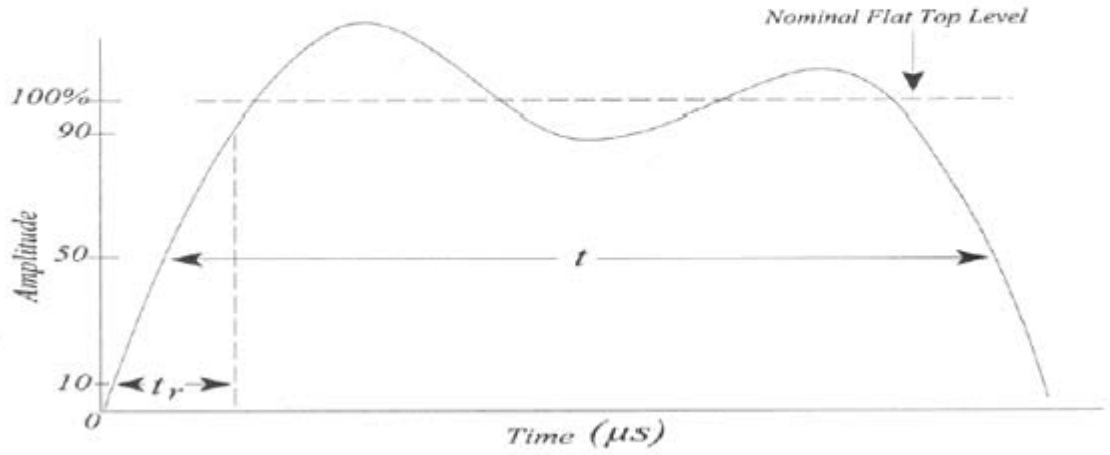
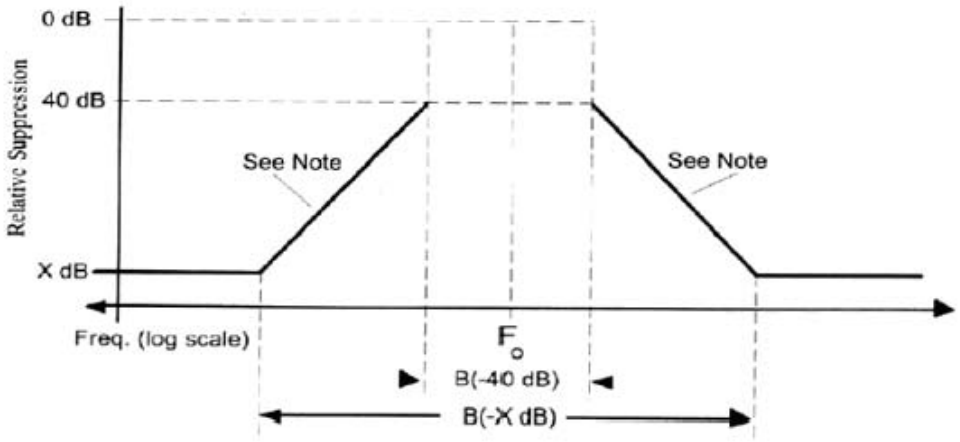


Figure 1. Determination of t and t_r



NOTE: The roll-off slope, S, from the -40 dB to -X dB points is at 20 dB per decade for Criteria B and C, and 40 to 80 dB per decade for Criteria D. The maximum emission spectrum level between the -40 dB and -X dB points for S dB per decade slope is described by the formula:

$$Suppression\ (dB) = -S * \log \left| \frac{F - F_o}{\frac{1}{2}B(-40dB)} \right| - 40$$

$$Where: \ \frac{1}{2}B(-40dB) \le \left| F - F_o \right| \le \frac{1}{2}B(-XdB)$$

and: F is the frequency at which suppression is calculated

$$and: \ B(-XdB) = (10^{\alpha})\, B(-40dB)$$

$$\alpha = \frac{X-40}{S}$$

Figure 2. Radar Emission Bandwidth and Emission Levels

Symbols Used

B = emission bandwidth, in MHz.

B_c = bandwidth of the frequency deviation. (The total frequency shift during the pulse duration) in MHz.

B_d = bandwidth of the frequency deviation (peak difference between instantaneous frequency of the modulated wave and the carrier frequency)--(FM/CW radar systems).

B_s = maximum range in MHz over which the carrier frequency will be shifted for a frequency hopping radar.

d = pulse compression ratio = emitted pulse duration/compressed pulsed duration (at 50% amplitude points).

F_o = operating frequency in MHz. For non-FM pulse radars the peak of the power spectrum; for FM pulse radars the average of the lowest and highest carrier frequencies during the pulse.

N = total number of chips (subpulses) contained in the pulse. (N = 1 for non-FM and FM pulse radars.)

PG = processing gain (dB).

P_p = peak power (dBm).

PRR = pulse repetition rate in pulses per second.

P_t = maximum spectral power density –dBm/kHz.

t = emitted pulse duration in μ sec. at 50% amplitude (voltage) points. For coded pulses the pulse duration is the interval between 50% amplitude points of one chip (sub-pulse). The 100% amplitude is the nominal flat top level of the pulse (see Fig. 1).

t_r = emitted pulse rise time in μ sec. from the 10% to the 90% amplitude points on the leading edge. See Fig. 1. For coded pulses it is the rise time of a sub-pulse; if the sub-pulse rise time is not discernible, assume that it is 40% of the time to switch from one phase or sub-pulse to the next.

t_f = emitted pulse fall time in μ sec. from the 90% to the 10% amplitude points on trailing edge. See Fig. 1 and endnote 15.

5.5.2 Criteria B

1. Effective Dates

Technical criteria for new radars became effective 1 October 1977 except as noted herein. (New radars are those for which development and subsequent procurement contracts are let after 1 October 1977.)

2. Applicability

These criteria are applicable to radars of Group B, "Radars having a rated peak power of more than 1 kW but not more than 100 kW and operating between 2900 MHz and 40 GHz."

3. Radar Emission Bandwidth

All radars procured prior to 1 January 1978 should be brought into compliance with the following standards when undergoing major overhaul.

The emission bandwidth for radars at the antenna input shall not exceed the following limits:

NOTE: There is also the "necessary bandwidth" parameter that is defined for radars. For the method of calculation, see Annex J.

3.1 For Non-FM pulse radars (including spread spectrum or coded pulse radars): [15]

$$B(-40dB) = \frac{7.6}{\sqrt{t_r t}} \quad \text{or} \quad \frac{64}{t}$$

whichever is less

3.2 For FM-pulse radars (intentional FM):[15]

$$B(-40dB) = \frac{7.6}{\sqrt{t_r t}} + 2(B_c + \frac{0.065}{t_r})$$

For FM-pulse radars with pulse rise time, t_r, of less than 0.1 microsecond, an operational justification for the short rise time shall be provided.

3.3 For FM pulse radars (intentional FM) with frequency hopping:[15, 16]

$$B(-40dB) = \frac{7.6}{\sqrt{t_r t}} + 2(B_c + \frac{0.065}{t_r}) + B_s$$

---

[15] If t_f is less that t_r, as defined in Part 5.5, t_f is to be used in place of t_r when performing the emission bandwidth calculations.

[16] These formulas yield the total composite B(–40 dB) bandwidth of a frequency hopping radar as if all channels included within B_s were operating simultaneously. Individual channels have a B(–40 dB) radar emission bandwidth given by the equations in paragraph 3.1 or 3.2 of Sections 5.5.2, 5.5.3, and 5.5.4.

For FM pulse radars (intentional FM) with frequency hopping, but with pulse rise time, t_r, of less than 0.1 microsecond an operational justification for the short rise time shall be provided.

3.4 For frequency hopping radars using non-FM pulses (including spread spectrum or coded pulses):[15, 16]

$$B(-40dB) = \frac{7.6}{\sqrt{t_r t}} + B_s$$

For this category of radars, an operational justification shall be provided if the pulse rise time, t_r, or fall time, tf, is less than 0.01 microseconds.

3.5 For CW radars:

$$B(-40dB) = 0.0003F_0$$

3.6 For FM/CW radars:

$$B(-40dB) = 0.0003F_0 + 2B_d$$

4. Emission Levels[17]

4.1 With the exception of CW and FM/CW radars, the radar emission level at the antenna input shall be no greater than the values obtainable from the curve in Figure 2. At the frequency B(–40dB)/2 displaced from F_0, the level shall be at least 40 dB below the maximum value. Between the –40dB and –XdB frequencies the level shall be below the 20dB per decade (S=20) roll-off lines in Figure 2. At and beyond the frequencies B(–XdB)/2 from F_0, the level shall be at least the dB value below the maximum spectral power density given by:

$$X(dB) = 60dB \quad \text{or} \quad X(dB) = P_t + 30$$

whichever is the larger value

NOTE: P_t may be measured or may for the purpose of these criteria be calculated from the following:

$$P_t = P_p + 20\log(N \times t) + 10\log(PRR) - PG - 90$$

where PG= 0, for non-FM, non-encoded pulse radars
10log(d), for FM pulse radars
10log(N), for coded pulse radars

[17] For frequency hopping radars, the radar spectrum shall not intrude into adjacent spectrum regions on the high or low side of the allocation band, defined by B_s, more than would occur if the radar were fixed tuned at carrier frequencies equivalent to the end values of B_s and was complying with the constraints given by paragraphs 4.1 and 4.2 of Sections 5.5.2, 5.5.3, and 5.5.4.

4.2 For CW and FM/CW radars, the levels of all emissions at the antenna input shall be no greater than the values obtainable from the curve in Figure 2. At the frequencies B(–40 dB)/2 displaced from F_0, the level shall be at least 40 dB below the maximum value. Between the –40 dB and –X dB frequencies, the level shall be below the 20 dB per decade (S=20) rolloff lines in Figure 2. At and beyond the frequencies B(X dB)/2 from F_0, the level shall be at least 60 dB below the maximum level of the signal contained within B(–40 dB). All levels are specified for a 1.0 kHz measurement bandwidth.

5. Antenna Pattern

No requirement is specified at present.

6. Radar Tunability

Each radar shall be tunable in an essentially continuous manner either over the allocated bands for which it is designed to operate, or over a band which is 10% of the midband frequency. Crystal controlled radars conform to this requirement if operation at essentially any frequency across the band can be achieved with a crystal change.

7. Radar Receivers

The overall receiver selectivity characteristics shall be commensurate with or narrower than the transmitter bandwidth, as portrayed in Figure 2. Rejection of spurious responses, other than image responses, shall be 50 dB or better except where broadband front ends are required operationally.

Receivers shall not exhibit any local oscillator radiation greater than -40 dBm at the receiver input terminals. The frequency stability shall be commensurate with, or better than, that of the associated transmitter.

8. Measurement Capability

See paragraph 2.1.2.B of Annex M.

5.5.3 Criteria C

1. Effective Dates

Technical criteria for new radars shall become effective 1 October 1977 except as noted herein. (New radars are those for which development and subsequent procurement contracts are let after 1 October 1977.)

2. Applicability

These criteria are applicable to radars of Group C, "all radars below 40 GHz not included in Group A, B or D".

3. Radar Emission Bandwidth

All radars procured prior to 1 January 1978 should be brought into compliance with the following standards when undergoing major overhaul.

The emission bandwidth for radars at the antenna input shall not exceed the following limits:

NOTE: There is also the "necessary bandwidth" parameter that is defined for radars. For the method of calculation, see Annex J.

3.1 For non-FM pulse radars (including spread spectrum or coded pulse radars): [15]

$$B(-40dB) = \frac{6.2}{\sqrt{t_r t}} \text{ or } \frac{64}{t}$$

whichever is less

3.2 For FM-pulse radars (intentional FM): [15]

$$B(-40dB) = \frac{6.2}{\sqrt{t_r t}} + 2(B_c + \frac{0.105}{t_r})$$

For FM pulse radars with pulse rise time, t_r, or fall time, t_f, of less than 0.1 microsecond, an operational justification for the short rise time shall be provided.

3.3 For FM pulse radars (intentional FM) with frequency hopping: [15, 16]

$$B(-40dB) = \frac{6.2}{\sqrt{t_r t}} + 2(B_c + \frac{0.105}{t_r}) + B_s$$

For FM pulse radars (intentional FM) with frequency hopping, but with pulse rise time, t_r, of less than 0.1 microsecond, an operational justification for the short rise time shall be provided.

3.4 For frequency hopping radars using non-FM pulses (including spread spectrum or coded pulses): [15, 16]

$$B(-40dB) = \frac{6.2}{\sqrt{t_r t}} + B_s$$

For this category of radars, an operational justification shall be provided if the pulse rise time, tr, is less than 0.01 microsecond.

3.5 For CW radars:

$$B(-40dB) = 0.0003F_0$$

3.6 For FM/CW radars:

$$B(-40dB) = 0.0003F_0 + 2B_d$$

4. Emission Levels[17]

4.1 With the exception of CW and FM/CW radars, the radar emission levels at the antenna input shall be no greater than the values obtainable from the curve in Figure 2. At the frequency ± B(–40 dB)/2 displaced from F_0, the level shall be at least 40 dB below the maximum value. Between the –40 dB and –X dB frequencies the level shall be below the 20 dB per decade (S=20) roll-off lines in Figure 2. At and beyond the frequencies ± B(–X dB)/2 from F_0, the level shall be at least the dB value below the maximum spectral power density given by:

$$X(dB) = 60dB \quad \text{or} \quad X(dB) = P_t + 30$$

whichever is the larger value

NOTE: Pt may be measured or may for the purpose of these criteria be calculated from the following:

$$P_t = P_p + 20\log(N \times t) + 10\log(PRR) - PG - 90$$

where PG = 0, for non-FM, non-encoded pulse radars
10log(d), for FM pulse radars
10log(N), for coded pulse radars

4.2 For CW and FM/CW radars, the levels of all emissions at the antenna input shall be no greater than the values obtainable from the curve in Figure 2. At the frequencies ± B(–40 dB)/2 displaced from F_0, the level shall be at least 40 dB below the maximum value. All levels are specified for a 1.0 kHz measurement bandwidth. Between the –40 dB and –X dB frequencies, the level shall be below the 20 dB per decade (S=20) rolloff lines in Figure 2. At and beyond the frequencies B(X dB)/2 from F_o, the level shall be at least 60 dB below the maximum level of the signal contained within B(–40 dB).

4.3 In the design and operation of systems in the radiolocation service that operate in the band 1350-1390 MHz, agencies are encouraged to take all feasible steps so that unwanted emission powers may not exceed −29 dBW in the Earth exploration-satellite service (passive) band 1400-1427 MHz.

5. Antenna Pattern

Since electromagnetic compatibility considerations involved phenomena which may occur at any angle, the allowable antenna patterns for many radars may be usefully described by "median gain" relative to an isotropic antenna.[18] Antennas operated by their rotation through 360° of the horizontal plane shall have a "median gain" of –10 dB or less, as measured on an antenna test range, in the principal horizontal plane. For other antennas, suppression of lobes other than the main antenna beam shall be provided to the following levels, referred to the main beam:

first three sidelobes: 17 dB;
all other lobes: 26 dB.

6. Radar Tunability

Each radar shall be tunable in an essentially continuous manner either over the allocated bands for which it is designed to operate, or over a band which is 10% of the midband frequency. Crystal controlled radars conform to this requirement if operation at essentially any frequency across the band can be achieved with a crystal change.

7. Radar Receivers

The overall receiver selectivity characteristics shall be commensurate with the transmitter bandwidth, as portrayed in Figure 2. Receivers shall be capable of switching bandwidth limits to appropriate values whenever the transmitter bandwidth is switched (pulse shape changed). Receiver image rejection shall be at least 50 dB; rejection of other spurious responses shall be at least 60 dB. Radar receivers shall not exhibit any local oscillator radiation greater than –40 dBm at the receiver input terminals. Frequency stability of receivers shall be commensurate with, or better than, that of the associated transmitters.

---

[18] Median gain is defined as that level over an angular region at which the probability is 50% that the observed or measured gain at any position of the antenna will be less than or equal to that level.

8. Measurement Capability

See paragraph 2.1.2.C of Annex M.

5.5.4 Criteria D

1. Effective Dates

Technical criteria for new fixed radars in the 2700-2900 MHz band shall become effective on 1 October 1982. (New radars are those for which the initial system procurement contract is let after 1 October 1982.)

2. Applicability

These criteria are applicable to fixed radars in the 2700-2900 MHz band. All radars subject to these criteria shall be designed and constructed to meet the basic minimum electromagnetic compatibility (EMC) requirements stated herein. In addition to the basic minimum EMC requirements, radar systems in the 2700-2900 MHz band which are intended to operate in close proximity to other equipment in the band or operate in areas specified in Annex D shall be designed and constructed to permit, without modification to the basic equipment, field incorporation of EMC enhancement provisions. These additional provisions will improve the electromagnetic compatibility of the radar thus improving the accommodation of the radar system in the band. These provisions are stated in Section 5.5.4, paragraph 8.

3. Radar Emission Bandwidth

The emission bandwidth for radars at the antenna input shall not exceed the following limits:

3.1 For non-FM pulse radars (including spread spectrum or coded pulse radars):[15]

$$B(-40dB) = \frac{6.2}{\sqrt{t_r t}}$$

For non-FM pulse radars, a pulse rise time, t_r, or fall time, t_f, of less than 0.1t shall be justified:

3.2 For FM-pulse radars (intentional FM):[15]

$$B(-40dB) = \frac{6.2}{\sqrt{t_r t}} + 2(B_c + \frac{0.105}{t_r})$$

For FM pulse radars with pulse rise time, t_r, of less than 0.1 microsecond, a justification for the short rise time shall be provided.

3.3 For FM pulse radars (intentional FM) with frequency hopping: [15, 16]

For FM pulse radars (intentional FM) with frequency hopping, but with pulse rise time, t_r, of less than 0.1 microsecond, an operational justification for the short rise time shall be provided.

$$B(-40dB) = \frac{6.2}{\sqrt{t_r t}} + 2(B_c + \frac{0.105}{t_r}) + B_s$$

3.4 For frequency hopping radars using non-FM pulses (including spread spectrum coded pulses):[15, 16]

$$B(-40dB) = \frac{6.2}{\sqrt{t_r t}} + B_s$$

For this category of radars, an operational justification shall be provided if the pulse rise time, t_r, is less than 0.01 microsecond.

3.5 For CW radars:

$$B(-40dB) = 0.0003F_0$$

3.6 For FM/CW radars:

$$B(-40dB) = 0.0003F_0 + 2B_d$$

4. Emission Level [17]

4.1 With the exception of CW and FM/CW radars, the radar emission levels at the antenna input shall be no greater than the values obtainable from the curve in Figure 2. At the frequencies ± B(–40 dB)/2 displaced from F_0 the level shall be at least 40 dB below the maximum value. Beyond the frequencies ± B(–40 dB)/2 from F_0, the emission level(s), with the exception of harmonic frequencies, shall be below the 40 dB per decade (S=40) roll-off lines of Figure 2 down to a –X dB level that is 80 dB below the maximum spectral power density. All harmonic frequencies shall be at a level that is at least 60 dB below the maximum spectral power density.

4.2 For CW and FM/CW radars, the levels of all emissions at the antenna input shall be no greater than the values obtainable from the curve in Figure 2. At the frequencies ± B(–40 dB)/2 displaced from F_0, the level shall be at least 40 dB below the maximum value. Between the –40 dB and –X dB frequencies, the level shall be below the 40 dB per decade (S=40) rolloff lines in Figure 2. At and beyond the frequencies B(-X dB)/2 from F_0, the level shall be at least 80 dB below the maximum level of the signal contained with B(–40 dB). All levels are specified for a 1.0 kHz measurement bandwidth.

5. Antenna Pattern

Since electromagnetic compatibility considerations involved phenomena which may occur at any angle, the allowable antenna patterns for many radars may be usefully described by "median gain" relative to an isotropic antenna.[19] Antennas operated by their rotation through 360 degrees of the horizontal plane shall have a "median gain" of –10 dB or less, as measured on an antenna test range, in the principal horizontal plane. For other antennas, suppression of lobes other than the main antenna beam shall be provided to the following levels, referred to the main beam:

first three sidelobes--17 dB;
all other lobes--26 dB.

6. Radar Tunability

Radar systems shall be tunable over the entire 2700-2900 MHz band.

7. Radar Receiver

The overall receiver selectivity characteristics shall be commensurate with the transmitter bandwidth, as portrayed in Figure 2. Receivers shall be capable of switching bandwidth limits to appropriate values whenever the transmitter bandwidth is switched (pulse shape changed). Receiver image rejection shall be at least 50 dB; rejection of other spurious responses shall be at least 60 dB. Radar receivers shall not exhibit any local oscillator radiation greater than –40 dBm at the antenna input terminals. Frequency stability of receivers shall be commensurate with, or better than, that of the associated transmitters.

8. Additional EMC Provisions

To improve the accommodation of radar systems in the 2700-2900 MHz band which operate in close proximity to other equipment in the band or operate in areas specified in Annex D, the radar shall be designed and constructed to permit, without modification to the basic equipment, field incorporation of system EMC provisions. These provisions include the requirement to meet specifications in accordance with paragraphs a. and b. below and the recommendation to meet guidelines in accordance with paragraph c. below.

a. Emission Levels

The radar emission levels at the antenna input shall be no greater than the values obtainable from the curves in Figure 2. At the frequency ± B(–40 dB)/2 displaced from F_o, the level shall be at least 40 dB below the maximum value. Beyond the frequencies ± B(–40 dB)/2 from F_o, the equipment shall have the capability to achieve up to 80 dB per decade (S=80) roll-off lines of Figure 2. The emission levels, with the exception of harmonic frequencies, shall be below the appropriate dB per decade roll-off lines of Figure 2 down to a –X dB level that is 80 dB below the maximum spectral power density. All harmonic frequencies shall be at a level that is at least 60 dB below the maximum spectral power density.

b. Radar System PRF

The radar system shall be designed to operate with an adjustable pulse repetition frequency(s), PRF (s), with a nominal difference of 1% (minimum). This will permit the selection of PRF's to allow certain types of receiver interference suppression circuitry to be effective.

c. Receiver Interference Suppression Circuitry

Radar systems in this band should have provisions incorporated into the system to suppress pulsed interference. The following information is intended for use as an aid in the design and development of receiver signal processing circuitry or software to suppress asynchronous pulsed interference. A description of the parametric range of the expected environmental signal characteristics at the receiver IF output is:

Peak Interference-to-Noise Ratio: < 50 dB
Pulse width: 0.5 to 4.0 μsec
PRF: 100 to 2000 pps

8. Measurement Capability

See paragraph 2.1.2.C of Annex M.

5.5.5 Criteria E

1. Effective Dates

Technical criteria for new wind profiler radars (WPR) operating on 449 MHz shall become effective on 1 January 1994. (New WPRs are those for which the initial systems procurement contract is let after 1 January 1994.)

2. Applicability

These criteria are applicable to WPR's operating on 449 MHz.

3. Emission Bandwidth

The emission bandwidth for WPR's at the antenna input shall not exceed the following limits:

3.1 For non-FM pulse radars (including coded pulse radars): [15]

$$B(-40dB) = \frac{6.2}{\sqrt{t_r t}} \quad \text{or} \quad \frac{64}{t}$$

whichever is less.

3.2 For FM-pulse radars (intentional FM):[15]

$$B(-40dB) = \frac{6.2}{\sqrt{t_r t}} + 2(B_c + \frac{0.105}{t_r})$$

3.3 For wind profiler radars, an operational justification shall be provided if the pulse rise time, t_r, is less than 0.01 microsecond.

3.4 For CW radars

$$B(-40dB) = 0.0003F_0$$

3.5 For FM/CW radars

$$B(-40dB) = 0.0003F_0 + 2B_d$$

4. Emission Levels[17]

WPR emission levels at the antenna input shall be no greater than the values obtainable from the curve in Figure 3. At the Frequencies ± B(-40 dB)/2 displaced from F_0, the level shall be at least 40 dB below the maximum value. Between the -40 dB and -X dB frequencies, the level shall be below the 40 dB per decade (S=40) roll-off lines in Figure 3. At and beyond the frequencies ± B(-X dB)/2 from F0, the level shall be at least the dB value below the maximum spectral power density given by:

$$X(dB) = 60dB \quad \text{or} \quad X(dB) = P_t + 30$$

whichever is the greater attenuation

All harmonic frequencies shall be at a level that is at least 60 dB below the maximum spectral power density.

NOTE: P_t may be measured or may for the purpose of these criteria be calculated from the following:

$$P_t = P_p + 20\log(N \times t) + 10\log(PRR) - PG - 90$$

5. **EIRP**

The EIRP[19] of any WPR operating at 449 MHz shall not exceed the following values:

		Median	Maximum
for	elevation angle > 70 deg[20]		110 dBm
for	60 <elevation angle < 70 deg	83 dBm	95 dBm
for	45< elevation angle < 60 deg	78 dBm	90 dBm
for	5< elevation angle < 45 deg	73 dBm	85 dBm
for	elevation angle < 5 deg	58 dBm	70 dBm

6. WPR Receiver

The -3 dB receiver bandwidth should be commensurate with the authorized emission bandwidth plus twice the transmitter frequency tolerance of 10 ppm (as specified in Section 5.2.1). The -60 dB receiver bandwidth shall be commensurate with the -60 dB emission bandwidth. Receivers shall be capable of switching bandwidth limits to appropriate values whenever the transmitter bandwidth is switched (pulse shape changed). Receiver IF image frequency rejection shall be at least 50 dB. Rejection of other spurious responses shall be at least 60 dB. WPR receivers shall not exhibit any local oscillator radiation greater than -40 dBm at the antenna input terminals.

7. EMC Provision

WPR's shall have the capacity to tolerate incoherent pulsed interference of duty cycles less than 1.5 percent such that peak interfering signal levels 30 dB greater than WPR receiver noise level at the IF output will not degrade WPR performance.

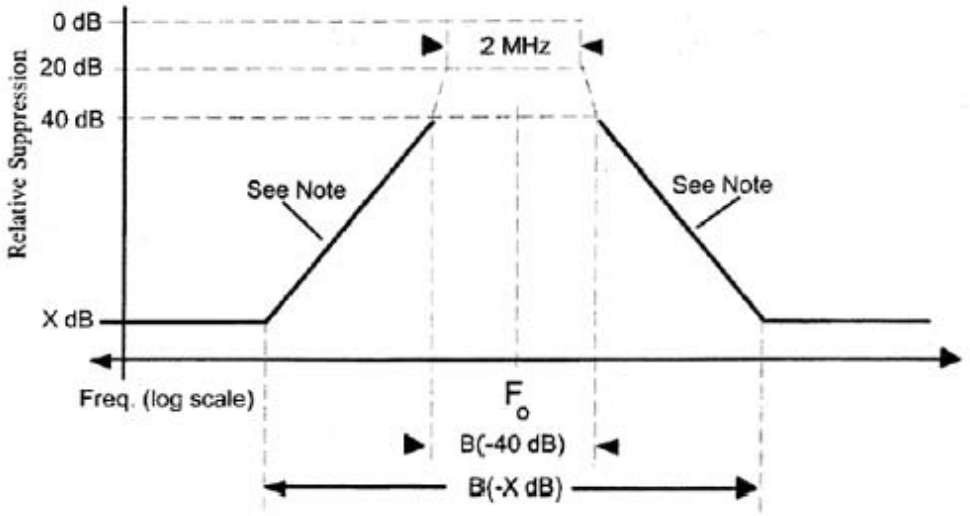
8. Measurement Capability

See paragraph 2.1.2.D of Annex M.

---

[19] EIRP is the sum of two quantities: peak transmitter power in dBm and antenna gain in dBi. The column labeled Median is based on median antenna gain and the column labeled Maximum is based on maximum antenna gain.

[20] The center of the antenna main beam generated at any time shall be limited to elevation angles greater than 70 degrees.



Note: The roll-off slope, S, from the -40 dB to -X dB points is at 40 dB per decade for Criteria E. The -20 dB bandwidth is limited to 2 MHz for Wind Profiler radars operating at 449 MHz. The maximum emission spectrum level between the -40 dB and -X dB points for S dB per decade slope is described by the formula:

$$Suppression\ (dB) = -S * \log\left|\frac{F - F_o}{\frac{1}{2}B(-40dB)}\right| - 40$$

$$Where:\ \frac{1}{2}B(-40dB) \le \left|F - F_o\right| \le \frac{1}{2}B(-XdB)$$

and: F is the frequency at which suppression is calculated

$$and:\ B(-XdB) = (10^{a})\ B(-40dB)$$

$$a = \frac{X-40}{S}$$

Figure 3. Radar Emission Bandwidth and Emission Levels for Wind Profiler Radars at 449 MHz (Criteria E)

5.6 SPACE SERVICES

5.6.1 General

These requirements are applicable to Federal space systems including associated earth terminals and space stations operating in portions of the spectrum allocated to the space services above 470 MHz. They do not apply to transmissions from radars on the ground or aboard spacecraft. Standards for radars aboard spacecraft are contained in Part 5.5. Standards for earth and space stations operating in bands below 470 MHz are contained in Part 5.2.

For planning and evaluation purposes this standard cannot be used alone. Modulation type, emission spectrum, power output, frequency tolerance, and maximum expected Doppler shift should be considered and provided in accordance with Chapter 10 of this Manual.

The requirements of this standard do not apply to deep space spacecraft transmitters while operating at distances greater than 2,000,000 km from Earth, in those frequency bands allocated to space research (space-to-earth) (Deep Space Only). This exemption of deep space spacecraft transmitters from unwanted emissions standards will be reviewed every 5 years, beginning in the year 2005. Such a review will take account of radio astronomy requirements (see RR **22.22-22.25**), as soon as radio astronomy activities on the Shielded Zone of the Moon, or in Deep Space get under way.

5.6.2 Unwanted Emission Mask

For frequencies offset from the assigned frequency less than the 50% of the necessary bandwidth (B_n), no attenuation is required. At a frequency offset equal to 50% of the necessary bandwidth, an attenuation of at least 8 dB is required. Frequencies offset more than 50% of the necessary bandwidth should be attenuated by the following mask:

$$40 \times \log\left(\frac{2 \times |f_d|}{B_n}\right) + 8 \text{ dBsd}$$

where f_d is the frequency displaced from the center of the emission bandwidth.

1) Annex J gives procedures for determining B_n.
2) dBsd is dB attenuation in a 4 kHz bandwidth, relative to the maximum power in any 4 kHz bandwidth within the necessary bandwidth (0dBsd). Above 15 GHz, a 1 MHz bandwidth may be used.
3) Attenuation in this sense refers to the reduction in level relative to the reference, 0 dBsd, unless otherwise specified.
4) The unwanted emission mask rolls off at 40 dB per decade to a maximum attenuation of 60 dBsd, at which point it continues on both sides of the carrier for all frequencies beyond this point. See Figure 5.6.1. Annex M gives measurement requirements.
5) For any narrowband or single frequency unwanted emission which is not spread by the modulation process, the required attenuation shall be at least 60 dBc, where dBc is attenuation below the mean transmit power, rather than the dBsd value determined above.
6) In the design of systems and operation of stations in the fixed-satellite service (Earth-to-space) in the band 30-31 GHz, agencies are encouraged to take all reasonable steps such that unwanted emission powers do not exceed: [21]
   a) −9 dBW into the 200 MHz of the Earth exploration-satellite service (passive) band 31.3-31.5 GHz for earth stations having an antenna gain greater than or equal to 56 dBi; and
   b) −20 dBW into the 200 MHz of the Earth exploration-satellite service (passive) band 31.3-31.5 GHz for earth stations having an antenna gain less than 56 dBi.

5.6.3 Multi-carrier Emissions and Multi-transponder Satellites

Multi-carrier transmitters/transponders are those where multiple carriers may be transmitted simultaneously from a final amplifier or an active antenna. For systems with multiple carriers, the limit on unwanted emissions should start at the edges of the total assigned bandwidth. For satellite systems, the necessary bandwidth used in the masks in 5.6.2 should be taken to be the lesser of 3 dB transponder bandwidth or the total assigned bandwidth. This bandwidth applies even when some of the carriers are not transmitted continuously, or when some carriers change in frequency. More information on unwanted emission masks for multi-carrier and multi-transponder systems can be found in ITU-R Recommendation SM.1541 and Appendix **3** to the ITU-R Radio Regulations.

5.6.4 Unwanted Emissions From One Transponder Falling Within The Frequency Band of Another Transponder On The Same Satellite

A single satellite operating with more than one transponder in the same service area may have unwanted emissions from one transponder falling on a frequency at which a second companion

---

[21] These recommended maximum levels apply under clear-sky conditions. During fading conditions, these levels may be exceeded by earth stations when using uplink power control.

transponder is transmitting. The limits should not be applied to those unwanted emissions of a satellite that fall within the necessary emission bandwidth of another transponder, on the same satellite, into the same service area.

5.6.5 Narrow Band Emissions

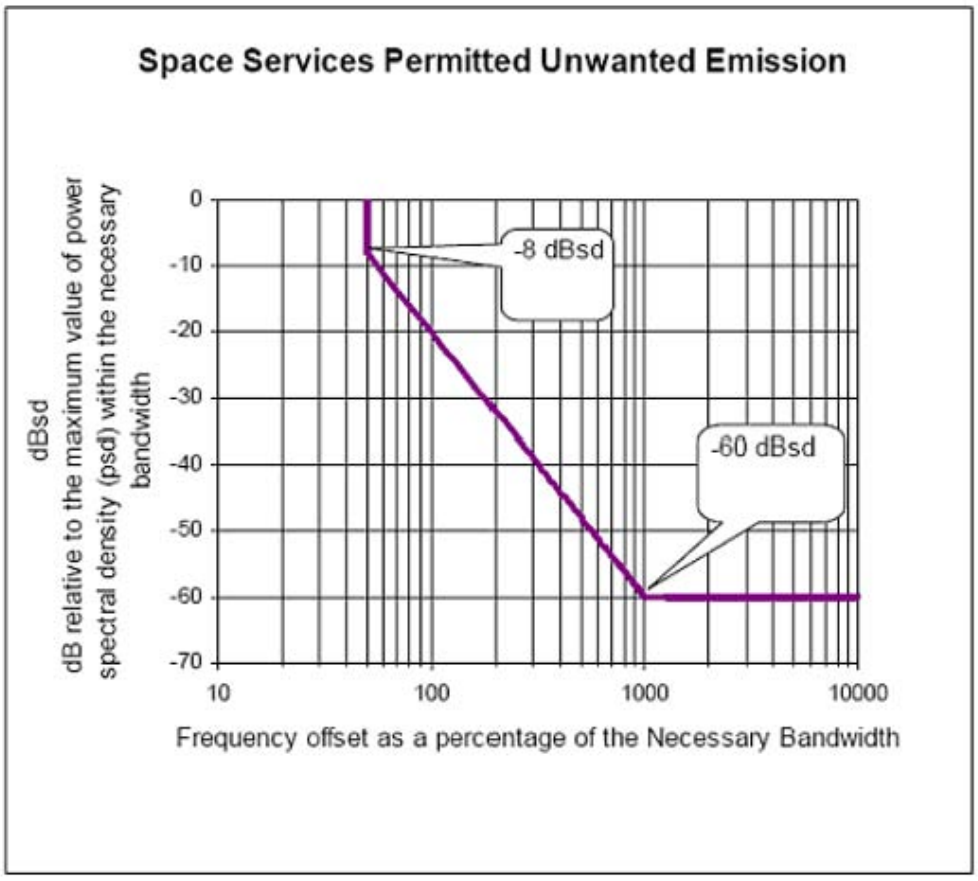
In the case of very narrow-band emissions where the necessary bandwidth is less than the minimum bandwidth (B_L) given in Table 5.6.1, B_L shall be used in place of B_n in Section 5.6.2 above. Examples include beacons, pilots and other unmodulated carriers.

5.6.6 Table 5.6.1 Minimum Bandwidth

Operating Frequency Range (f_c)	Minimum Bandwidth (B_L)
470 MHz < fc < 1 GHz	25 kHz
1 GHz < fc < 10 GHz	100 kHz
10 GHz < fc < 15 GHz	300 kHz
15 GHz < fc < 26 GHz	500 kHz
fc > 26 GHz	1 MHz

In Table 5.6.1, f_c is the center frequency of the emission. If the assigned frequency band of the emissions extends across two frequency ranges, then the values corresponding to the higher frequency range may be used for the whole assignment.

Figure 5.6.1 Maximum Unwanted Emission Levels for Space Services



(Last Page in Chapter 5)