Chapter 5
Spectrum Standards

5.1 GENERAL

5.1.1 Introduction

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

2. 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:

a. Assisting consideration of telecommunications systems for the National spectrum review process (Chapter 10),

b. Systems planning, design, and procurement,

c. Consideration of protection devices for the transmission of classified, and/or sensitive but unclassified information, and their spectrum needs.

3. 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.

4. 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.

5. 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

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

Desired Relationship of Occupied Bandwidth to Necessary Bandwidth

2. 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

3. 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, Chapter 6, in addition for the definitions of special terms including authorized bandwidth and mean power.

Resolution Bandwidth

4. 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

1. 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.

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

3. 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.

4. 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.

5. 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 radiotelephone	10
B. SSB radiotelephone	20 Hz
II. Mobile (Aeronautical, Land, Maritime) Stations	
A. Aeronautical Mobile Stations	
1. Aeronautical a. pY ≤ 200W except SSB radiotelephone b. pY > 200W except SSB radiotelephone 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 radiotelephone b. pY > 200W, except SSB radiotelephone 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 radiotelegraphy and data	 40 (f) 40 Hz 40 Hz
3. Survival Craft a. EPIRB	 100
III. Radiodetermination Stations	
A. Radionavigation 1. pY ≤ 200W 2. pY > 200W	 20 10
B. Radiolocation	10
IV. 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	20
b. pY > 500W, except SSB	10
c. SSB Radiotelephone	20 Hz
2. Land Mobile	
a. All except SSB	30
b. SSB Radiotelephone	20 Hz
C. Maritime mobile stations	
1. Coast	
a. SSB radiotelegraph	20 Hz
b. Direct printing telegraph and data	10 Hz
c. Other than above	20 Hz (g)
2. Ship	
a. Class A1A emission	10
b. Other than A1A emissions	
(1) SSB Radiotelephone	50 Hz
(2) Direct printing, telegraphy and data	10 Hz
(3) Other than above	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	5
2. pY > 10W	2
D. 406-470 MHz	
1. 406.1-420 MHz	
a. Multi-Channel	2.5 (m)(n)
b. Analog/Digital FM/PM	
(1) Wideband	2.5 (i)
(2) Narrowband	1.0 (o)
2. Other than above	
a. pY ≤ 10 W	5
b. pY > 10 W	2.5
II. Mobile (Aeronautical, Land, Maritime) Stations	
A. Aeronautical mobile stations	
1. Aeronautical	
a. Analog/digital FM/PM	
(1) 162-174 MHz	5(i)
(a) Wideband	1.5(o)
(b) Narrowband	
(2) 406.1-420 MHz	2.5 (i)
(a) Wideband	1.0 (o)
(b) Narrowband	
b. Other than above	20
2. Aircraft	
a. 156-174 and 406.1-420 MHz	
(1) 162-174 MHz analog/digital FM/PM	
(a) Wideband	5(i)
(b) Narrowband	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)
(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)162.0125 - 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 - 162.0125 MHz except for above	10
c. 162.0125 - 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)
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)
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)
B. TV Broadcasting Translators	200
V. Space and Earth Stations	20

Frequency Band 960 to 1215 MHz	**Frequency Tolerance**

I. Aeronautical RadionavigationStations	
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. 4000 MHz 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 5.3.8, or NOAA Weather Radio Transmitters. The measurement method for the receiver frequency tolerance is contained in paragraph M.2.1.5.1.(b) 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 M.2.1.3.1.(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 5.3.8, 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 M.2.1.2, 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 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, and 23.275 GHz only.

(v) Stations already operational, or have been approved by NTIA/SPS shall conform to a 2.5 ppm tolerance standard.

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)	5.3.6
Analog or Digital FM/PM Narrowband Operations (138-150.8,162-174, and 406.1-420 MHz)	5.3.7
Low Power Channels and Splinter Channels (162-174 MHz and 406.1-420 MHz)	5.3.8
Telemetry, Terrestrial (1435-1525, 2200-2290, 2310-2320, 2345-2395, 4400-4940, and 5091-5150 MHz)	5.3.9
Analog Transmissions and Low Power Transmit (21.2-23.6 GHz)	5.3.10
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)	5.3.6
Analog or Digital FM/PM Narrowband Operations (138-150.8, 162-174 MHz and 406.1-420. MHz)	5.3.7
Low Power Channels and Splinter Channels (162-174 MHz and 406.1-420 MHz)	5.3.8
Telemetry, Terrestrial (1435-1525, 2200-2290, 2310-2320, 2345-2395, 4400-4940, and 5091-5150 MHz)	5.3.9
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)	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	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:

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

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

c. On any frequency removed from the assigned frequency by more than 300 percent of the authorized bandwidth, and the image, 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:

(1) 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.

(2) 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).

(3) 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).

(4) 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):

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

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

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

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

(2) 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:

(a) 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.

(b) 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.

(c) 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 these 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.

5.3.1.1 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

2. 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.

3. For the land mobile service, the peak power of any emission on any frequency removed from the center of the authorized bandwidth1 (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
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)

4. 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.

5. 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.

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

5.3.1.2 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.

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.

5.3.1.3 Antenna Standards[3]

1. Fixed Station

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

b. 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

---

[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.

[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

reference antenna used in an actual measurement must be specified relative to an isotropic antenna.

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

2. 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.

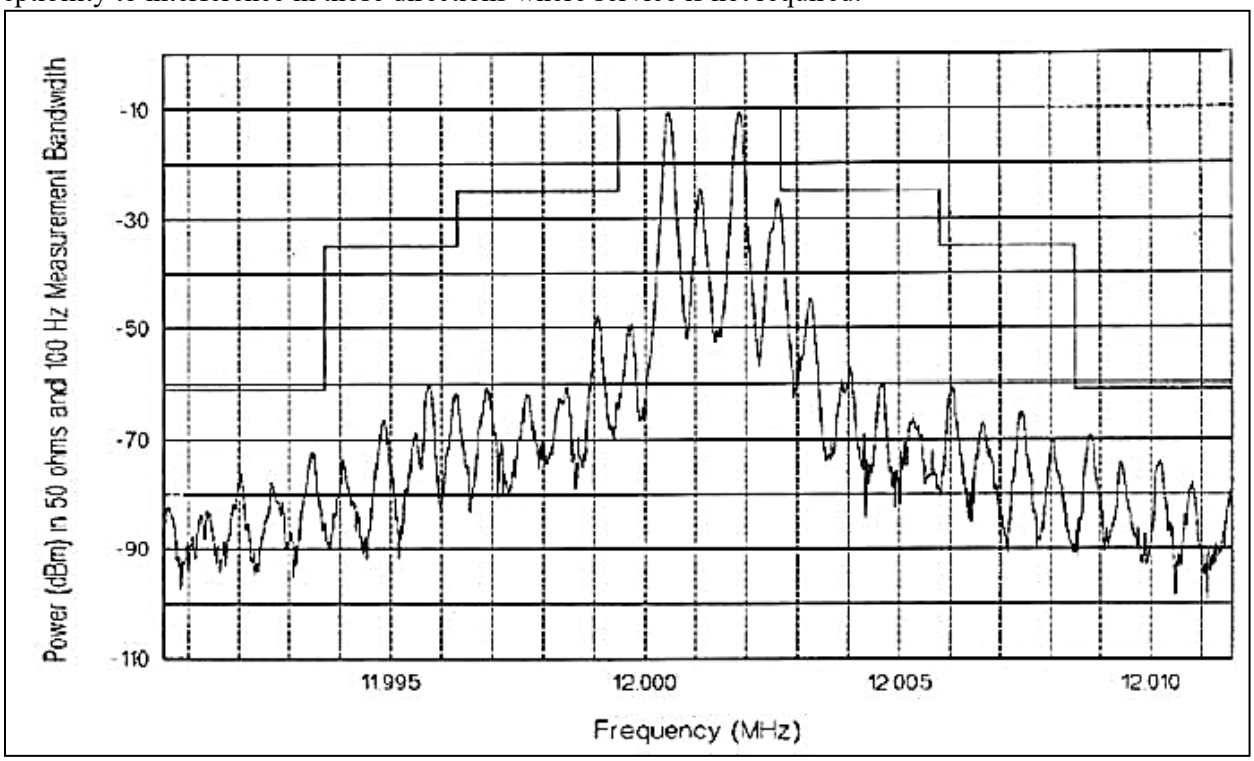


Figure 5.3.1
RSL (dBm) vs. Frequency (MHz)
Example of Measured Emission for HF SSB Transmitter Fundamental with NTIA Standard in Section 5.3.1.
Modulation Tones = 400 Hz and 1800 Hz, Resolution BW = 100 Hz, Span = 21.1 kHz

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

1. 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.

2. 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, the 1780 MHz-15.35 GHz, the 21.8-22.075 GHz and 23-23.275 GHz Frequency Ranges)

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, (c) point-to-point and transportable type equipment operating between 1710 MHz and 15.35 GHz (except for systems designed to use scatter techniques), or (d) point-to-point type equipment operating between 21.8-22.075 GHz and 23-23.275 GHz.

---

space, in order to account for ground reflection.

5.3.3.1 Transmitter Standards

1. 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 5.3.3.a for a sample application of this standard)

b. For transmissions employing digital modulation techniques:[5]

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 or an absolute power of less than -13/dBm/MHz 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 M.2.1.3.1.(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(fd/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(fd/5.3) decibels;

(4) On any frequency removed from the center of the authorized bandwidth by a displacement frequency

[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.

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
1780-1850	80
2200-2290	For Path Length of Less than 25 km: 80 - 40*Log (25/Path Length in km) For Path Length of Greater than 25km: 80
4400-4940	For Path Length of Less than 25 km: 80 - 40*Log (25/Path Length in km) For Path Length of Greater than 25km: 80
7125-8500	For Path Length of Less than 25 km: 80 - 40*Log (25/Path Length in km) For Path Length of Greater than 25km: 80
14400-15350	85
21800-22075	85
23000-23275	85
The effective date for the new EIRP limits is January 1, 2013. All existing systems will be grandfathered under the current EIRP limits.	

(a) Federal agencies shall be granted an exemption to the EIRP limits in this table if an appropriate technical rationale is provided. Federal agencies using microwave links to safeguard property and lives will be afforded additional considerations by the NTIA committees to ensure that integrity of those microwave links are not negatively impacted by reduction of the EIRP limits.

(b) Transmitters shall use automatic transmitter power control (ATPC) where feasible. The EIRP of a fixed microwave system using ATPC shall not exceed the authorized limit. The effective date for use of ATPC is July 31, 2017. All existing systems will be grandfathered prior to the effective date.

5.3.3.2 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 M.2.1.3.2.(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.

4. 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.

5. 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.

6. 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).

5.3.3.3 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.

a. 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.

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

c. Directional antennas shall meet the performance standards indicated in Table 5.3.3, Table 5.3.4 and Table 5.3.5. 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.

Table 5.3.3

Frequency Band	Maximum Half Power Beamwidth (3 dB point)	Minimum Suppression at Angle in degrees off Mainbeam Axis (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
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 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 5.3.3.3. These suppression levels could be met, e.g., by a 1.83 meter (6 foot) diameter parabolic antenna.

Table 5.3.4

Frequency Band	Category	Maximum Half Power Beamwidth (3dB Point)	Minimum Suppression at Angle in degrees Off Mainbeam Axis (dB)						
			5-10	10-15	15-20	20-30	30-100	100-140	140-180
4.4-4.94 GHz	A	4	13	20	23	24	29	31	31
	B1	7.5	5	15	22	24	27	29	31
	B2	14	**5-10**	**10-15**	**15-30**	**30-60**	**60-100**	**100-140**	**140-180**
			1.3	5	10	15	20	29	31

Notes:

1. There are three categories of antenna standards in the 4.4-4.94 GHz band:
   Category A: Applicable to all antennas.
   Category B1: Applicable to parabolic antennas with a diameter of less than 1.2 meters (4 foot).
   Category B2: Applicable to flat panel antennas.
2. The use of high performance standard antennas is required where interference problems occur.
3. The new standard is applicable to antennas procured after January 1, 2017. Antenna systems that have been procured prior to January 1, 2017 will be "grandfathered" under the new rules.

Table 5.3.5

Frequency Band	Category	Maximum Half Power Beamwidth (3dB point)	Minimum Suppression at Angle in degrees off Mainbeam Axis (dB)						
			5-10	10-15	15-20	20-30	30-100	100-140	140-180
7.125-8.5 GHz	A	2.5	19	23	28	30	34	35	43
	B	4.7	11	17	21	23	27	51	51

Notes:

1. There are two categories of antenna standards in the 7.125-8.5 GHz band:
   Category A: Applicable to all antennas in the band.
2. Category B: Applicable to parabolic dish antennas with a diameter of less than 1.2 meters (4 foot). The use of high performance standard antennas is required where interference problems occur.
3. The new standard is applicable to antennas procured after July 1, 2018. Antenna systems procured and approved by NTIA prior to July 1, 2018 will be "grandfathered" under the new rules.

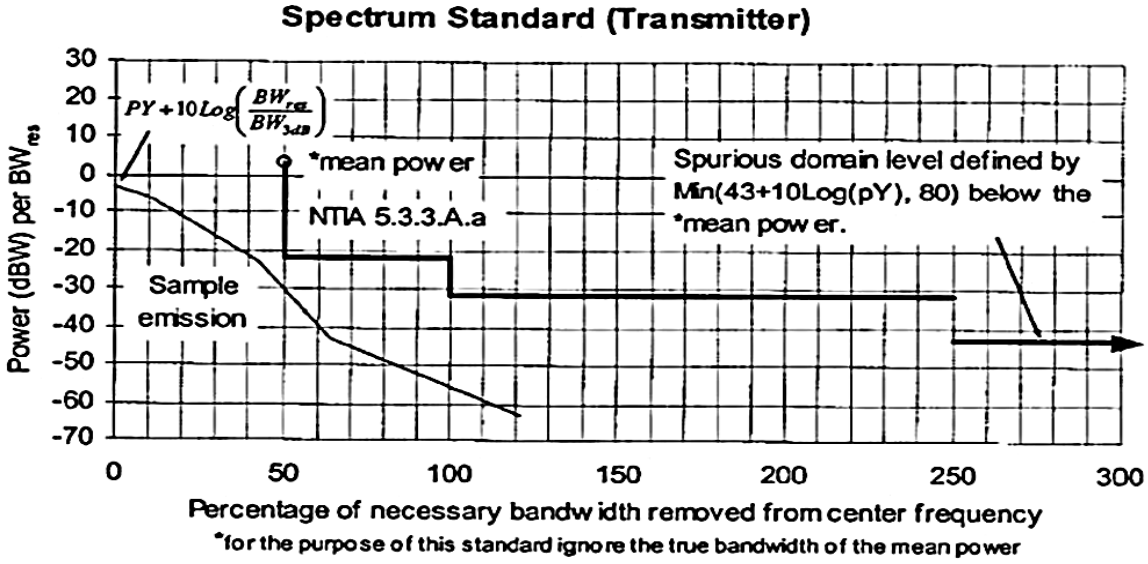


Figure 5.3.3a

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.

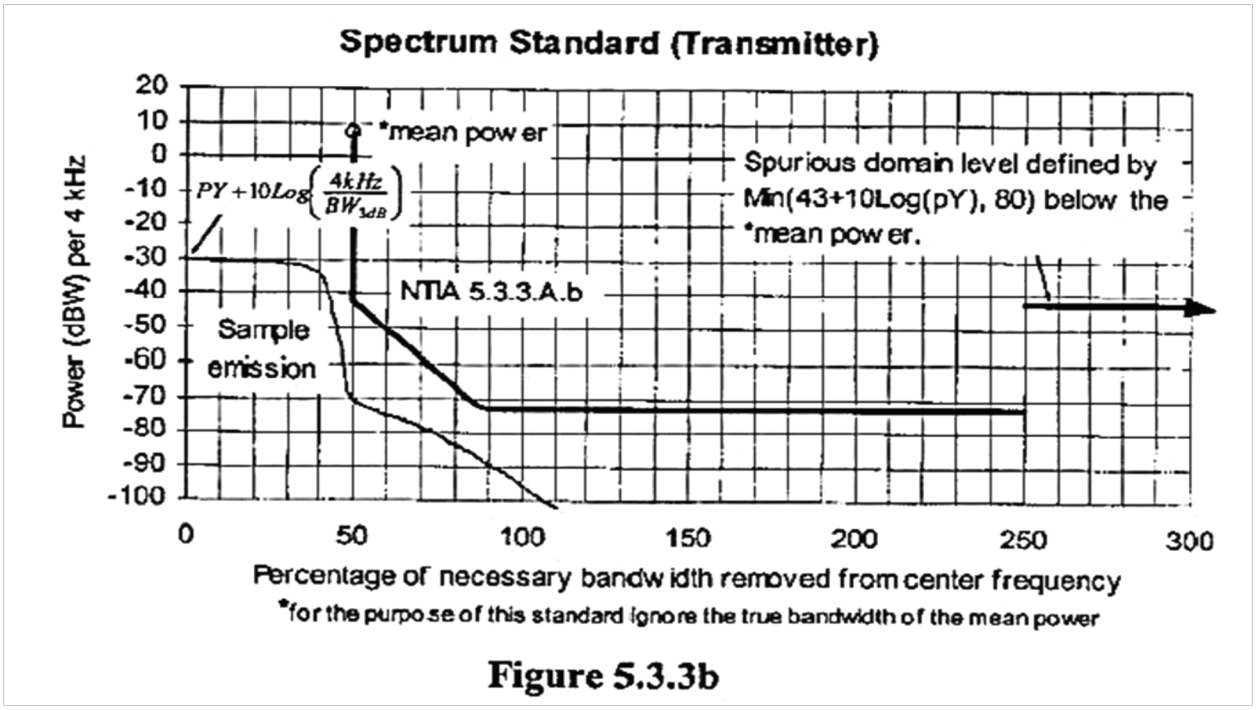


Figure 5.3.3b

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.

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.

5.3.3.4 Interference Analysis Methodology for Frequency Coordination

1. Fixed microwave systems shall apply interference analysis methodology specified in the Telecommunication Industry Association's Telecommunications Systems Bulletin TSB - 10F (TSB - 10F) for frequency coordination or established engineering practices.

2. Fixed microwave systems that operate ATPC in the bands of 1780-1850 MHz, 2200-2290 MHz, 4400-4940 MHz, and 7125-8500 MHz, nominal transmit power, ATPC trigger level, and coordinated transmit power shall be provided for frequency assignment.

5.3.3.5 Spectrum Efficiency Standards

For all Fixed Service bands in Section 5.3.3 with the exception of three bands shown in the Table below, the bit rate (in bits per second) of digital microwave transmitters must be equal to or greater than the bandwidth specified by the emission designator in Hertz.

For the following bands, the minimum efficiency standards for the payload capacity of digital equipment apply:

Frequency	**Emission bandwidth ≤5 MHz**	**Emission bandwidth >5 MHz and ≤20 MHz**	**Emission bandwidth >20 MHz**
4400-4940 MHz	2.4 bits/second/Hertz	4.4 bits/second/Hertz	4.4 bits/second/Hertz
7125-8500 MHz	2.4 bits/second/Hertz	4.4 bits/second/Hertz	4.4 bits/second/Hertz
14.4-15.35 GHz	2.4 bits/second/Hertz	4.4 bits/second/Hertz	3.0 bits/second/Hertz

Traffic loading payload shall exceed 50 percent of payload capacity within 60 months of obtaining a frequency authorization. Fixed Service links must comply with the capacity and loading requirements that use digital equipment capable of adjusting modulation and must be designed using generally accepted multipath fading and rain fading models to meet the specified capacity and loading requirements at least 99.95 percent of the time, in the aggregate for both directions in a two-way link.

The effective date is January 1, 2021. A waiver request may be submitted in accordance with Section 10.1.3 (and/or Section 5.1.2 if relevant) or Section 8.2.6, providing a justification that should include a narrative and relevant technical information for evaluation. Existing Fixed Service systems will be grandfathered. Fixed service systems used for backup and frequency diversity are exempted from the traffic-loading requirement.[6]

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.

5.3.4.1 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**
	the	$30 + 20(f_d-2)$ or
$2 < f_d \leq 3.75$	lesser	$55 + 10\log(pX)$ or
	of	65
$3.75 < f_d$	at least	$55 + 10\log(pX)$

The Measurement Method is in paragraph M.2.1.4 of Annex M.

5.3.4.2 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.

[6] Frequency diversity is the process of receiving a radio signal on multiple frequencies to reduce the effects of radio signal distortions (such as multipath fading) that occur on one frequency but do not occur on another frequency. A backup microwave system is a redundant system, and only becomes operational when the primary system is down.

** 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 5.3.4.3)

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 μ signal level contour.

5.3.4.3 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)[7]

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

1. Standards in this section related specifically to digital systems became effective on October 1, 1990.
2. 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.

[7] 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).

- Equipment operating on splinter channels. (see Section 5.3.8).
- Fixed stations equipment with multichannel emissions (see Section 5.3.3).

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.[8]

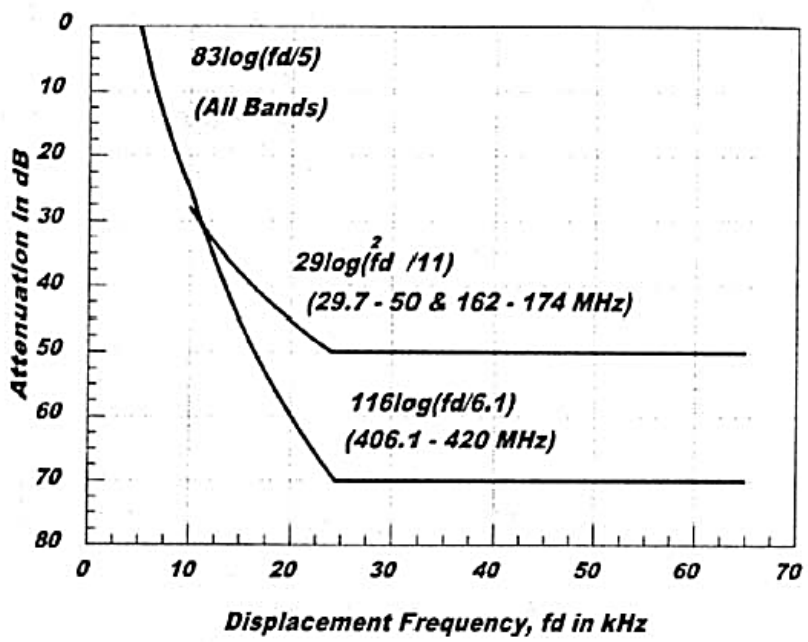
Stations with digital input may require a different necessary bandwidth but still must meet all other standards.

5.3.6.1 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 5.3.6.1.

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 5.3.6.1



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 5.3.6.1 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 M.2.1.5.1 of Annex M.

[8] The spacing of channels (adjacent channel spacing) is 20 kHz in the 30-50 MHz band and 12.5 kHz in the 162-174 and 406.1-420 MHz bands.

5.3.6.2 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 M.2.1.5.1 of Annex M.

5.3.7 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, and 5.3.8.
- NOAA Weather Radio Transmitters.

5.3.7.1 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.

5.3.7.2 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 lifecycle of the equipment.

5.3.7.3 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

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 5.3.7.1.

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 M.2.1.5.2 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 M.2.1.5.2 of Annex M.

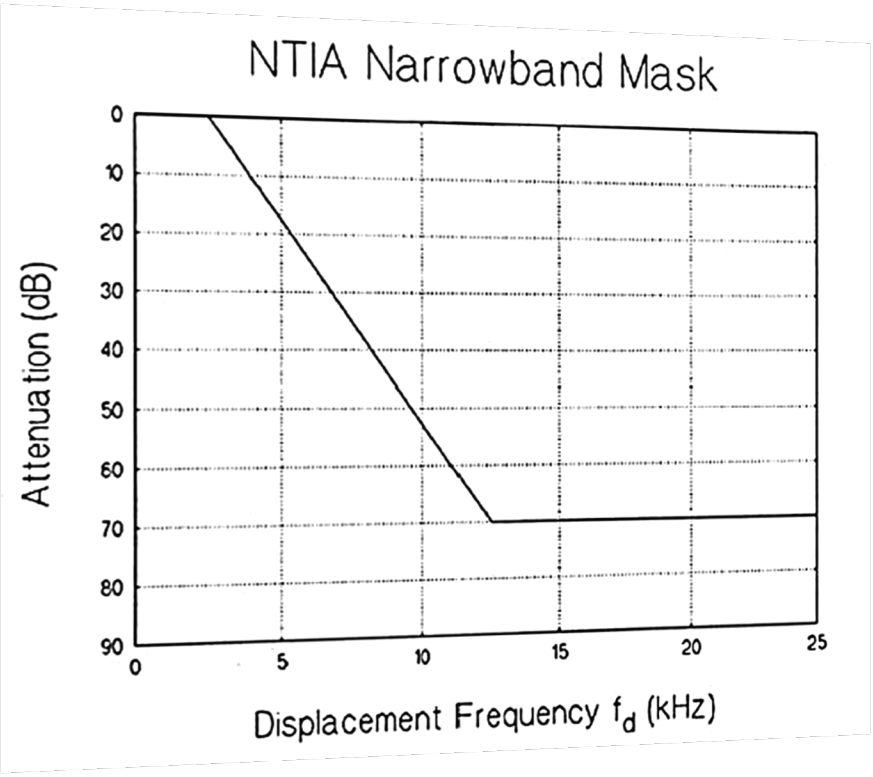


Figure 5.3.7.1

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.)

5.3.8 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.

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 (f_d 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 ≤ 100% BW	25
100%BW < f_d ≤ 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 406.1-420 MHz band shall be limited to 30 watts.

5.3.9 Telemetry, Terrestrial (1435-1525, 2200-2290, 2310-2320, 2345-2395, 4400-4940, and 5091-5150 MHz Bands)

This standard is applicable to terrestrial telemetering stations, authorized for operation in the bands 1435-1525,

2200-2290, 2310-2320, 2345-2395, 4400-4940, and 5091-5150 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.irig106.org/docs/106-15/. Subsequent revisions of this document will be reviewed by the Technical Subcommittee prior to adoption.

5.3.10 Low Power Transmit (21.8-22.075 and 23.0-23.275 GHz Band Segments)[9]

1. 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

2. **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 degrees with a minimum front-to-back ratio of 38 dB.

5.3.11 Standard for Fixed and Mobile Digital 6.25 kHz Channel Equipment in the 162-174 MHz and 406.1-420 MHz Band

The provisional standards outlined in this section applies to land mobile radio equipment employing a 6.25 kHz channel in the 162-174 MHz and 406.1-420 MHz band.

5.3.11.1 Standards

The following standards apply to fixed and mobile/land mobile services employing fixed, land, mobile, and portable stations using 6.25 kHz channels in the 162-174 MHz and 406.1-420 MHz band. The transmitter standard is based upon the FCC emission mask for 6.25 kHz or less channel bandwidth equipment specified in 47 C.F.R. Section 90.210(e)(1)-(3). The receiver standard is based upon Class A receiver limits as specified in the appropriate TIA publication.

---

[9] 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.

5.3.11.2 Effective Dates

These provisional standards for fixed, land, mobile, and portable stations using 6.25 kHz channels in the subject frequency band shall became effective on February 1, 2016.

5.3.11.3 Waivers

Waivers of this provisonal standard are not necessary.

A. Transmitter

1. For transmitters designed to operate with a 6.25 kHz or less bandwidth, any emission must be attenuated below the power (P) in watts of the highest emission contained within the authorized bandwidth as follows:

a. On any frequency from the center of the authorized bandwidth f_0 to 3.0 kHz removed from f_0: Zero dB.

b. On any frequency removed from the center of the authorized bandwidth by a displacement frequency (f_d in kHz) of more than 3.0 kHz but no more than 4.6 kHz: At least 30 + 16.67(f_d−3 kHz) or 55 + 10 log (P) or 65 dB, whichever is the lesser attenuation.

c. On any frequency removed from the center of the authorized bandwidth by more than 4.6 kHz: At least 55 + 10 log (P) or 65 dB, whichever is the lesser attenuation.

2. The Measurement Method is in paragraph M.2.1.5.3 of Annex M.

B. Receiver

1. Spurious Response Attenuation:

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

2. Adjacent Channel Selectivity:

Station Class	Digital
Land, Fixed	60 dB
Mobile	60 dB
Portable	60 dB

3. Intermodulation Rejection:

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

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

5. The Measurement Method is in paragraph M.2.1.5.3 of Annex M.

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.690-3 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

1. 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. Agencies typically submit the necessary information on the radar system to NTIA via the EL-CID so that NTIA can perform a system review of the radar system, to see if it adheres to the NTIA RSEC standards and criteria contained in this section. The criteria, and their standards, were developed by NTIA and the federal agencies with the realization that many different types of radars operate in frequency bands allocated to the radiodetermination service.

2. These criteria are concerned with promoting effective 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 emissions are closely related to. 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 radars must be reviewed from a frequency management viewpoint prior to development of new equipment.

3. Useful receiver techniques are available for reduction of the susceptibility of radars to low-duty-cycle pulsed interference. The applicability of such devices as video integrators, correlators, pulse repetition rate 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.

4. All primary radars shall be classified in one of five groups as shown in the following table and shall come under the criteria indicated for that group.[10] They are identified as RSEC Criteria A, B, C, D, and E. The method to

[10] 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, 2015 Edition.)

determine which criteria a primary radar is grouped within for each category are contained in the following sections. NTIA also permits federal agencies to operate commercial off-the-shelf (COTS) radars, used for non-federal applications. Those radars are exempt from the RSEC but must adhere to the radar FCC type acceptance regulations and must not be modified in any manner by the federal agency using it. A complete description of types of radars that NTIA permits under those regulations and the frequency bands they operate in can be found in Section 5.5.7.6.

5.5.2 Applicability of RSEC

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-portable[11] radars; or Man-transportable[12] radars; or as described above; or Expendable, non-recoverable radars on missiles	Criteria A See 5.5.7.1
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 5.5.7.2
Group C All radars not included in Group A, B, D, or E	Criteria C See 5.5.7.3
Group D All fixed radars in the 2700-2900 MHz band	Criteria D See 5.5.7.4
Group E Wind Profiler Radar (WPR) operating on 449 MHz	Criteria E See 5.5.7.5

COTS

Radar Description	Applicable
Commercial off-the-shelf maritime radionavigation radars, airborne weather radars, and altimeters	FCC Criteria See 5.5.7.6

5. For radars employing more than a single emitter, including phased array radars, variable pulse repetition rate (PRR) 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.

6. The provisions of Section 5.5.7.2, Criteria B, are applicable to Class 1 spacebased radar systems on a case-by-case basis.[13] The provisions of Section 5.5.7.2 or Section 5.5.7.3 (i.e. Criteria B or C as appropriate) are applicable to Class 2 spacebased radar systems[14] and active spaceborne sensors[15] on a case-by-case basis.

---

[11] 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).

[12] 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).

[13] 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.

[14] 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.

[15] 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 phenomena are obtained through transmission and reception of radio waves.

Measurement procedures for RSEC may be found in Annex M, paragraph M.2.2.1. For those interested in measuring radar emissions, the "*Measurement Procedures for the Radar Spectrum Engineering Criteria (RSEC)*", is available at http://www.its.bldrdoc.gov/pub/ntia-rpt/05-420/index.php. 7. The symbols used in the RSEC emission mask and bandwidth equations are defined as follows:

$B(-40\ dB)$ = The radar's permitted bandwidth as determined by the equation for the specific type of modulation, based on the time characteristics of the waveform at the fundamental frequency, which is 40 dB below the peak transmitted power, in MHz.

B_c = The bandwidth of the frequency deviation for a intenionally FM modulated pulsed waveform (The total frequency shift during the pulse duration) in MHz.

$B_{FM/CW}$ = Total frequency deviation for the carrier frequency for the FM/CW radar system.

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

CPI = Coherent Pulse Interval, a group of transmitted pulses with the same waveform parameters (i.e., pulsewidth, chirp, modulation) that are received and processed by the radar.

d = Pulse compression ratio = emitted pulse duration/compressed pulsed duration (specified at the 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.

F = Frequency at which suppression level is calculated for the RSEC mask.

F_L = Lowest operating carrier frequency.

F_H = Highest operating carrier frequency.

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).

S = Slope of the RSEC emision mask from the -40 dB point to the –X dB level.

t = Emitted pulse duration in microseconds specified at the 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 Figure 5-3).

t_r = Emitted pulse rise time in microseconds from the 10% to the 90% amplitude points on the leading edge (See Figure 5-3). 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 microseconds from the 90 % to the 10 % amplitude points on trailing edge (See Figure 5-3).

$T_{FM/CW}$ = The FM (chirp) period for the FM/CW radar system.

Waivers of RSEC

8. 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.

5.5.3 RSEC Emission Mask

The RSEC is intended to enhance effective use of spectrum and electromagnetic compatibility (EMC) between radars and other radio systems by placing limits on the amount of energy that a radar system can radiate in various parts of its RF emissions. The RSEC focuses on several emission parameters, including the -40 dB bandwidth, the roll-off in the out-of-band (OOB) region, and the suppression levels in the spurious region. Figure 5-1 shows the various parts of the radar's emissions.

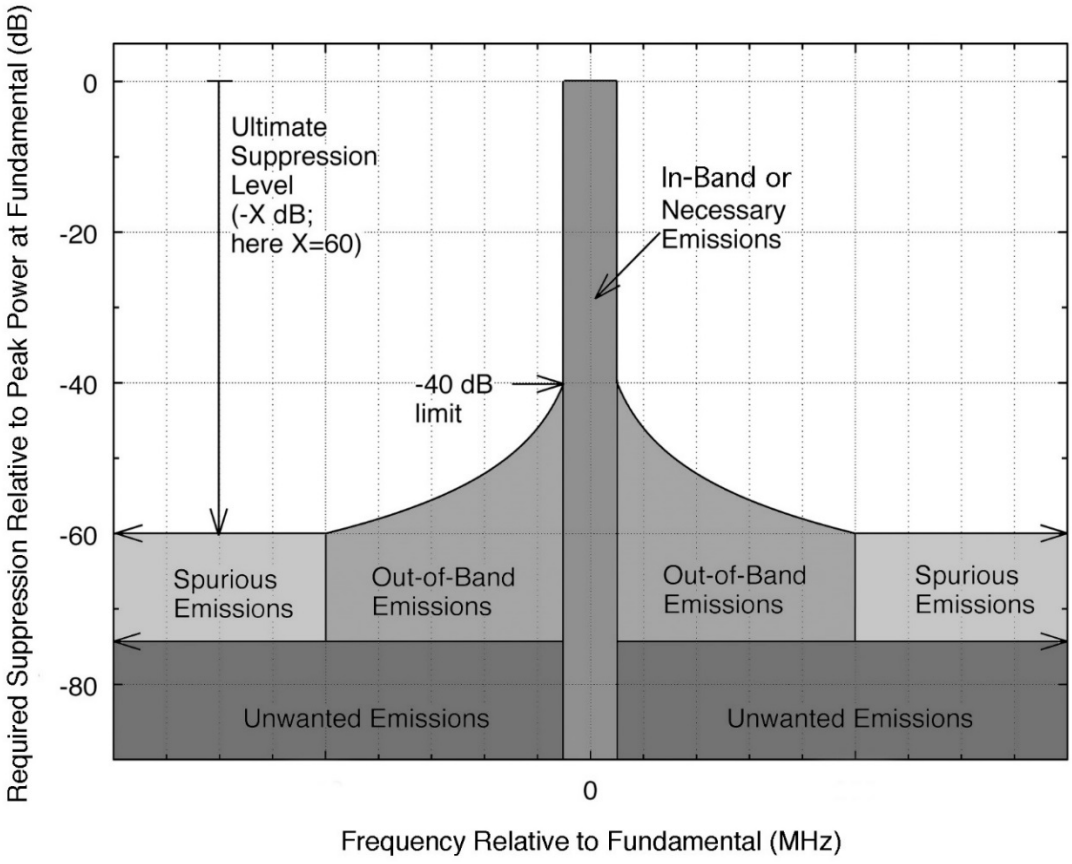


Figure 5.5.3

Radar spectrum emission regions of in-band or necessary emissions, out-of-band (OOB) emissions, spurious emissions, and unwanted emissions (which include both the OOB and spurious emissions).

5.5.3.1 Non-Hopping radars

The RSEC mask was developed to place limits on the radar's emissions in all of these regions. An RSEC emission mask is shown in Figure 5-2. Note that in this figure the roll-off is shown both as 20 and 30 dB per decade. Each RSEC criteria has its own set of specifications for the emission mask.

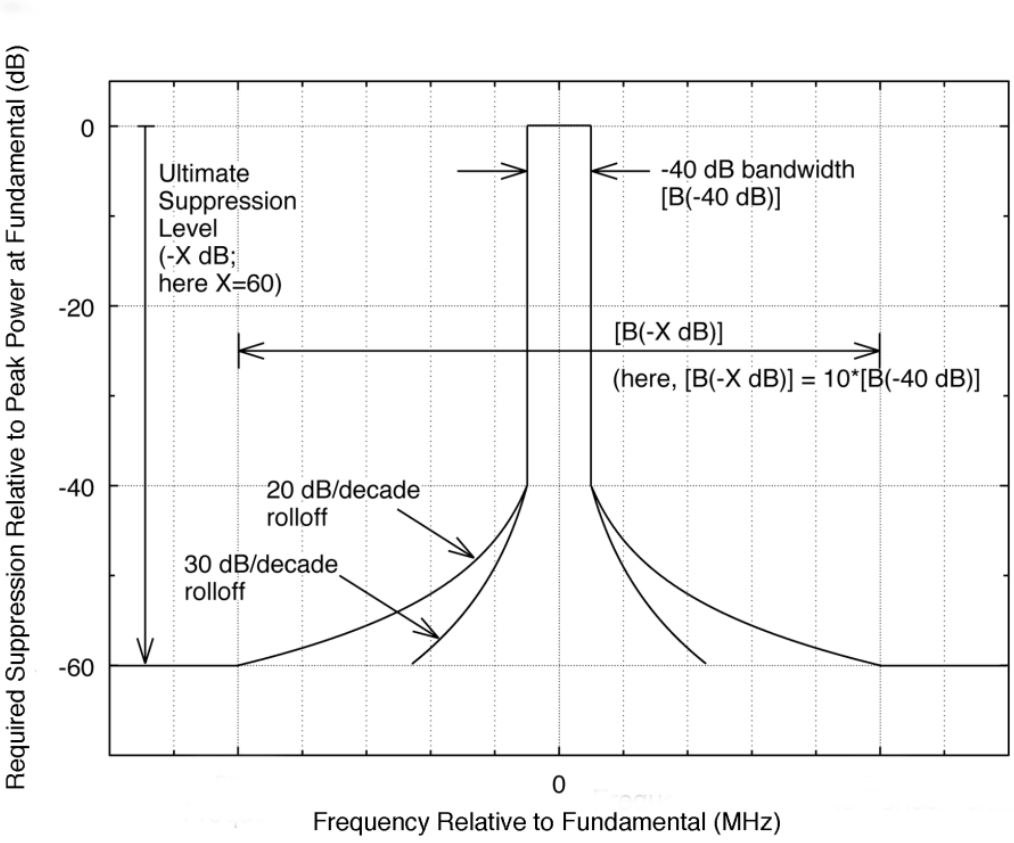


Figure 5.5.3.1a

The RSEC Emission mask.

The RSEC spectrum emission mask consists of three parts: a -40 dB "chimney" around the radar fundamental frequency, an ultimate suppression level of –X dB (where X is between 60 to 80 dB, depending upon radar type in the spurious domain), and a sloping roll-off in the out-of-band region that connects the in-band emissions to the spurious emissions. The mask is based on best-case theoretical performance but allows for real-world engineering factors. The -40 dB bandwidth is determined by the radar's pulse characteristics. The equations are as follows to construct the mask.

$$\text{Eq.1: Suppression (dB)} = -S * \text{Log}\left|\frac{F - F_o}{\frac{1}{2}B(-40dB)}\right| - 40$$

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

F is the frequency at which suppression is calculated.

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

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

Note that the RSEC suppression level in the spurious region is based on emission levels *relative* to the *peak power* of the transmitter. The B(-40 dB) values are calculated based on bandwidth equations in Section 5.5.4 for specific waveform modulations.

The ultimate suppression level at –X dB in the spurious domain is based on the maximum performance limits of radar transmitter amplifiers. The steepness of the roll-off from the -40 dB bandwidth in the out-of band domain to the –X dB suppression level depends on a combination of theoretical and real-world performance capabilities.

The time characteristics of the waveform determine the limits of the emission mask based on bandwidth equations for the various types of modulation, including frequency modulated continuous wave, un-modulated pulsed, frequency modulated pulsed, and phase coded pulses. The pulse width (t), rise time (t_r), and fall time (t_f) of a radar pulse for the bandwidth equations are based on the 50% voltage, 10 to 90%, and 90 to 10% time voltages; respectively, as shown in Figure 5-3. The figure is for illustrative purposes only.

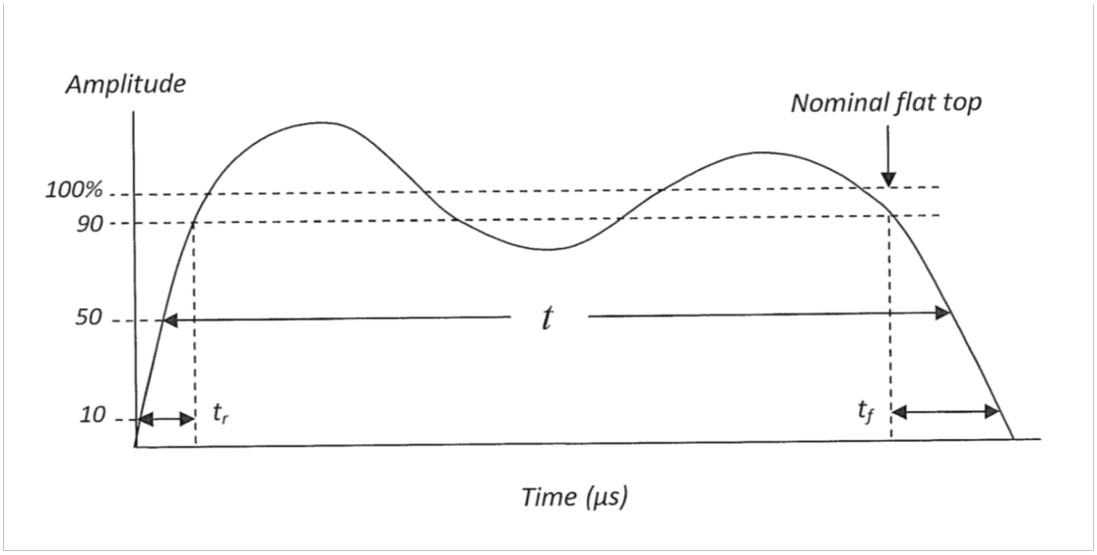


Figure 5.5.3.1b
Schematic radar pulse diagrammed with cursors for rise time, fall time, and width

The power levels of the radar's emissions must be less than the values defined by the emission mask for the radar to be compliant with the RSEC. That is, the frequency components of the radar emissions must be contained in the -40 dB bandwidth chimney and the levels in the out-of-band and spurious regions must be below the value defined by the mask.

5.5.3.2 Hopping Radars (Contiguous Frequencies)

Many radars in the federal inventory operate by hopping across some number of contiguous channels/frequencies. For these types of radars that cannot normally operate on a single frequency[16], the RSEC also has a emission masks, based on the lowest operating frequency, the highest operating frequency, and the -40 dB bandwidth of a single instantaneous frequency. Figure 5-4 shows a 16-frequency-hopping radar with its RSEC Criteria C mask. Here, the RSEC mask has been computed for the radar as if it had a single frequency, the mask has been split into two equal halves, each half has been plotted relative to the lowermost and uppermost radar frequencies, and then the center portion of the spectrum, where all of the fourteen remaining frequencies are used, has been connected between the two split halves.

Frequency hopping radars that operate over non-contiguous spectrum will be evaluated on a case-by-case basis.

[16] Past measurements have shown that frequency hopping radars that are forced to operate on a single frequency show poorer performance with respect to suppressing spurious emissions.

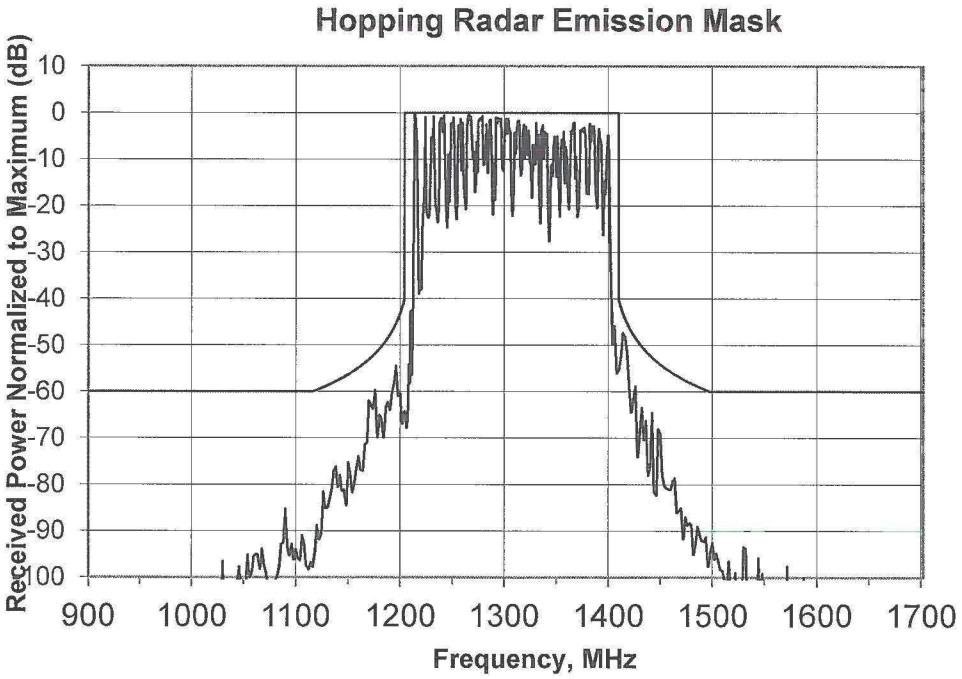


Figure 5.5.3.2
Frequency-hopping Radar Emission Spectrum with RSEC-C Mask

5.5.3.3 Shifting the RSEC Mask

The RSEC mask does not need to be centered on the fundamental frequency of the emission spectrum. Figure 5-5 shows a hypothetical case in which an RSEC mask has been shifted upward in frequency to accommodate a feature in a measured emission spectrum. The RSEC mask bandwidths and suppression levels are *not* changed; only the centering of the mask can be shifted. Note that if the RSEC mask were shifted to have the fundamental frequency component centered, the frequency component at about 150 MHz above the fundamental frequency (F_0) would exceed the mask's limits.

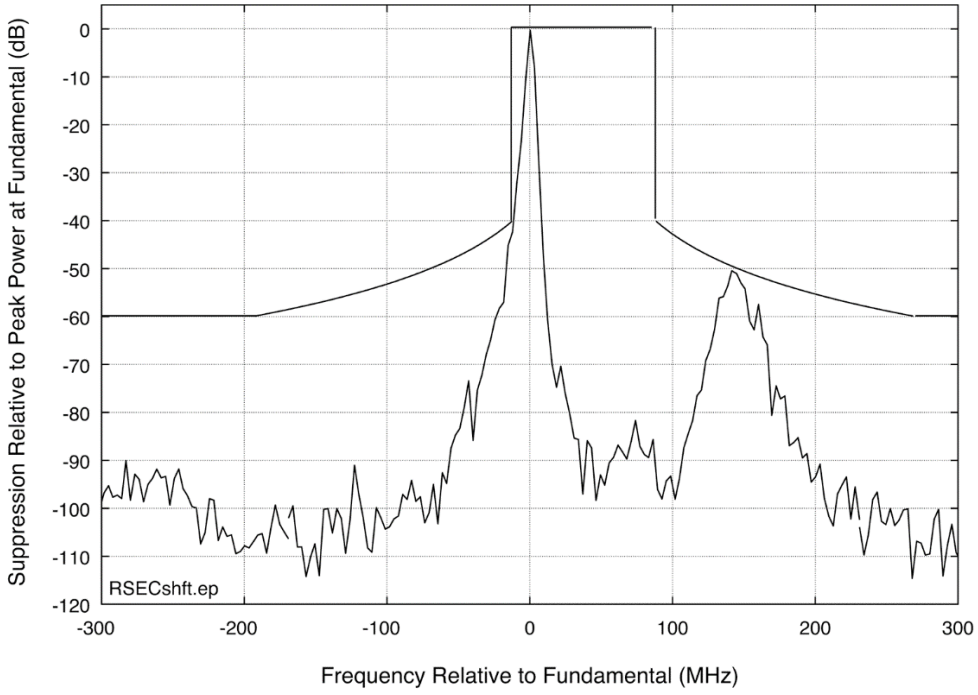


Figure 5.5.3.3
RSEC Mask Shifted in Frequency to Accommodate an Emission Spectrum Feature

5.5.4 Non-Hopping Radar -40 dB Bandwidth Equations

The RSEC emission mask is derived from the radar time waveform characteristics, with a key element of the mask being the -40 dB bandwidth. There are many types of radars operating in the various RSEC Categories. However, the waveforms they employ have been arranged into four separate categories. The categories are continuous wave (CW)/frequency modulated continuous wave (FMCW), un-modulated pulsed, FM modulated pulsed, and phase coded pulsed. An -40 dB bandwidth equation was developed for each category that is used in the formation of the RSEC emission mask. The -40 dB bandwidth equations for each type of waveform modulation are as follows.

Continuous Wave (CW)/Frequency Modulated Continuous Wave (FMCW) -40 dB Bandwidth Equations

The -40 dB bandwidth equations for radars using CW or FMCW modulated waveforms for Criteria A, B, C, D, and E radars are:

For CW radars: $Eq.2:\ B(\ \ 40dB) = 0.0003F_0$

For FM/CW: $$Eq.3: B(-40dB) = 1.2 * B_{FM/CW}\left(1+\frac{200}{\pi\sqrt{B_{FW/CW}T_{FM/CW}}}\right)^{1/2}$$

Non-FM pulse radars (including Spread Spectrum and Phase Coded pulse radars) -40 dB Bandwidth Equations

The -40 dB bandwidth equation for **Criteria A and B** radars using non-FM pulsed waveforms is:

$$Eq.4a:\ B(-40dB) = \frac{7.6}{\sqrt{t_r t}} \text{ or } \frac{64}{t}$$

whichever is less.

The -40 dB bandwidth equation for **Criteria C** radars using non-FM pulsed waveforms is:

$$Eq.4b:\ B(-40dB) = \frac{6.2}{\sqrt{t_r t}} \text{ or } \frac{64}{t}$$

whichever is less.

The -40 dB bandwidth equation for **Criteria D** radars using non-FM pulsed waveforms is:

$$Eq.4c:\ B(-40dB) = \frac{6.2}{\sqrt{t_r t}}$$

The -40 dB bandwidth equation for **Criteria E** radars using non-FM pulsed waveforms is:

$$Eq.4d:\ B(-40dB) = \frac{6.2}{\sqrt{t_r t}} \text{ or } \frac{64}{t}$$

whichever is less.

If t_f is less than t_r, as defined in Section 5.5.1, t_f is to be used in place of t_r when performing the emission bandwidth calculations for equations 4a through 4d. Note that Phase-coded waveform refers to the change of the phase during the sub-pulses.

FM-pulse radars (intentional FM) -40 dB Bandwidth Equations

The -40 dB bandwidth equations for radars using intentional frequency modulated pulsed frequency waveforms (linear and non-linear) are:

For radars procured before October 1, 2020:

For Criteria A and B Radars. $Eq.5a: B(-40dB) = \frac{7.6}{\sqrt{t_r t}} + 2(B_c + \frac{0.065}{t_r})$

For Criteria C Radars. $Eq.5b: B(-40dB) = \frac{6.2}{\sqrt{t_r t}} + 2(B_c + \frac{0.105}{t_r})$

For Criteria D Radars. $Eq.5c: B(-40dB) = \frac{6.2}{\sqrt{t_r t}} + 2(B_c + \frac{0.105}{t_r})$

For Criteria E Radars. $Eq.5d: B(-40dB) = \frac{6.2}{\sqrt{t_r t}} + 2(B_c + \frac{0.105}{t_r})$

If t_f is less than t_r, as defined in Section 5.5.1, t_f is to be used in place of t_r when performing the emission bandwidth calculations for Equations 5a through 5d.

For Criteria A, B, C, D, and E radars procured after October 1, 2020:

For Cases when the following two conditions exist:

$$B_c * \min(t_r, t_f) \geq 0.10$$

$$B_c * t \geq 10$$

The following equation will be used:

$$Eq6: B(-40) =$$

$$1.5 * [B_C + 1.77 * [In(B_C * t)^{0.53} * [Min(B_{Rise}, B_{Fall}, B_{Rise_{Fall}}) + Max(B_{Rise}, B_{Fall}, B_{Rise_{Fall}})]]]$$

Where:

$B_{Rise} = 1/\sqrt{t * t_r}$, $B_{Fall} = 1/\sqrt{t * t_f}$, $B_{Rise\_Fall} = 1/(t * t_r * t_f)^{1/3}$

Otherwise, equations 5a through 5d shall be used for the appropriate RSEC Criteria for FM pulsed systems.

5.5.4.1 Frequency Hopping -40 dB Bandwidth Equations

1. For frequency hopping radars the -40 dB bandwidth equations shall be based on the characteristics of the radar operating on a single frequency, according to the modulation and waveform parameters as outlined in Section 5.5.3, where the radar is capable of normally operating in such a mode.

2. For frequency hopping radars where the radar cannot operate on a single frequency for normal operations, the -40 dB bandwidth equations shall be based on the characteristics of the radar operating on a single frequency according to the modulation and waveform parameters as outlined in Section 5.5.3, summed with the hopping

bandwidth, B_S. These formulas yield the total composite B(–40dB) bandwidth of a frequency hopping radar as if all channels included within Bs were operating simultaneously. Individual channels have a B(–40 dB) radar emission bandwidth given by the equations in Section 5.5.4.

Frequency Hopping Non-FM pulse and Phase Coded -40 dB Bandwidth Equations

For Criteria A and B Radars. Eq. 7a : $B(-40dB) = \frac{7.6}{\sqrt{t_r t}} + B_S$

For Criteria C Radars. $Eq.7b: B(-40dB) = \frac{6.2}{\sqrt{t_r t}} + B_S$

For Criteria D Radars. $Eq.7c: B(-40dB) = \frac{6.2}{\sqrt{t_r t}} + B_S$

Frequency Hopping FM-pulse radars (intentional FM) -40 dB Bandwidth Equations

For radars procured before October 1, 2020:

For Criteria A and B Radars. $Eq.$ 8a : $B(-40dB) = \frac{7.6}{\sqrt{t_r t}} + 2(B_c + \frac{0.065}{t_r}) + B_S$

For Criteria C Radars. $Eq.8b: B(-40dB) = \frac{6.2}{\sqrt{t_r t}} + 2(B_c + \frac{0.105}{t_r}) + B_S$

For Criteria D Radars. $Eq.8c: B(-40dB) = \frac{6.2}{\sqrt{t_r t}} + 2(B_c + \frac{0.105}{t_r}) + B_S$

If t_f is less than t_r, as defined in Section 5.5.1, t_f is to be used in place of t_r when performing the emission bandwidth calculations for Equations 8a through 8c.

For radars procured after October 1, 2020:

For cases when the following two conditions exist:

$$B_c * \min(t_r, t_f) \geq 0.10$$

$$B_c * t \geq 10$$

The following equation will be used:

$$Eq9: B(-40) =$$

$$1.5 * [B_C + 1.77 * \left[In(B_C * t)^{0.53} * \left[Min(B_{Rise}, B_{Fall}, B_{Rise_{Fall}}) + Max(B_{Rise}, B_{Fall}, B_{Rise_{Fall}})\right]\right]] + B_S$$

Where:

$$B_{Rise} = 1/\sqrt{t * t_r},\ B_{Fall} = 1/\sqrt{t * t_f},\ B_{Rise\_Fall} = 1/(t * t_r * t_f)^{1/3}$$

Otherwise, Equations 8a through 8c shall be used for the appropriate RSEC Criteria for FM pulsed systems with frequency hopping.

5.5.5 The Applicability of the RSEC Effective Dates

Technical criteria for new radars become effective October 1, 2020 except as noted herein. New radars are those for which development and subsequent procurement contracts are let after October 1, 2020. All radars procured prior to October 1, 2020 should be brought into compliance with the following new RSEC standards when any of the following parameters are changed after October 1, 2020: pulse width, pulse rise/fall time, pulse repetition rate, output device, or pulse chirp frequency. The existing radar systems that have been procured, approved by the NTIA SPS up to and including stage four certification prior to October 1, 2020 will be "grandfathered" under the new RSEC rules. These radar systems will not need to be recertified through the SPS unless they are modified as noted.

5.5.6 Compliance with RSEC -40 dB Bandwidth and Emission Mask

1. The -40 dB emission bandwidth for radars at either the antenna input or output (radiated) shall not exceed the following limits as defined in Sections 5.5.3.1 for non-hopping radar and 5.5.3.2 for hopping radars for the -40 dB bandwidth equations, based on the type of modulation. Noting that the emission measurements at the antenna input may be used provided they show compliance with the emission mask.

2. Compliance with the emission limits described below for each RSEC Criteria must be shown for all modes and emitted waveforms of the radar system for the emission in-band, roll-off, and spurious limits. For the case where multiple waveforms are emitted on a single frequency, the -40 dB bandwidth for the emission mask should be based on the waveform which results in the largest -40 dB bandwidth. Radars that change waveform parameters during a coherent pulse interval (CPI) will be evaluated on a case-by-case basis.

3. For frequency hopping radars, emission mask as shown in Figure 5-2 shall be determined as if the radar were fixed tuned at the operating frequency of the lowest frequency (F_L) and the highest frequency (F_H). That is the value of F_0 in equation under Figure 5-2 should be set to the values of F_L and F_H for determining the roll-off from the -40 dB bandwidth point. The mid value of the frequency hopping range shall not be used for the value of F_0. An example of an emission mask applied to a frequency hopping radar is shown in Figure 5-4.

4. Normally the emission mask is centered at F_0, however the mask can be moved to the right or left of F_0 if the power of a frequency component(s) exceed the mask's limits. Shifting the mask frequency permits radars to show that their emissions are compliant. Figure 5-5 illustrates this case. Note that in this figure, the mask itself is not changed with respect to the -40 dB bandwidth, roll-off, and spurious emission limits. Figure 5-5 shows that the mask has been shifted to the right to permit the frequency component at about 150 MHz above the fundamental to be under the power limits specified by the mask at that frequency while the component at F_0 is also still compliant. Shifting the mask to make one area of the radar's emissions compliant, while causing another area to become non-compliant, is not permitted.

5. A computer model is available to calculate the emission mask, import measured data, and allow the user to enter discrete emission points to determine whether a radar is compliant with the RSEC emission limits. The model can be obtained by contacting NTIA's Spectrum Engineering Branch.

5.5.7 RSEC Criteria

The RSEC has five different criteria identified as A, B, C, D, and E. The following sections give details with respect to standards for roll-off, tunability, receiver standards, antenna patterns, and interference suppression for each criterion. The -40 dB bandwidth equations are contained in Section 5.5.4 for single frequency radars and 5.5.4.1 for frequency hopping radars.

5.5.7.1 RSEC Criteria A

RSEC A radar systems that have been submitted to or certified by NTIA before December 31, 2013, are exempt from meeting new RSEC A requirements and shall be "grandfathered". Grandfathered systems shall be certified under the NTIA rules applicable prior to December 31, 2013. Systems certified by NTIA at Stage 3 to Section 5.2.2.2 of the NTIA Manual before the date shall be certified at Stage 4 using the same criteria until December 31, 2015. On January 1, 2016 all systems seeking Criteria A certification must meet these requirements.

Criteria A Applicability

Radars shall be grouped into Criteria A that have the following system characteristics: 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-portable11 radars; or man-transportable12 radars; or as described above; or expendable, non-recoverable radars on missiles.

Previously certified Criteria A systems must adhere to the revised regulations when any of the following system parameters are changed, including power output, pulse width, pulse repetition rate, chirp rate, chirp bandwidth, rise time, and fall time.

Criteria A Emission Mask

For systems operating in the band 2700 – 2900 MHz

Systems operating in this band must adhere to the RSEC Criteria D standard in section 5.5.2.4.

For systems operating in other frequency bands

For these types of radars, the emission levels at the antenna input or output (radiated) shall be no greater than the values obtainable from the curve in Figure 5-2.

-40 dB bandwidth Equations

The -40 dB bandwidth equations are contained in Section 5.5.4 for single frequency radars and 5.5.4.1 for frequency hopping radars.

Roll-off in the Out-of–Band (OOB) Domain

At the frequency B(–40dB)/2 displaced from F0, the level shall be at least 40 dB below the maximum value. Between the –40dB and –XdB frequencies the level shall meet a slope (S) of 20 dB per decade (S=20) for all waveforms when the peak power is greater than 1 watt.

Spurious Domain Limits

At and beyond the frequencies B(–XdB)/2 from F0, the X(dB) level shall be at least the dB value below the maximum spectral power density given by:

For radar systems with peak power above 100 watts: $X(dB) = 55\,dB$.

For radar systems with peak power less than 100 watts but more than 1 watt: $X(dB) = 50\,dB$.

For radar systems with peak power equal to and less than 1 watt: $X(dB) = 40\,dB$.

For radar systems with a duty cycle equal to and greater than 10 percent: $X(dB) = 55\,dB$.

All harmonic levels shall be at a level that is at least 55 dB below the maximum power spectral density.

The two figures illustrate the suppression levels and masks for Criteria A systems.

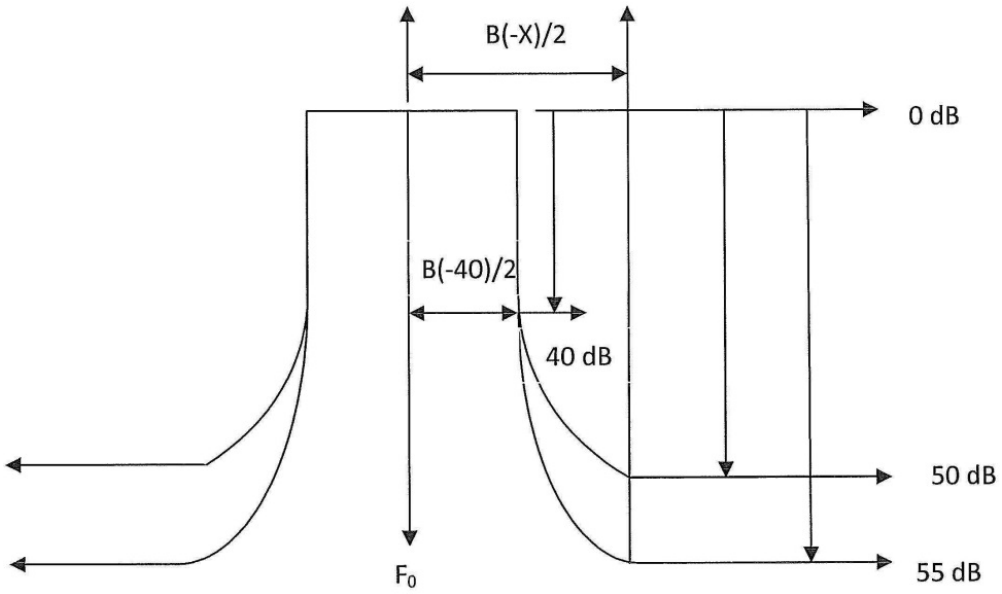


Figure 5-6
RSEC A Masks for Systems with Peak Power Above 1 Watt

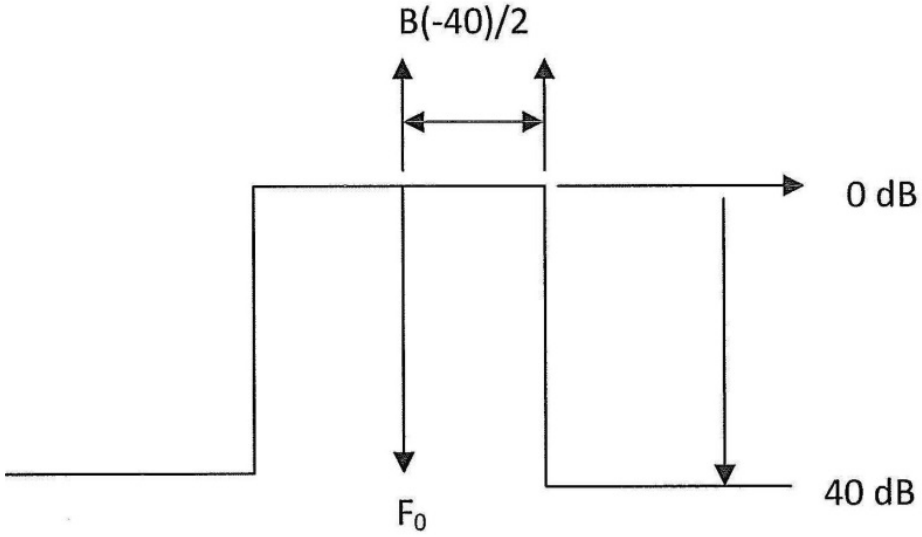


Figure 5-7
RSEC A Mask for Systems with Peak Power Equal to and Below 1 Watt

Criteria A Antenna Pattern

For systems operating in the bands 1215-1390, 5600-5650, and 9000-9200 MHz the first antenna sidelobe shall be supressed 10 dB when the peak power is greater than 1 watt. An exceptions to the policy will be made for radar systems employing an omni directional antenna.

Criteria A 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. A digital tuner having stepwise tuning increments no greater than 1% of the overall tuning range of the device, across the entire tuning range, shall be considered as meeting the RSEC-A tunability criterion. Fixed tuning is permitted if there is some means or method to change the operating frequency to mitigate interference or justification is provided.

Criteria A Radar Receivers

The overall receiver selectivity characteristics shall be commensurate with the transmitter bandwidth, as portrayed in Figure 5-2. This standard applies until January 1, 2022.

The 3 dB IF bandwidth of the radar receiver shall be equal to or less than 13 times the 3 dB bandwidth of the emissions, for all modulation types. For multi-stage IF radar receivers, the standard would apply to the final IF stage, prior to the detector or I and Q digitizer. This standard only applies to radars with superhetrodyne receivers. Stage 4 systems will be grandfathered, but they will have to meet the standard if the receiver is altered or redesigned. This standard will come into effect on January 1, 2022.

Rejection of spurious responses, other than image responses, shall be 50 dB or better. 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.

Criteria A Measurement Capability

See paragraph M.2.2 of Annex M.

5.5.7.2 RSEC Criteria B

Criteria B Applicability

Radars shall be grouped into Criteria B that have the following system characteristics: 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 Emission Mask for Un-modulated Pulsed, FM Pulsed, and Phase Coded Radars

For these types of radars, the emission levels at the antenna input or output (radiated) shall be no greater than the values obtainable from the curve in Figure 5-2. The -40 dB bandwidth equations are contained in Section 5.5.4 for single frequency radars and 5.5.4.1 for frequency hopping radars. At the frequency B(–40dB)/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 5-2 for those radars procured before October 1, 2020. For radars procured after October 1, 2020 the slope shall be 30 dB per decade (S=30) for all Un-modulated pulsed, FM pulsed and FM pulsed frequency hopping radars. The roll-off of phase coded radars will remain at a slope of 20 dB per decade (S=20). In addition, the roll-off of any other waveforms that are not specified in this section will remain at a slope of 20 dB per decade (S=20). 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:

$X(dB) = 60dB$ or $X(dB) = P_t + 30$

whichever is the larger value

NOTE: Pt may be measured or may for the purpose of these criteria be calculated from the following:[17]

$Eq.10: \; P_t = P_p + 20\log(N * \mathrm{t}) + 10\log(PRR) - PG - 90$

where PG = 0, for non-FM, non-encoded pulse radars

[17] Although this equation seems incorrect to have 10 and 20 log terms in it, the equation is correct. In essence it make the X(dB) term lower (more suppression) when the radar's duty cycle increases.

PG = 10log(d), for FM pulse radars, where d = pulse compression ratio = emitted pulse duration/compressed pulsed duration (at 50% amplitude points).

PG = 10log(N), for coded pulse radars, where N = total number of chips (subpulses) contained in the pulse. (N = 1 for non-FM and FM pulse radars.)

Criteria B Emission Mask for Continuous Wave (CW) and FM/CW Radars

For these types of radars, the levels of all emissions at the antenna input or output (radiated) shall be no greater than the values obtainable from the curve in Figure 5-2. The -40 dB bandwidth equations are contained in Section 5.5.4. 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) roll-off lines in Figure 5-2. 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.

Criteria B Antenna Pattern

No requirement is specified.

Criteria B 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.

Criteria B Radar Receivers

The overall receiver selectivity characteristics shall be commensurate with or narrower than the transmitter bandwidth, as portrayed in Figure 5-2. This standard applies until January 1, 2022.

The 3 dB IF bandwidth of the radar receiver shall be equal to or less than 20 times the 3 dB bandwidth of the emissions, for all modulation types. For multi-stage IF radar receivers, the standard would apply to the final IF stage, prior to the detector or I and Q digitizer. This standard only applies to radars with superhetrodyne receivers. Stage 4 systems will be grandfathered, but they will have to meet the standard if the receiver is altered or redesigned. This standard will come into effect on January 1, 2022.

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.

Criteria B Measurement Capability

See paragraph M.2.2.2 of Annex M.

5.5.7.3 RSEC Criteria C

Criteria C Applicability

Radars shall be grouped into Criteria C that have the following system characteristics: All radars below 40 GHz not included in Group A, B, D, or E. Figure 5-8 shows a RSEC C mask applied to a radar system.

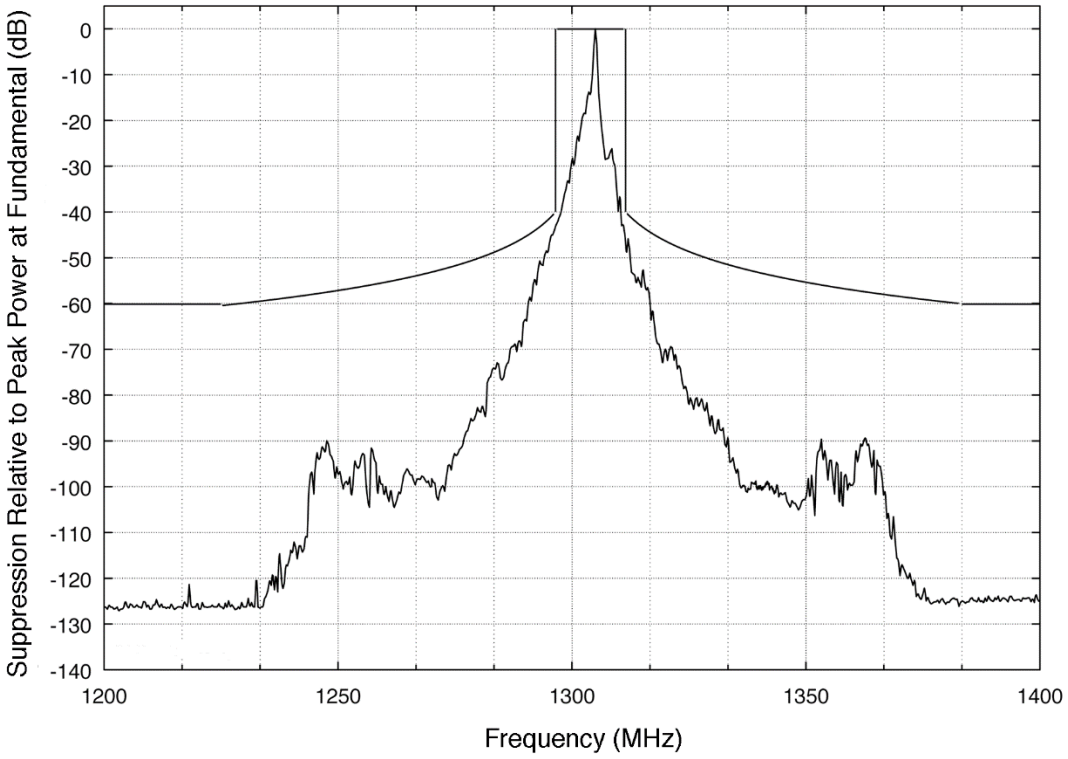


Figure 5-8
Example of Criteria C Mask Applied to a Radar

Criteria C Emission Mask for Un-modulated Pulsed, FM Pulsed, and Phase Coded Radars

For these types of radars, the emission levels at the antenna input or output (radiated) shall be no greater than the values obtainable from the curve in Figure 5-2. The -40 dB bandwidth equations are contained in Section 5.5.4 for single frequency radars and 5.5.4.1 for frequency hopping radars. At the frequency B(–40dB)/2 displaced from F0, 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 5-2 for those radars procured before October 1, 2020. For radars procured after October 1, 2020 the slope shall be 30 dB per decade (S=30) for all Un-modulated pulsed, FM pulsed and FM pulsed frequency hopping radars. The roll-off of phase coded radars will remain at a slope of 20 dB per decade (S=20). In addition, the roll-off of any other waveforms that are not specified in this section will remain at a slope of 20 dB per decade (S=20). At and beyond the frequencies B(–XdB)/2 from F0, the level shall be at least the dB value below the maximum spectral power density given by:

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

whichever is the larger value

NOTE: Pt may be measured or may for the purpose of these criteria be calculated from the following:[18]

$$Eq.11:\ P_t = P_p + 20\log(N * t) + 10\log(PRR) - PG - 90$$

[18] Although this equation seems incorrect to have 10 and 20 log terms in it, the equation is correct. In essence it make the X(dB) term lower (more suppression) when the radar's duty cycle increases.

where PG = 0, for non-FM, non-encoded pulse radars

PG = 10log(d), for FM pulse radars, where d = pulse compression ratio = emitted pulse duration/compressed pulsed duration (at 50% amplitude points).

PG = 10log(N), for coded pulse radars, where N = total number of chips (subpulses) contained in the pulse. (N = 1 for non-FM and FM pulse radars.)

Criteria C Emission Mask for Continuous Wave (CW) and FM/CW radars

The levels of all emissions for these types of radars at the antenna input or output (radiated) shall be no greater than the values obtainable from the curve in Figure 5-2. The -40 dB bandwidth equations are contained in Section 5.5.4. 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 5-2. 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).

Compatibility with EESS (Passive Systems)

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.

Criteria C 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 dBi 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, relative to the main beam:

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

Criteria C 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 mid-band frequency. Crystal controlled radars conform to this requirement if operation at essentially any frequency across the band can be achieved with a crystal change.

Criteria C Radar Receivers

The overall receiver selectivity characteristics shall be commensurate with or narrower than the transmitter bandwidth, as portrayed in Figure 5-2. This standard applies until January 1, 2022.

The 3 dB IF bandwidth of the radar receiver shall be equal to or less than 20 times the 3 dB bandwidth of the emissions, for all modulation types. For multi-stage IF radar receivers, the standard would apply to the final IF stage, prior to the detector or I and Q digitizer. This standard only applies to radars with superhetrodyne receivers. Stage 4 systems will be grandfathered, but they will have to meet the standard if the receiver is altered or

[19] 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.

redesigned. This standard will come into effect on January 1, 2022.

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.

Criteria C Measurement Capability

See paragraph M.2.2.3 of Annex M

5.5.7.4 RSEC Criteria D

Criteria D Applicability

Radars shall be grouped into Criteria D that have the following system characteristics: Fixed radars operating 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 5.5.7.4, in subsection titled Criteria D EMC Provisions. A Criteria D mask applied to a pulsed radar is shown in Figure 5-9. The measured emissions are within the -40 dB bandwidth limit, and the frequency components in the out-of-band and spurious regions do not exceed the emission mask limits, which were based on the time waveform characteristics of the radar signal.

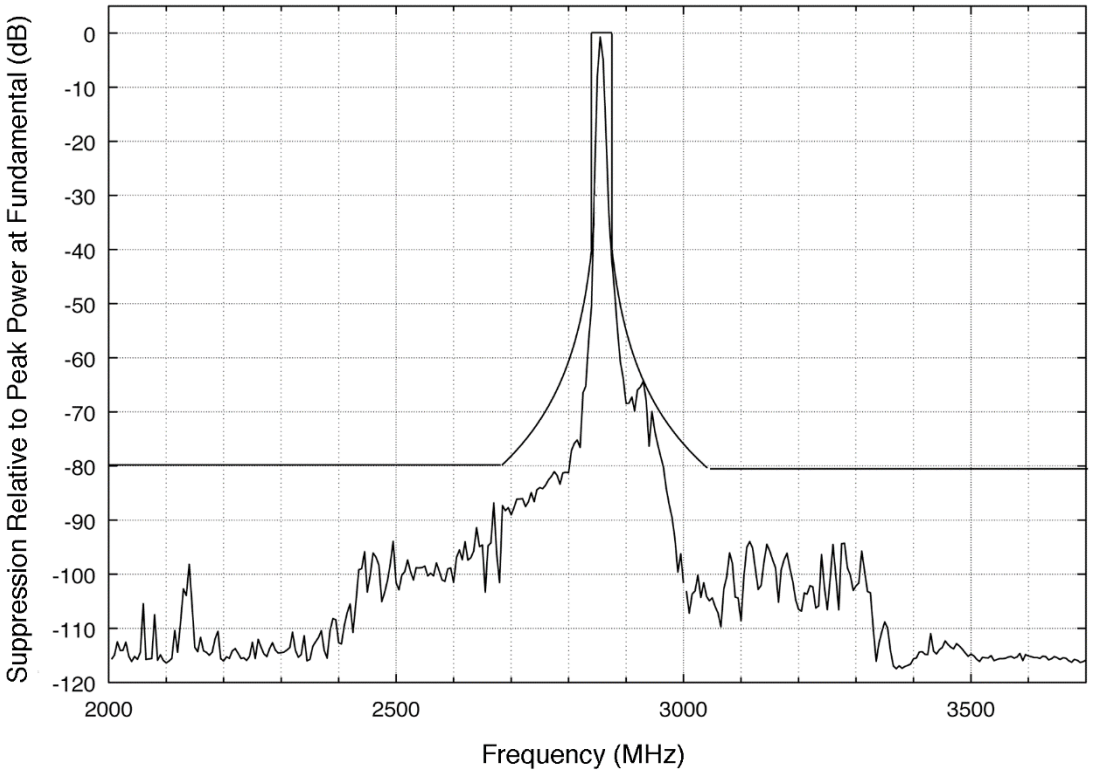


Figure 5-9

Criteria D Mask Applied to Radar Emissions

Criteria D Emission Mask for Non-FM Pulsed, FM Pulsed, and Phase Coded radars

The emission levels at the antenna input or output (radiated) for these types of radars shall be no greater than the values obtainable from the curve in Figure 5-2. The -40 dB bandwidth equations are contained in Section 5.5.4 for single frequency radars and 5.5.4.1 for frequency hopping radars. 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 5-2 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.

Criteria D Emission Mask for Continuous Wave (CW) and FM/CW radars

The levels of all emissions at the antenna input or output (radiated) for these types of radars shall be no greater than the values obtainable from the curve in Figure 5-2. The -40 dB bandwidth equations are contained in Section 5.5.4. 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 5-2. 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.

Criteria D 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[20]. Antennas operated by their rotation through 360 degrees of the horizontal plane shall have a "median gain" of –10 dBi 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, relative to the main beam:

First three sidelobes 17 dB;
All other lobes 26 dB.

Criteria D Radar Tunability

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

Criteria D Radar Receivers

The overall receiver selectivity characteristics shall be commensurate with the transmitter bandwidth, as portrayed in Figure 5-2. This standard applies until January 1, 2022.

The 3 dB IF bandwidth of the radar receiver shall be equal to or less than 1.75 times the 3 dB bandwidth of the emissions, for all modulation types. For multi-stage IF radar receivers, the standard would apply to the final IF stage, prior to the detector or I and Q digitizer. This standard only applies to radars with superheterodyne receivers. Stage 4 systems will be grandfathered, but they will have to meet the standard if the receiver is altered or redesigned. This standard will come into effect on January 1, 2022.

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

[20] 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.

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.

Criteria D 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 geographical 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 or output (radiated) shall be no greater than the values obtainable from the curves in Figure 5-2. 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 5-2. The emission levels, with the exception of harmonic frequencies, shall be below the appropriate dB per decade roll-off lines of Figure 5-2 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 PRR

The radar system shall be designed to operate with an adjustable pulse repetition rate (s), PRR (s), with a nominal difference of 1% (minimum). This will permit the selection of PRRs to allow certain types of receiverinterference 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 Intermediate Frequency (IF) output is:

Peak Interference-to-Noise Ratio: < 50 dB
Pulse width: 0.5 to 4.0 microseconds
PRR: 100 to 2000 pulses per second

Criteria D Measurement Capability

See paragraph M.2.2.3 of Annex M.

5.5.7.5 RSEC Criteria E

Criteria E Applicability

Radars shall be grouped into Criteria E that have the following system characteristics: Wind Profile Radar (WPR) operating on 449 MHz. Note that the mask for Criteria E radars is different from the other criteria masks in that it has two sections of different slope in the out-of-band region. Figure 5-10 is an example of a Criteria E mask applied to a WPR. The measured emissions are within the -40 dB bandwidth limit, and the frequency components in the out-of-band and spurious regions do not exceed the emission limits of the mask, which were based on the time waveform characteristics of the radar signal.

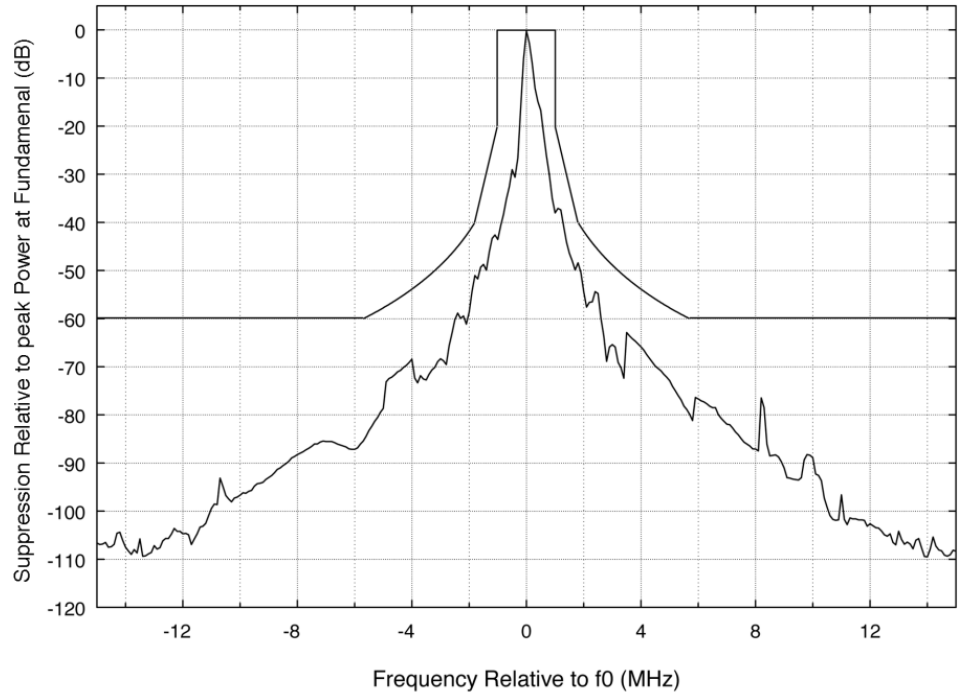


Figure 5-10
Example of Criteria E Mask applied to Wind Profile Radars

Criteria E Emission Mask for all Modulations

WPR emission levels at the antenna input or output (radiated) shall be no greater than the values obtainable from the curve in Figure 5-9. The -40 dB bandwidth equations are contained in Section 5.5.4. 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 5-11.

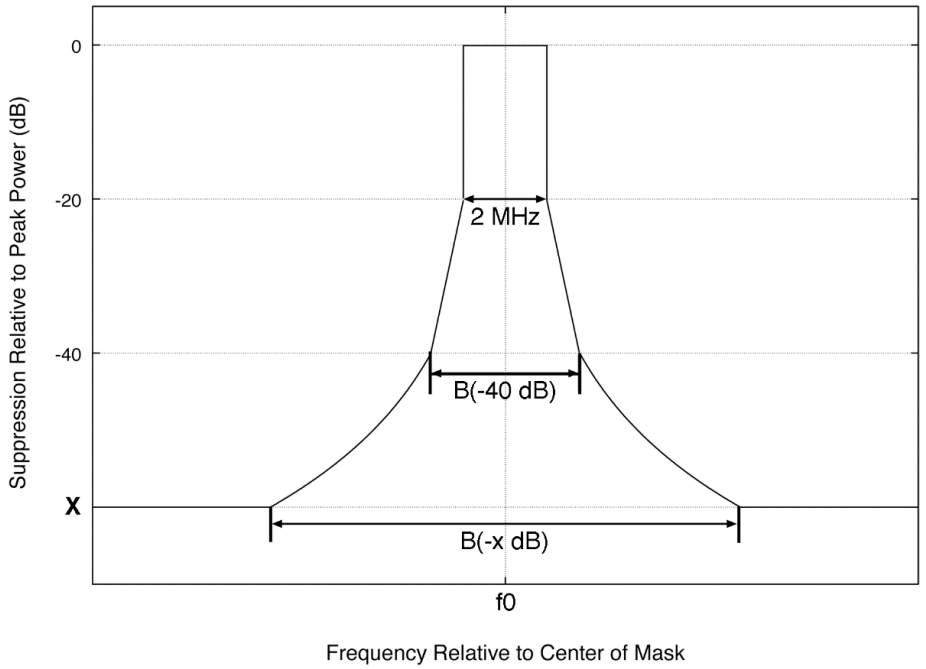


Figure 5-11
Radar Emission Bandwidth and Emission Levels for Wind Profiler Radars at 449 MHz (Criteria E)

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 and -X dB points for S dB per decade slope is described by the formula:

$$\text{Eq.12 Suppression (dB)} = -S * \text{Log}\left|\frac{F - F_o}{\frac{1}{2}B(-40dB)}\right| - 40$$

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

And: F is the frequency at which suppression is calculated.

$$and: B(-XdB) = \left(10^{\alpha}\right) B\left(-40dB\right)$$
$$where\ \alpha = \frac{X - 40}{S}$$

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:

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

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:[21]

$$Eq.13: P_t = P_p + 20\log(N * t) + 10\log(PRR) - PG - 90$$

where PG = 0, for non-FM, non-encoded pulse radars

PG = 10log(d), for FM pulse radars, where d = pulse compression ratio = emitted pulse duration/compressed pulsed duration (at 50% amplitude points).

PG = 10log(N), for coded pulse radars, where N = total number of chips (subpulses) contained in the pulse. (N = 1 for non-FM and FM pulse radars.)

Criteria E Permitted EIRP

The EIRP[22] of any WPR operating at 449 MHz shall not exceed the following values:

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

Criteria E 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

[21] Although this equation seems incorrect to have 10 and 20 log terms in it, the equation is correct. In essence it makes the X(dB) term lower (more suppression) when the radar's duty cycle increases.
[22] 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.

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.

Criteria E EMC Provisions

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

Criteria E Measurement Capability

See paragraph M.2.2.4 of Annex M.

5.5.8 Commercial off-the-shelf (COTS) Radar Systems

1. In cases where government radionavigation radars operate in the shared federal/non-federal bands, there is an acceptable degree of electromagnetic compatibility associated with the radar equipment commercially available to the non-federal community of users. The vast preponderance of the non-federal use of these bands by domestic and foreign ships and commercial aircraft creates a situation where relatively inexpensive commercial equipment is available off-the-shelf. Accordingly, this commercial off-the-shelf (COTS) equipment is not required to meet the more stringent NTIA RSEC standards. Federal agencies may procure COTS equipment; however, federal agencies procuring COTS radars operating in the radiodetermination frequency bands shall comply with FCC standards required for commercially available equipment as defined in 47 CFR, Part 80 Sub-Parts E, F, and M regarding maritime radars and Part 87 Sub-Part D regarding aviation radars. The following services and bands are affected:

a. Maritime radionavigation radars in the bands 2900-3100 MHz, 5470-5650 MHz, and 9200-9500 MHz;

b. Airborne aeronautical weather, windshear, and radionavigation radars in the bands 5350-5470, 8750-8850, 9300-9500, 13250-13400, and 15400-15700 MHz; and

c. Radar altimeters in the band 4200-4400 MHz.

2. This regulation is for COTS radionavigation radars procured after October 1, 2020.

3. The agencies must comply with the following criteria:

a. Federal agencies shall only procure equipment which has been approved by the FCC for use in the United States.

b. Federal agencies must use the system as it was marketed and shall not modify the equipment in any way that would invalidate the FCC equipment compliance certifications. If federal agencies modify a COTS radar system, the radar system will be required to meet applicable NTIA RSEC standards.

c. Federal agencies shall only use this COTS equipment for the purpose for which it is marketed.

4. The standards and applicability of these regulations will be re-examined if there are any changes to the allocation and/or operational status in these bands.

5.6 Space Services

5.6.1 General

1. 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 Section 5.5. Standards for Earth and space stations operating in bands below 470 MHz are contained in Section 5.2.

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.

3. 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:

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

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

a. Annex J gives procedures for determining B_n.
b. 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.
c. Attenuation in this sense refers to the reduction in level relative to the reference, 0 dBsd, unless otherwise specified.
d. 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. 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.
e. 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: [23]

    (1) −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

    (2) −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 transponder is transmitting. The limits should not be applied to those unwanted emissions of a satellite that fall within the necessary emission

[23] 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.

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.

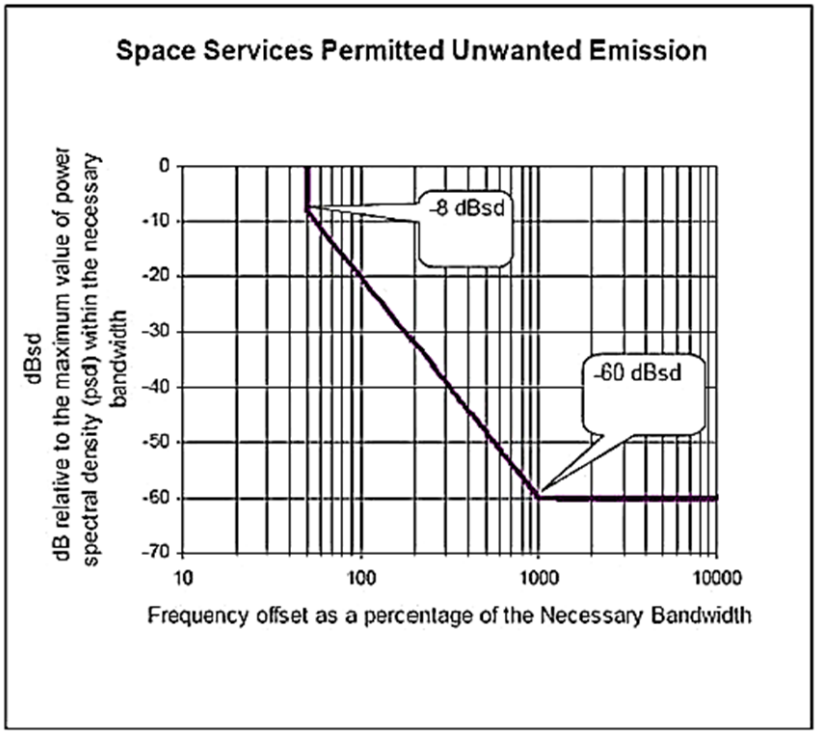
5.6.6 Table 5.6.1 Minimum Bandwidth

Table 5.6.1 Minimum Bandwidth	
Operating Frequency Range (f_c)	**Minimum Bandwidth (B_L)**
470 MHz $< f_c <$ 1 GHz	25 kHz
1 GHz $< f_c <$ 10 GHz	100 kHz
10 GHz $< f_c <$ 15 GHz	300 kHz
15 GHz $< f_c <$ 26 GHz	500 kHz
$f_c >$ 26 GHz	1 MHz

In Table 5.6.1, fc 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 5-12

Maximum Unwanted Emission Levels for Space Services



(Last Page in Chapter 5)