Quantitative Assessments of Spectrum Usage

U.S. Department of Commerce

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CONTENTS

ABBREVIATIONS

AF	United States Air Force
AR	United States Army
ASR	Airport Surveillance Radar
ATC	Air Traffic Control
CDA	Command and Data Acquisition
dB	Decibel
dBi	Decibels relative to an isotropic antenna
dBW	Decibels relative to a watt
DCP	Data collection platform
DCPR	Data Collection Platform Report
DHS	Department of Homeland Security
DOC	Department of Commerce
DOE	Department of Energy
DOD	Department of Defense
DOT	Department of Transportation
DC	Duty cycle
EIRP	Equivalent isotropically radiated power
EMWIN	Emergency Managers Weather Information Network
EPA	Environmental Protection Agency
FAA	Federal Aviation Administration
GHz	Gigahertz
GMF	Government Master File
GOES	Geostationary Operational Environmental Satellites
GRB	GOES Rebroadcast
GVAR	GOES VARiable
HRIT	High Rate Information Transmission
IRAC	Interdepartment Radio Advisory Committee
ITM	Irregular Terrain Model

km	Kilometers
Log	Common logarithm
MARAD	Maritime Administration
MC	United States Marine Corps
MDL	Multi-use data link
MHz	Megahertz
MOU	Memorandum of Understanding
MPAR	Multi-function phased array radar
N	United States Navy
NAS	National Airspace System
NASA	National Aeronautics and Space Administration
NDS	Nuclear Detonation and Detection System
NESDIS	National Environmental Satellite Data and Information Service
NEXRAD	Next Generation Radar
NOAA	National Oceanic and Atmospheric Administration
NWS	National Weather Service
NTIA	National Telecommunications and Information Administration
PPSG	Policy and Plans Steering Group
PSD	Power spectral density
RACON	Radar Beacon
SD	Sensor Data
SENSR	Spectrum Efficient National Surveillance Radar
SLDSC	Saint Lawrence Seaway Development Corporation
TARS	Tethered Aerostat Radar Systems
UAS	Unmanned Aircraft System
US&P	United States and Possessions
USCG	United States Coast Guard

EXECUTIVE SUMMARY

In this report, the National Telecommunications and Information Administration (NTIA) presents a summary of the results of its quantitative assessments of spectrum usage in response to the *2013 Presidential Memorandum* entitled *Expanding America's Leadership in Wireless Innovation*. Through this memorandum, the President sought to make more spectrum available by allowing and encouraging shared access by commercial providers to spectrum that is currently allocated for federal use. As the President's memorandum makes clear, spectrum sharing can enhance efficiency among all users and can expedite commercial access to additional spectrum bands where technically and economically feasible. Accordingly, the memorandum directed NTIA and the federal agencies to take a number of steps to accelerate shared access to spectrum, such as conducting quantitative assessments of frequency bands that have the greatest potential to be shared with non-federal users without adversely affecting agencies' missions.

In response to the President's directive, NTIA's *Plan for Quantitative Assessments of Spectrum Usage* (NTIA Plan) called for the evaluation of existing use in 960 megahertz of spectrum in five frequency bands previously identified for potential future sharing studies. These bands are: 1300-1390 MHz, 1675-1695 MHz, 2700-2900 MHz, 2900-3100 MHz, and 3100-3550 MHz. The NTIA Plan required applicable agencies to verify system characteristics associated with their frequency assignments to enable calculation of the geographic coverage area used by these systems. The NTIA Plan further required each applicable agency to provide estimates of time of use which, together with the coverage area and other metrics, allows for an overall approximation of the extent to which each system uses its assigned spectrum. The cumulative total of each agency's use within a range of frequencies and across systems using a tool developed by NTIA serves as the quantitative assessment for the particular band under review. In bands and locations where multiple agencies have systems, NTIA has aggregated the data in this summary as prescribed by the *2013 Presidential Memorandum*.

The *2013 Presidential Memorandum* and NTIA Plan also required the applicable agencies to provide information on projected increases in their spectrum usage and needs, and to identify where access to non-federal spectrum could aid in fulfilling agency missions. The NTIA Plan also requested these agencies identify relevant and essential mission-related factors that must be considered.

These quantitative assessments can be used as an intermediate step in a process for identifying and prioritizing strategic options for potential repurposing of bands. The information developed in the quantitative assessments will help NTIA and the White House's Spectrum Policy Team, in consultation with the agencies, determine the extent to which frequencies assigned to these agencies could be further evaluated for sharing with commercial users, particularly in major metropolitan areas. Based on the quantitative assessments and associated implications, this report identifies potential sharing opportunities suitable for further examination through feasibility studies. Such detailed evaluations would analyze technical, operational, and cost considerations to ascertain whether such frequencies are appropriate candidates for repurposing for shared federal/non-federal use.

1. INTRODUCTION

1.1 Background

To promote economic growth and unleash the potential of wireless broadband, President Obama's *2010 Presidential Memorandum* unveiled an initiative to reform spectrum policy and increase the amount of spectrum available for commercial wireless broadband services. The *2010 Presidential Memorandum* specifically directed the Secretary of Commerce, working through the National Telecommunications and Information Administration (NTIA) and in collaboration with the Federal Communications Commission (FCC), to identify and make available 500 megahertz of federal and non-federal spectrum by 2020 for expanded wireless broadband use.[1] The launch of this initiative represented a critical first step toward creating a more efficient and innovative wireless broadband infrastructure and catalyzing new private sector investment and economic activity by making more spectrum available for emerging technologies.

In October 2010, pursuant to the *2010 Presidential Memorandum*, NTIA, with input from the Policy and Plans Steering Group (PPSG), issued a plan and timetable to achieve the President's 500 megahertz goal over the next ten years.[2] The plan and timetable took into account the need to ensure no loss of critical existing federal, state, local, and tribal government capabilities, the international implications, and the need for appropriate enforcement mechanisms and authorities.[3] The *Ten-Year Plan* identified more than 2,200 megahertz of federal and non-federal spectrum for evaluation, proposed a process for evaluating candidate bands, and set forth the steps necessary to select and make spectrum available for commercial wireless broadband services.

On June 14, 2013, President Obama issued a second, related memorandum entitled *Expanding America's Leadership in Wireless Innovation,* through which the Administration sought to make more spectrum available for commercial use by allowing and encouraging shared access by commercial providers to spectrum that is currently allocated for federal use.[4] At the

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[1] *See* Memorandum for the Heads of Executive Departments and Agencies, *Unleashing the Wireless Broadband Revolution* (rel. June 28, 2010), *published at* 75 Fed. Reg. 38387 (July 1, 2010), *available at* http://www.whitehouse.gov/the-press-office/presidential-memorandum-unleashing-wireless-broadband-revolution (*2010 Presidential Memorandum*).

[2] NTIA, *Plan and Timetable to Make Available 500 Megahertz of Spectrum for Wireless Broadband* (Oct. 2010), *available at* http://www.ntia.doc.gov/files/ntia/publications/tenyearplan_11152010.pdf (*Ten-Year Plan*). The PPSG is an advisory group of senior federal officials who advise NTIA on achieving the objectives of the *2010 Presidential Memorandum*. *See 2010 Presidential Memorandum* at § 1(c).

[3] *Id.* at § 1(b).

[4] *See* Memorandum for the Heads of Executive Departments and Agencies, *Expanding America's Leadership in Wireless Innovation* (rel. June 14, 2013), *published at* 78 Fed. Reg. 37431 (June 20, 2013), *available at* http://www.whitehouse.gov/the-press-office/2013/06/14/presidential-memorandum-expanding-americas-leadership-wireless-innovatio (*2013 Presidential Memorandum*).

same time, the President again recognized the need to ensure that federal, state, local, tribal, and territorial governments are able to maintain mission critical capabilities that depend on spectrum today, as well as effectively and efficiently meet future requirements. The *2013 Presidential Memorandum* recognized the ongoing efforts spawned three years earlier and re-emphasized how spectrum sharing can enhance efficiency among all users and expedite commercial access to additional spectrum bands where technically and economically feasible. The second memorandum reflected a new reality of spectrum management in which we can achieve spectrum efficiency by maximizing shared access to spectrum between federal and non-federal users, noting that federal agencies have long shared spectrum allocated for federal use. This new spectrum management approach recognizes that it is becoming increasingly difficult to identify feasible alternatives for relocating essential federal capabilities and services without incurring substantial costs and imposing significant operational limitations and delays. Consistent with this shift to promoting more spectrum sharing in federal and non-federal bands, the *2013 Presidential Memorandum* directed federal agencies to take a number of steps to accelerate shared access to spectrum, including making quantitative assessments of actual spectrum usage in frequency bands that NTIA had previously identified and prioritized pursuant to the PPSG efforts noted above.[5]

Since the release of its *Ten-Year Plan*, NTIA has issued six interim progress reports summarizing and assessing the progress that has been made during each reporting period.[6] The *2013 Presidential Memorandum* required NTIA, in consultation with the White House Spectrum Policy Team and appropriate agencies, to develop a plan in the *Fourth Interim Report* directing the applicable agencies to provide quantitative assessments of their actual usage of the spectrum in the frequency bands that NTIA had previously identified and reprioritized in its *Third Interim Report*.[7] NTIA's *Fourth Interim Report* included a *Plan for Quantitative Assessments of Spectrum Usage*, setting forth the methodology for the quantitative assessments called for by the President.[8]

1.2 Objective

The *2013 Presidential Memorandum* stipulated that each agency's assessments are to be prepared according to such metrics and other parameters as are reasonably necessary to determine the extent to which spectrum assigned to the agency potentially could be made available for sharing with or release to commercial users, particularly in major metropolitan areas, without adversely affecting agencies' missions especially those related to national security, law enforcement, and safety of life. This report summarizes the results of the quantitative assessments and makes findings to support the development of further

[5] *See id.* at § 3(a).

[6] *See 2010 Presidential Memorandum* at § 1(d); *see also* NTIA 500 MHz Initiative, *available at* http://www.ntia.doc.gov/category/500-mhz-initiative.

[7] *See* NTIA, *Third Interim Progress Report on the Ten-Year Plan and Timetable* at 12-13 (Nov. 29, 2012), *available at* http://www.ntia.doc.gov/files/ntia/publications/third_interim_progress_report_final.pdf (*Third Interim Report*).

[8] NTIA, *Fourth Interim Progress Report on the Ten-Year Plan and Timetable and Plan for Quantitative Assessments of Spectrum Usage* at Appendix A (June 5, 2014), *available at* http://www.ntia.doc.gov/files/ntia/publications/fourth_interim_progress_report_final.pdf (*Fourth Interim Report*).

recommendations, as appropriate, for future feasibility studies. Section 3(b) of the *2013 Presidential Memorandum* provides that "NTIA shall release a summary of the assessments publicly to the extent consistent with law." It provides further that "NTIA and the Spectrum Policy Team shall make any appropriate recommendations regarding the possible availability of spectrum in the subject bands for innovative and flexible commercial uses, including broadband, taking into account factors such as the nature of the Federal systems in the bands and the extent to which those systems occupy and use the bands."[9]

1.3 Approach

NTIA's *Fourth Interim Report* identified 960 megahertz of spectrum in five frequency bands for the quantitative assessments: 1300-1390 MHz, 1675-1695 MHz, 2700-2900 MHz, 2900-3100 MHz, and 3100-3550 MHz. To supplement the parameters already associated with their frequency assignments contained in the Government Master File (GMF), NTIA's *Plan for Quantitative Assessments of Spectrum Usage* required the affected agencies to submit additional data for each system's individual transmitting and receiving stations as necessary to develop an approximation of each system's actual use of the spectrum. The data includes parameters for spectrum (frequency and bandwidth), geographic area, and estimated time of usage for each operation in accordance with the metrics in the methodology stipulated in the plan. Based on each agency's assessment of the most up-to-date and validated parameters and data elements, the key metric that NTIA derived from such data is the cumulative Total Spectrum Usage. Total Spectrum Usage represents the cumulative data resulting from the aggregation of each agency's quantitative assessment using three independent components: frequency (bandwidth) use, geographic use, and time of use. The findings based on this data can be used as one input to narrow down, select, and prioritize the identified frequency bands for more detailed feasibility studies.

In June 2014, NTIA requested each agency with current operations in the bands under review for the quantitative assessment to report on their projected usage, termination, and future developments.[10] It asked each applicable agency to provide information regarding planned new uses, expected expansion of current uses, and potential relocation or cessation of use, projecting where and when these future uses or changes would increase or decrease its spectrum usage in the bands under review.

From June 5, 2014 to June 5, 2015, in accordance with the *Plan for Quantitative Assessments of Spectrum Usage*, NTIA and the affected agencies took the following steps:

- NTIA provided each agency with additional detailed instructions, including guidance on the methodology used in performing the quantitative assessment, along with a list

[9] *2013 Presidential Memorandum* at § 3(b).

[10] Reference to termination or cessation of frequency assignments and relocation of systems to other frequencies are only related to the normal NTIA frequency assignment process as opposed to repurposing considerations which requires detailed feasibility studies, as well as specific accommodations such as comparable spectrum.

of GMF frequency authorization and spectrum certification data for the bands identified in the NTIA Plan.[11]

- Each agency reviewed and verified its frequency assignment and spectrum certification data.

- After verification, each agency updated the information for any assignments omitted from the list provided by NTIA, and for any station, system, or facility using or authorized to use the bands identified for the quantitative assessment that was not included in the GMF data or not otherwise required to obtain an assignment from NTIA (*e.g.*, receivers).

- For each assignment, each agency provided an estimated percentage of time of actual use, based on the metric provided in the plan to represent access and availability needs for mission or operational requirements.

- Using the data provided, validated and supplemented by the agencies, NTIA computed the spectrum usage contours and the estimated percentage of the population impacted using a new analytical tool NTIA developed for the purpose of compiling and summarizing usage.[12]

The methodology used by NTIA to compute Total Spectrum Usage was coordinated with the federal agencies through the Technical Subcommittee of the Interdepartment Radio Advisory Committee (IRAC).

In August 2015, NTIA reminded the affected agencies that the *Plan for Quantitative Assessments of Spectrum Usage* required them to address projected future spectrum usage in each band under review and to provide NTIA supplemental information on the following: all expected expansion of current systems and uses (*e.g.*, geographic expansion, additional frequencies or bandwidth, and increased time of use); all planned new systems and uses; and any potential relocation, cessation, or modification of current systems and uses. For each of these systems and uses, NTIA asked these agencies to provide any available data elements for the transmit and receive stations listed in the *Plan for Quantitative Assessments of Spectrum Usage* along with the information that would otherwise be required by Section 10.8.1 of the *NTIA Manual*.[13] At a minimum, if such data and information was not readily available, NTIA requested that the agencies specifically identify for each system or use:

- the affected geographic location(s);

[11] The quantitative assessment is a snapshot of the federal frequency assignment data from the GMF as of December 2015.

[12] The spectrum usage contours were developed assuming antenna heights and power thresholds consistent with terrestrial systems. The geographic usage contours do not take into account United States and Possessions (US&P) frequency assignments.

[13] NTIA *Manual of Regulations and Procedures for Federal Radio Frequency Management* at § 10.8.1 (September 2015 Revision of the May 2013 Edition) (*NTIA Manual*).

- projected timelines (*e.g.*, for submission of new or modified requests for certification of spectrum support, field testing, procurement, deployment, expansion, relocation, cessation, *etc.*);

- other federal agencies that could benefit or be affected by such changes (*e.g.*, enhanced or consolidated services or systems, reduced or increased interference risks, reduced or increased costs, *etc.*); and

- how such projected changes would increase or decrease the agency's Total Spectrum Usage in the bands under review (*i.e.*, geographic coverage, necessary bandwidth, and estimated time of use).

NTIA also requested that these agencies provide a description of how and where access to non-federal spectrum bands could aid in fulfilling their mission (as well as any other agencies' missions). This included relevant and detailed information regarding:

- candidate frequency band(s) currently allocated to non-federal use on an exclusive or primary basis;

- the type(s) of federal operations that would be conducted in such band(s) and its (their) necessary bandwidth and performance requirements;

- the likely source(s) of equipment and technology for such systems (*i.e.*, commercial or government off-the-shelf, repurposed specialized/proprietary, new or undeveloped, *etc.*);

- the type, size, and scope of the geographic area(s) in which such operations would occur; and

- the estimated percentage of time the band(s) would be used within the geographic area(s).

Throughout this process, NTIA consulted with federal agency representatives on the Spectrum Working Group of the PPSG on the progress and challenges associated with accurately estimating and assessing actual spectrum usage.

The quantitative assessments are one input in a process for identifying and prioritizing strategic options for detailed feasibility studies to examine potential sharing options in a band.[14] This report documents the results of the actions taken by NTIA and the affected agencies in performing the quantitative assessments based on the information derived from NTIA's tool. Section 2 describes the data used in the assessments. Sections 3 and 4 describe the

[14] *See* NTIA, *An Assessment of the Viability of Accommodating Wireless Broadband in the 1755-1850 MHz Band* (Mar. 2012), *available at* http://www.ntia.doc.gov/files/ntia/publications/ntia_1755_1850_mhz_report_march2012.pdf. The detailed feasibility studies will consider all relevant scenarios and potential impacts to the federal systems which could include the effects of aggregate interference.

methodologies to compute the transmit and receive station spectrum usage contours. The population impacted and geographic availability calculations are described in Section 5.[15] Section 6 provides an overview of the federal operations in the quantitative assessment frequency bands. Section 7 describes the calculation of Total Spectrum Usage. The detailed results of the quantitative assessments are presented in Section 8.

1.4 Summary

Based on the quantitative assessments, NTIA has identified several bands with potential sharing opportunities, contingent upon the successful completion of feasibility studies. The more detailed evaluation of a band for sharing would need to take into account all current and future uses in a band, including those that can occur anywhere in the US&P, as well as technical, operational, and cost considerations.[16]

While the results of quantitative assessments can assist in representing an approximation of spectrum use, the nature of the federal operations and mission requirements may directly impact the specific risks associated with sharing feasibility considerations. For example, while some federal systems may operate intermittently, these systems may support operations such as critical national security applications, which require high spectrum availability when and where needed.

1.4.1 Overview of Quantitative Assessments Results. Using the criteria in Table 1-1, NTIA identified spectrum for future feasibility studies to assess potential sharing opportunities. The quantitative assessments and the associated criteria are components of a complex process for determining options for detailed sharing feasibility studies.

Table 1-1. Criteria Used to Identify Potential Sharing Opportunities

Sharing Opportunity	**Criteria**
Frequency Sharing	No frequency assignments (excluding band, airborne, and United States and Possessions (US&P) frequency assignments) within a 5 megahertz band segment
Geographic Sharing	For approximately 70% of the 5 megahertz band segments the following criteria must be satisfied: - percentage of population impacted: less than approximately 60% - percentage of geographic availability: greater than approximately 50%
Time Sharing	Station time of usage less than 10% for approximately 70% of the frequency assignments within a 5 megahertz band segment

The results of the quantitative assessments were used to identify the bands for which potential future feasibility studies to assess potential sharing opportunities would be most beneficial, as shown in Table 1-2.

[15] For the purpose of the quantitative assessments, geographic availability represents the area as a percentage of the contiguous United States that geographically is not covered by the spectrum usage contours.

[16] *See Ten-Year Plan* at 12-13.

Table 1-2. Potential Feasibility Studies Based on Quantitative Assessment of Spectrum Usage

Frequency Band (MHz)	Types of Feasibility Studies		
	Frequency Sharing	Geographic Sharing	Time Sharing
1300-1350	No	No	No
1350-1390*	No	No	Yes
1675-1695	No	Yes	No
2700-2900	No	No	No
2900-3100	No	Yes	No
3100-3505*	No	Yes	Yes
3505-3550*	Yes	Yes	Yes
* Indicates there are airborne operations in the band or US&P assignments.			

Total Spectrum Usage derived from the quantitative assessments data was computed using NTIA's tool with updated and validated frequency authorization data in the GMF. This data reflects the maximum parameters (bandwidth, power, and antenna gain) for a transmit station as well as the maximum geographic area over which the transmit station is authorized to operate. Therefore, the spectrum usage contours for each transmit or receive station, when taken in the aggregate, represent an upper bound on Total Spectrum Usage. Sections 3 and 4 explain the methods used to develop the spectrum usage contours. US&P assignments are not included in the spectrum usage contours since they do not have a specific geographic location but are taken into consideration in the frequency usage component.

1.4.2 1300-1390 MHz Band. As shown in Table 7-1 and the figures in Appendix A, Total Spectrum Usage on a nationwide basis in the 1300-1350 MHz and the 1350-1390 MHz sub-bands is significantly different. In the 1300-1350 MHz sub-band, the average number of transmit stations in each 5 megahertz band segment is 52. In the 1350-1390 MHz sub-band, the average number of transmit stations in each 5 megahertz band segment is 135. The types of systems operating in these two sub-bands are also different. For example, the long-range radar systems operated by the Federal Aviation Administration (FAA) with the Department of Defense (DOD) and the Department of Homeland Security (DHS) and used for Air Traffic Control (ATC) in the National Airspace System (NAS) defense and homeland security, primarily operate across the country in the 1300-1350 MHz sub-band. The DOD operates radars in this frequency range. The DOD operates fixed and transportable tactical radar systems, ground-based and airborne tactical communication systems, and airborne telemetry systems in the 1350-1390 MHz sub-band. Based on the results of the quantitative assessment, the heavy and diverse usage currently occurring in the 1300-1390 MHz band appears to limit the potential sharing opportunities. Other measures would be necessary in order to enable sharing in the band, including consideration of potential relocation of major widespread systems to other spectrum bands if feasible. A detailed feasibility study of the band would have to consider numerous factors beyond the results of the quantitative assessment.

The FAA, DOD, DHS, and Department of Commerce (DOC) operate single function radars in the 1300-1390 MHz and 2700-3100 MHz frequency bands. Ongoing work apart from the quantitative assessment initially considered combining the operational requirements of different single function radar systems with a multi-function phased array radar (MPAR) capability which could include various radar functions of several nationwide networks operating in different frequency bands, including 1300-1350 MHz and 2700-3100 MHz. Combining these functions is intended to effect savings of acquisition and maintenance costs without impacting performance, while potentially freeing up a significant geographic and spectrum footprint for new uses.[17] Currently, the MPAR technology demonstration has evolved into a feasibility study for a Spectrum Efficient National Surveillance Radar (SENSR) capability that could also include capabilities for national and homeland defense, whether as a single system or a system of systems, as part of a potential reallocation feasibility study of the 1300-1350 MHz band. Currently, the 2700-3100 MHz frequency range is one option under consideration for potential relocation of the surveillance systems out of the 1300-1350 MHz band as part of the SENSR capability. The feasibility studies necessary to define the SENSR operational requirements, procurement, migration, and deployment are in the early stages. A relocation feasibility study has not started pending the development and approval of the study plan by impacted agencies and attainment of funding.

Thus, one of several options for future feasibility studies to assess the potential accommodation of wireless broadband in the 1300-1390 MHz band would include making contiguous or non-contiguous blocks of cleared or partially cleared spectrum in the 1300-1350 MHz sub-band available for wireless broadband if the FAA/DOD/DHS long-range radars can be migrated from the 1300-1390 MHz band.

The studies considering compatibility with federal systems that will not be replaced by a SENSR capability could first focus on the geographic areas around major cities where the spectrum need and congestion are the greatest. To the extent practical, provisions for sharing in the non-federal fixed and mobile bands (*e.g.*, 1850-2690 MHz frequency range) to accommodate federal systems with the ability to operate in this frequency range could be considered. The relocation studies could also take into account frequency and angular (azimuth angle and elevation angle) restrictions that the federal systems can employ to limit the impact on non-federal operations in major cities.

Any consideration of sharing feasibility studies would also have to consider the impact of proposed wireless broadband systems on federal systems that would likely remain in the 1300-1390 MHz band.

1.4.3 1675-1695 MHz Band. As shown in Table 7-2 and the figures in Appendix B, Total Spectrum Usage in the 1675-1685 MHz sub-band is much less than that in the 1685-1695 MHz sub-band. Total Spectrum Usage will be further reduced when the radiosonde receive stations are migrated to the 400 MHz band as shown in Table 7-3 and the figures in Appendix B. When the radiosonde receive stations complete their planned migration to the 400 MHz band, opportunities may exist to accommodate wireless broadband, contingent upon the successful completion of a feasibility study. The impact to non-federal users of the DOC meteorological-satellite data, particularly the Emergency Managers Weather Information Network (EMWIN) users, would have to be taken into account in assessing potential sharing options with wireless broadband.

[17] *See* NOAA, Fact Sheet: Multi-Function Phased Array Radar, *available at* http://www.nssl.noaa.gov/news/factsheets/MPAR_2015.March.16.pdf.

1.4.4 2700-2900 MHz and 2900-3100 MHz Bands. As shown in Table 7-4 and Table 7-5 and the figures in Appendix C and Appendix D, Total Spectrum Usage in the 2900-3100 MHz band is much less than in the 2700-2900 MHz band. This indicates that potential sharing opportunities may exist in the 2900-3100 MHz band, contingent upon the successful completion of feasibility studies.

At this point, the affected agencies have not determined the spectrum requirements for the SENSR option, including how its multiple functions could be configured throughout the 2700-3100 MHz frequency range.[18] As previously noted, the feasibility studies necessary to define the SENSR operational requirements, procurement, migration, and deployment are in the early stages. The feasibility studies would also have to consider the impact of proposed wireless broadband systems on federal systems that would likely remain operating in the 2700-3100 MHz band.

1.4.5 3100-3550 MHz Band. As shown in Table 7-6 and the figures in Appendix E, Total Spectrum Usage is much less in the 3505-3550 MHz portion of the band as compared to the rest of the band. This indicates that an opportunity exists to examine the possibility of sharing with wireless broadband.

The 3100-3505 MHz portion of the band is used heavily on a frequency and geographic basis, limiting the opportunities for sharing with wireless broadband. However, as shown in Table 7-6, the transmit stations which are used for tactical systems operate at lower percentages of time as calculated using NTIA's tool, in the range of 1 percent to 10 percent, indicating that opportunities for sharing on a time basis exist. To accomplish this spectrum sharing, wireless broadband systems would have to employ techniques that can take advantage of temporal sharing. In the 3550-3700 MHz band, a regulatory framework is being implemented that requires employment of both sensing and database spectrum sharing technologies in order to protect DOD shipborne and ground-based radar systems.[19] As experience with this innovative spectrum sharing approach is gained, it potentially could be implemented in portions of the 3100-3505 MHz band for wireless broadband. Any sharing feasibility studies would also include consideration of airborne systems that operate in the frequency band.[20]

Based on experience in assessing this band in past analyses, any detailed sharing feasibility study would have to account for the impact to all categories of radar systems operating in the band (ground-based, shipborne, and airborne). In addition, radar transmitters have such high peak power levels that any feasibility studies in the 3100-3550 MHz band must also examine large signal effects on non-federal user equipment such as burnout and saturation.[21]

[18] The radars under consideration for relocation from other bands to the 2700-3100 MHz band are currently used for aircraft surveillance and weather sensing and include: the FAA Airport Surveillance Radar, Terminal Doppler Weather Radar, Air Route Surveillance Radar, and the NOAA Next-Generation Weather Radar.

[19] *See* 47 C.F.R Part 96, Citizens Broadband Radio Service.

[20] A database approach may not be practical for sharing with airborne systems. Some form of sense and avoid capability is an option to enable time sharing with airborne systems. Additionally, a critical component of any sharing approach is a practical enforcement mechanism.

[21] *See* NTIA, *An Assessment of the Near-Term Viability of Accommodating Wireless Broadband Systems in the 1675-1710 MHz, 1755-1780 MHz, 3500-3650 MHz, and 4200-4400 MHz, 4380-4400 MHz Bands* (Nov. 15, 2010),

2. DESCRIPTION OF TRANSMIT AND RECEIVE STATION DATA

2.1 Introduction

This section provides a description of the transmit station and receive station data elements used in the quantitative assessments for the systems that were analyzed using the NTIA tool. The methodology for estimating time of usage for the transmit and receive stations is also provided.

2.2 Transmit Station Data

NTIA's *Plan for Quantitative Assessments of Spectrum Usage* established metrics and other parameters for the quantitative assessments of the applicable bands. The data parameters necessary to develop an approximation of the extent to which a system uses the spectrum include spectrum (frequency and bandwidth), geographic, and time components. NTIA provided each agency a list of its current frequency assignments and spectrum certifications for each band within the GMF. Each applicable agency was requested to review, verify, update, or supplement the data elements contained in Table 2-1 for transmit stations operating in the bands under consideration in the quantitative assessments.

Table 2-1. Transmit Station Data Elements

Parameter	**Units**
Frequency	Megahertz
Class of Station	NTIA Manual – Chapter 6
Latitude and longitude	Degrees/Minutes/Seconds
Transmitter necessary bandwidth	Hertz
Transmitter power	Watts
Transmit mainbeam antenna gain	Decibels referenced to an isotropic antenna
Transmit antenna height	Meters
Area of operation (for mobile and transportable systems): Radius of operation defining area of operation Latitudes and longitudes defining area of operation Authorized state(s)/nationwide defining area of operation	 Kilometers Degrees/Minutes/Seconds Annex G[22]
Pulse width (for pulsed systems)	Microseconds
Pulse repetition rate (for pulsed systems)	Pulses per second

(*Fast Track Report*) at 4-78 and Appendix G, *available at* http://www.ntia.doc.gov/reports/2010/FastTrackEvaluation_11152010.pdf.

[22] Annex G of the *NTIA Manual* contains the abbreviations used in the transmitter state/country fields of the GMF.

2.3 Receive Station Data

As stated in the NTIA Plan, each applicable agency was requested to provide the data elements contained in Table 2-2 for receive stations operating in the bands under consideration in the quantitative assessments.

Table 2-2. Receive Station Data Elements

Parameter	**Units**
Frequency	Megahertz
Class of Station	NTIA Manual – Chapter 6
Latitude and longitude	Degrees/Minutes/Seconds
Intermediate frequency receiver 3 dB bandwidth	Hertz
Receive mainbeam antenna gain	Decibel referenced to an isotropic antenna
Receive antenna gain pattern	Decibel referenced to an isotropic antenna as a function of off-axis angle in degrees
Receive antenna height	Meters
Receive antenna azimuth angle	Degrees
Receive antenna minimum elevation angle	Degrees

2.4 Time of Usage

The agencies were requested to provide estimated time of use data for each transmit and receive station based on the guidance provided in Table 2-3.[23]

Table 2-3. Guidance on Time of Use

GMF TME Field Entry	**Description of Actual Use**	**Percentage of Time Frequency is Used per Day**
1	Constant or nearly	50 to 100
2	Regular/frequent	10 to 50
3	Intermittent	1 to 10
4	Sporadic/occasional	Less than 1

NTIA used the transmit station, receive station, and time of use data to compute the spectrum usage contours for each agency and the aggregate spectrum usage contours that are used to determine Total Spectrum Usage in the quantitative assessments.

[23] There is no standardized method for federal users to collect time of use data for their spectrum dependent systems, and as a result these calculations serve as a first order approximation of estimated time of usage.

3. METHODOLOGY FOR COMPUTING TRANSMIT STATION CONTOURS

3.1 Introduction

This section provides the methodology for computing the transmit station contours used in the quantitative assessments. The required propagation loss based on a generic power spectral density threshold was used to compute the individual transmit station contours for the systems analyzed using the NTIA tool. The following sections describe the methodology used for computing the transmit station spectrum usage contours.

3.2 Methodology for Computing Transmit Station Contours

The required propagation loss for the transmit station contour was determined using the following equation:

$$L_{Required} = [10 \text{ Log } (P_T) - 10 \text{ Log } (BW)] + 10 \text{ Log } (DC/100) + G_T(\theta) + G_R - PSD_T \quad (3\text{-}1)$$

Where:

$L_{Required}$ is the required terrain-dependent propagation loss (dB);
P_T is the transmitter power (Watts);
BW is the transmitter emission necessary bandwidth (Hz);
DC is the transmitter duty cycle (percent);
$G_T(\theta)$ is the transmitter antenna gain for a specific up-tilt angle (dBi);
G_R is the receiver antenna gain (dBi); and
PSD_T is the power spectral density threshold (dBW/Hz).

The frequency, transmitter necessary bandwidth, transmitter power, transmitter mainbeam antenna gain, and transmitter antenna height for a frequency assignment are available in the GMF.

The transmitter power in the GMF is specified as peak power. The duty cycle is the fraction of the time that a pulsed system is in an "active" state. The duty cycle is the product of the pulse duration and pulse repetition rate of a pulse carrier in the GMF, equal to the percentage of time that the pulse power is on over a period of time. For non-pulsed signals the duty cycle is 100 percent.

The antenna gain of the transmitter was computed based on a 1 degree up-tilt angle. A statistical gain antenna model is used to determine the radar antenna gain in the azimuth and elevation orientations.[24] The model gives the antenna gain as a function of off-axis angle (θ) for a given main beam antenna gain (G). The model includes separate algorithms for very high-gain (G > 48 dBi), high-gain (22 < G < 48 dBi), and medium-gain (10 < G < 22 dBi) antennas. Figure 3-1 illustrates the general form of the antenna gain distribution. The equations for the

[24] National Telecommunications and Information Administration, NTIA Technical Memorandum 09-461, *Description of a Model to Compute the Aggregate Interference from Radio Local Area Networks Employing Dynamic Frequency Selection to Radars Operating in the 5 GHz Frequency Range* (May 2009) at 4-2.

angles θ_M (first side-lobe region), θ_R (near side-lobe region), and θ_B (far side-lobe region) are given in Table 3-1. The antenna gains, as a function of off-axis angle, are given in Table 3-2 for very high-gain antennas, in Table 3-3 for high-gain antennas, and in Table 3-4 for medium-gain antennas. The angle θ is in degrees and all gain values are given in terms of decibels relative to an isotropic antenna (dBi).

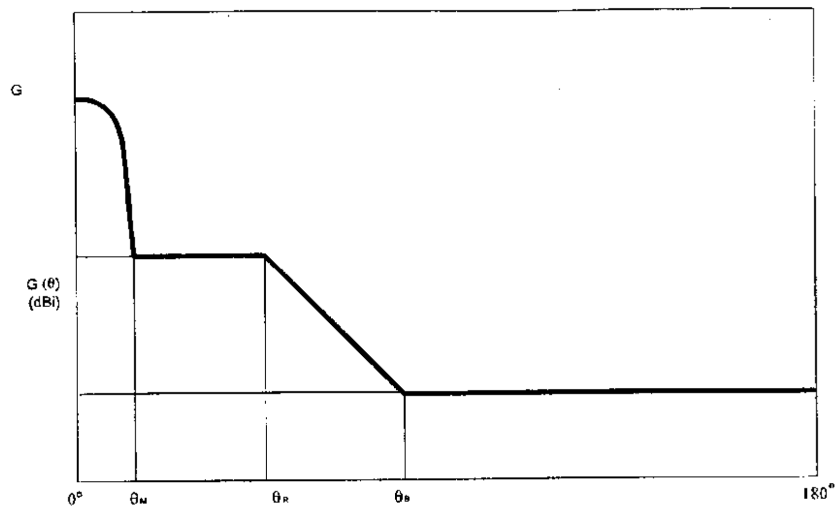

Figure 3-1. General Form of Antenna-Gain Distribution

Table 3-1. Angle Definitions

Very high-gain (G > 48 dBi)	**High-gain (22 < G < 48 dBi)**	**Medium-gain (10 < G < 22 dBi)**
$\theta_M = 50\ (0.25\ G + 7)^{0.5}/10^{G/20}$ $\theta_R = 27.466\ 10^{-0.3G/10}$ $\theta_B = 48$	$\theta_M = 50\ (0.25\ G + 7)^{0.5}/10^{G/20}$ $\theta_R = 250/10^{G/20}$ $\theta_B = 48$	$\theta_M = 50\ (0.25\ G + 7)^{0.5}/10^{G/20}$ $\theta_R = 250/10^{G/20}$ $\theta_B = 131.8257\ 10^{-G/50}$

Table 3-2. Equations for Very High-Gain Antennas (G > 48 dBi)

Angular interval (degrees)	**Gain (dBi)**
0 to θ_M θ_M to θ_R θ_R to θ_B θ_B to 180	$G - 4 \times 10^{-4}\ (10^{G/10})\ \theta^2$ 0.75 G - 7 29 - 25 log (θ) -13

Table 3-3. Equations for High-Gain Antennas (22 < G < 48 dBi)

Angular interval (degrees)	**Gain (dBi)**
0 to θ_M θ_M to θ_R θ_R to θ_B θ_B to 180	$G - 4 \times 10^{-4}\ (10^{G/10})\ \theta^2$ 0.75 G - 7 53 - (G/2) - 25 log (θ) 11 - G/2

Table 3-4. Equations for Medium-Gain Antennas (10 < G < 22 dBi)

Angular interval (degrees)	Gain (dBi)
0 to θ_M	$G - 4 \times 10^{-4} (10^{G/10}) \theta^2$
θ_M to θ_R	0.75 G - 7
θ_R to θ_B	53 - (G/2) - 25 log (θ)
θ_B to 180	0

For transmitter antenna gain values of less than 10 dBi, the mainbeam antenna gain specified in the GMF frequency assignment was used to compute the transmit station contour. The transmit station contours were computed for a receive antenna gain of 0 dBi and height of 2 meters.

The propagation loss used to compute the transmit station contour is based on a terrain-dependent model. The Irregular Terrain Model (ITM) in the Point-to-Point Mode was used for computing the propagation loss for the transmit station contours.[25] Since the Point-to-Point Mode uses actual terrain data, it will provide a better estimate of the propagation loss.[26] The statistical and environmental parameters used with the actual terrain profiles in calculating propagation loss are shown in Table 3-5.

Table 3-5. Transmit Station ITM Point-to-Point Mode Parameters

Parameter	Value
Mode	Single Message
Surface Refractivity	301 N-units
Conductivity of Ground	0.005 S/M
Dielectric Constant of Ground	15
Polarization	Vertical
Reliability[a]	50 percent
Confidence[a]	50 percent
Frequency	Variable
Transmitter Antenna Height	Variable
Receiver Antenna Height	2 meters[27]
Radio Climate	Continental Temperate
Terrain Database	United States Geological Survey - 3 Second
Note a: The reliability and confidence percentages used in generating the transmit station contours do not take into account anomalous propagation effects (*e.g.*, ducting conditions)	

For transmit station contours, the PSD threshold was determined based on a 1 dB increase in the receiver thermal noise density of -204 dBW/Hz. The 1 dB increase results in an interference-to-noise density ratio of -6 dB. The PSD threshold used to compute the transmit station contour was -210 dBW/Hz.

[25] *See* NTIA Report 82-100, *A Guide to the Use of the ITS Irregular Terrain Model in the Area Prediction Mode* (April 1982).

[26] ITM in the Point-to-Point mode takes into account terrain but does not include local clutter (*e.g.*, buildings).

[27] An antenna height of 2 meters is the minimum value that can be used in the ITM propagation model.

The technical parameters that affect the size of the transmit station contours include: the PSD threshold, receive antenna height, antenna model, propagation model, and other losses (*e.g.*, clutter).[28] The selection of the technical parameters used in the quantitative assessments is intended to be technology neutral. The selection of other technical parameters could affect the size of the transmit station contours. These technical parameters can be refined when the more detailed feasibility studies are performed to assess potential sharing opportunities with a specific technology.

NTIA authorizes transmit stations for terrestrial and airborne systems that operate across large areas such as statewide, regional, in the conterminous United States, or the entire United States and Possessions (US&P). Spectrum usage contours were not generated for these transmit stations; however, they were included in the frequency and time usage component of Total Spectrum Usage.[29]

Transmit station contours were not computed for meteorological-satellite downlink and radiosonde airborne transmitters due to the relatively low received signal levels at the surface of the Earth.[30] For assessing spectrum usage, it was deemed more appropriate to compute spectrum usage contours for the meteorological-satellite and radiosonde receive stations as discussed in Section 4.

3.2.1 Fixed Transmit Station Contour. The transmit station latitude and longitude was used as the center point for the contour. The ITM terrain dependent propagation loss satisfying the required propagation loss values from Equation 3-1 was used to determine the transmit station contour. A terrain profile was generated at each 1 degree increment around a transmit station location. Using the computed values of required propagation loss in Equation 3-1, the point farthest away along the terrain profile corresponding to the required propagation loss is used to determine the transmit station contour distance.

3.2.2 Transportable Transmit Station Contour. The area of operation for a transportable transmit station in the GMF was described in terms of: 1) a circle with a latitude and longitude as the center point and a radius of operation; or 2) a rectangle with the latitude and longitude specifying the northeast and southwest corner. In both cases, multiple transmit contours were generated along the edge of the circle/rectangle. The multiple transmit contours were combined to generate a composite transmit contour around the area of operation.[31] Taking the convex hull of the composite transmit contour generally results in a smoother-shaped polygon, because the points creating concave angles was removed.

[28] Building clutter losses were not included in the generation of the transmit station contours shown in the appendices.

[29] The feasibility studies to assess the potential sharing or relocation opportunities will take into account federal US&P operations.

[30] *Fast Track Report* at 4-9 and Appendix C.

[31] Graham, R.L. (1972). *An Efficient Algorithm for Determining the Convex Hull of a Finite Planar Set*, Information Processing Letters 1, 132-133.

3.2.3 Shipborne Transmit Station Contour. For the shipborne transmit stations, a ship was moved along the coast in 10 kilometer (km) increments. The ship was positioned 10 km off shore. The ITM path started at 475 km inland then stepped in 10 km increments toward the shore until the PSD threshold was crossed. This was performed with a ± 20 degrees sweeping angle perpendicular to the shore. The angle sweep was in 2 degree steps from -20 degrees to +20 degrees. Using the computed values of required propagation loss, the point farthest in-land along the terrain profile corresponding to the required propagation loss was used to determine the transmit station contour distance. The shipborne transmit contour will encompass the full length of the shoreline off of which the shipborne system operates as specified in the GMF (*e.g.,* East, West, or Gulf coast).

3.2.4 Airborne Transmit Station Contour. For the airborne stations, the area of operation specified in the GMF frequency authorization was used to represent the transmit station contour.

4. METHODOLOGY FOR COMPUTING RECEIVE STATION CONTOURS

4.1 Introduction

This section provides the methodology for computing the receive station contours used in the quantitative assessments. The methodology described in this section was used for meteorological-satellite, radiosonde, and nuclear detonation detection receive stations. The required propagation loss based on a generic power spectral density threshold was used to compute the individual receive station contours. The following sections describe the methodology used for computing the receive station spectrum usage contours.

4.2 Methodology for Computing Receive Station Contours

The required propagation loss for the receive station contour was determined using Equation 4-1.

$$L_{Required}(\varphi) = [EIRP - 60] + G_R(\varphi) - PSD_T \qquad (4\text{-}1)$$

Where:

$L_{Required}(\varphi)$ is the required terrain-dependent propagation loss as a function of the off-axis angle (dB);
EIRP is the transmitter equivalent isotropically radiated power (dBW);
$G_R(\varphi)$ is the receive antenna gain as a function of off-axis angle (dBi); and
PSD_T is the power spectral density threshold (dBW/Hz).

The receive station contours were computed for a transmitter EIRP of 0 dBW and antenna height of 2 meters. The emission bandwidth used in computing the receive station contours was 1 megahertz.[32]

Signals from polar orbiting satellites can be received at any azimuth so the mainbeam was rotated 360 degrees in azimuth at the minimum elevation angle. For geostationary satellites, signals are received at a specific elevation angle and azimuth angle. The receive antenna gain associated with the mainbeam region and the off-mainbeam region was used in the calculation of the receive station contour. The antenna model for the meteorological-satellite receive Earth stations was based on Recommendation ITU-R F.1245-1.[33] In cases where the ratio between the antenna diameter and the wavelength is greater than 100 ($D/\lambda > 100$), the following equations were used:

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[32] A 1 megahertz reference bandwidth is commonly used for Federal Communications Commission emission standards for commercial services. The 60 dB in Equation 4-1 is determined by taking 10 Log ($1x10^6$).

[33] Recommendation ITU-R F.1245-1, *Mathematical Model of Average or Related Radiation Patterns for Line-of-Sight Point-to-Point Radio Relay System Antenna for Use in Certain Coordination Studies and Interference Assessment in the Frequency Range from 1 GHz to About 70 GHz* (2000).

$G(\varphi) = G_{max} - 2.5 \times 10^{-3} ((D/\lambda)\,\varphi)^2$	for $0° < \varphi < \varphi_m$	(4-2)
$G(\varphi) = G_1$	for $\varphi_m \leq \varphi < \max(\varphi_m, \varphi_r)$	(4-3)
$G(\varphi) = 29 - 25 \text{ Log } (\varphi)$	for $\max(\varphi_m, \varphi_r) \leq \varphi < 48°$	(4-4)
$G(\varphi) = -13$	for $48° \leq \varphi \leq 180°$	(4-5)

Where:

G_{max}:	Maximum antenna gain (dBi)
$G(\varphi)$:	Gain relative to an isotropic antenna (dBi)
φ:	Off-axis angle (degrees)
D:	Antenna diameter (m)
λ:	Wavelength (m)
G_1:	Gain of the first side lobe = $2 + 15 \log (D/\lambda)$

$\varphi_m = (20\,\lambda)/D\,(G_{max} - G_1)^{0.5}$	degrees	(4-6)
$\varphi_r = 12.02\,(D/\lambda)^{-0.6}$	degrees	(4-7)

In cases where the ratio between the antenna diameter and the wavelength is less than or equal to 100 ($D/\lambda \leq 100$), the following equations were used:

$G(\varphi) = G_{max} - 2.5 \times 10^{-3} ((D/\lambda)\,\varphi)^2$	for $0° < \varphi < \varphi_m$	(4-8)
$G(\varphi) = 39 - 5 \text{ Log } (D/\lambda) - 25 \text{ Log } (\varphi)$	for $\varphi_m \leq \varphi < 48°$	(4-9)
$G(\varphi) = -3 - 5 \text{ Log } (D/\lambda)$	for $48° \leq \varphi \leq 180°$	(4-10)

D/λ is estimated using the following expression:

$$20 \text{ Log } (D/\lambda) \approx G_{max} - 7.7 \tag{4-11}$$

Where:

G_{max}: Maximum antenna gain (dBi)

The antenna pattern for a 43 dBi mainbeam antenna gain is shown in Figure 4-1.

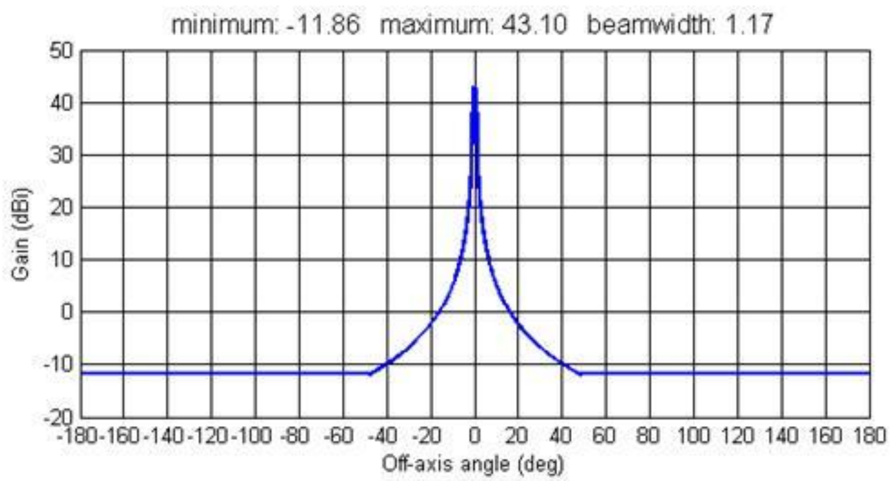

Figure 4-1. Azimuth and Elevation Antenna Pattern

For radiosonde receive antennas, the statistical gain antenna model described in Tables 3-1 through 3-4 was used. A 5 degree up-tilt angle was used to compute the off-axis antenna gain.[34]

The propagation loss used to compute the receive station contours in the quantitative assessments was based on a terrain-dependent model. ITM in the Point-to-Point Mode was used for computing the propagation loss for the receive station contours. Since the Point-to-Point Mode uses actual terrain data, it will provide a better estimate of the propagation loss. The statistical and environmental parameters used with the actual terrain profiles in calculating propagation loss are shown in Table 4-1.

Table 4-1. Receive Station ITM Point-to-Point Mode Parameters

Parameter	**Value**
Mode	Single Message
Surface Refractivity	301 N-units
Conductivity of Ground	0.005 S/M
Dielectric Constant of Ground	15
Polarization	Vertical
Reliability[a]	10 percent
Confidence[a]	10 percent
Frequency	Variable
Transmitter Antenna Height	2 meters[35]
Receiver Antenna Height	Variable
Radio Climate	Continental Temperate
Terrain Database	United States Geological Survey - 3 Second
Note a: The reliability and confidence percentages used in generating the receive station contours do not take into account anomalous propagation effects (*e.g.*, ducting conditions)	

[34] When flights are at maximum range, radiosonde receive antennas can track down to the horizon.

[35] An antenna height of 2 meters is the minimum value that can be used in the ITM propagation model.

For receiving stations, the PSD threshold was determined based on a 0.5 dB increase in the receiver thermal noise density of -204 dBW/Hz. The 0.5 dB increase results in an interference-to-noise density ratio of -9 dB. The PSD threshold used to compute the receive station contour in the quantitative assessments was -213 dBW/Hz.

The technical parameters that affect the size of the receive station contours include: the PSD threshold, transmit antenna height, antenna model, propagation model, and other losses (*e.g.,* building blockage). The selection of the technical parameters used in the quantitative assessments was intended to be technology neutral. The selection of other technical parameters would affect the size of the receive station contours. These technical parameters can be refined when the more detailed compatibility studies are performed to assess potential sharing opportunities with a specific technology.

The receive station latitude and longitude is used as the center point for the contour. The ITM terrain dependent propagation loss satisfying the required propagation loss values from Equation 4-1 was used to determine the receiver station contour. At each 1 degree increment around a receive station location, a terrain profile was generated. Using the computed values of required propagation loss in Equation 4-1, the point farthest away along the terrain profile corresponding to the required propagation loss was used to determine the receive station contour distance.

The mainbeam of a receive station is pointed at a fixed azimuth angle and a fixed elevation angle is taken into account when computing the contour. Because of the directivity of the receive antenna, a "keyhole" concept may be used to compute the receive contour. The keyhole concept takes into account the larger distance along the mainbeam (keyhole region) of a receive antenna. It then follows that the region outside the keyhole region (the area off the mainbeam) requires smaller distances as shown in Figure 4-2. The specific numerical figures for the distances associated with the keyhole regions and off-mainbeam regions depend on the specific type(s) of receive antennas.

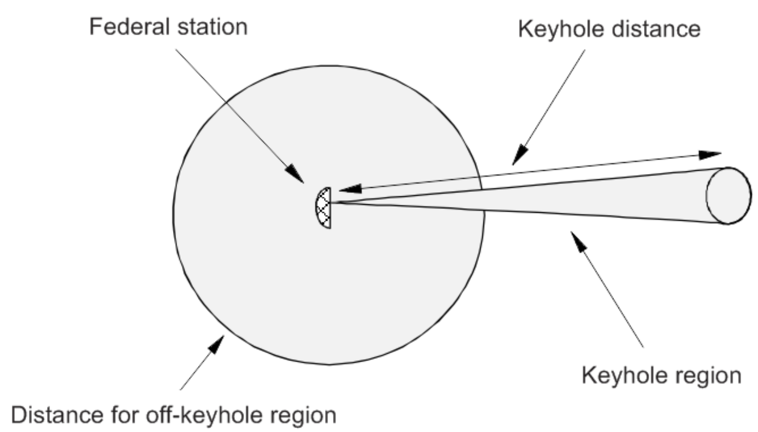

Figure 4-2. Example of Keyhole Receive Station Contour

4.3 Radio Astronomy Observatories

As specified in footnote US385, of the U.S. Table of Frequency Allocations the radio astronomy observatories listed in Table 4-2 operate in the 1350-1400 MHz band on an unprotected basis.

Table 4-2. Radio Astronomy Observatories in the 1350-1400 MHz Band

Location	**Geographical Area**
Hat Creek, CA	Rectangle between latitudes 40° 00' N and 42° 00' N and between longitudes 120° 15' W and 122° 15' W
Goldstone, CA	80 kilometer radius centered on 35° 20' N, 116° 53' W
Arecibo, PR	Rectangle between latitudes 17° 30' N and 19° 00' N and between longitudes 65° 10' W and 68° 00' W
Socorro, NM	Rectangle between latitudes 32° 30' N and 35° 30' N and between longitudes 106° 00' W and 109° 00' W
Green Bank, WV	Rectangle between latitudes 37° 30' N and 39° 15' N and between longitudes 78° 30' W and 80° 30' W
Brewster, WA	80 kilometer radius centered on 48° 08' N, 119° 41' W
Fort Davis, TX	80 kilometer radius centered on 30° 38' N, 103° 57' W
Hancock, NH	80 kilometer radius centered on 42° 56' N, 71° 59' W
Kitts Peak, AZ	80 kilometer radius centered on 31° 57' N, 111° 37' W
Los Alamos, NM	80 kilometer radius centered on 35° 47' N, 106° 15' W
Mauna Kea, HI	80 kilometer radius centered on 19° 48' N, 155° 27' W
North Liberty, IA	80 kilometer radius centered on 41° 46' N, 91° 34' W
Owens Valley, CA	80 kilometer radius centered on 37° 14' N, 118° 17' W
Pie Town, NM	80 kilometer radius centered on 34° 18' N, 108° 07' W
Saint Croix, VI	80 kilometer radius centered on 17° 45' N, 64° 35' W
Big Pine, CA	Two contiguous rectangles, one between latitudes 36° 00' N and 37° 00' N and between longitudes 117° 40' W and 118° 30' W and the second between latitudes 37° 00' N and 38° 00' N and between longitudes 118° 00' W and 118° 50' W

The geographical areas specified in Table 4-2 was be used to generate spectrum usage contours for the radio astronomy observatories.

5. PERCENTAGE OF POPULATION IMPACTED AND GEOGRAPHIC AVAILABILITY CALCULATIONS

5.1 Introduction

This section provides a description of how the estimated percentage of population impacted and the percentage of geographic availability values were computed for the transmit station and receive station spectrum usage contours in the quantitative assessments.

5.2 Percentage of Population Impacted Calculation

The population data is based on the 2015 U.S. Census data. The population centers and their corresponding coordinates and population counts were downloaded from the Centers of Population by Census Tract link at https://www.census.gov/geo/reference/centersofpop.html.[36]

The population impacted for a given spectrum usage contour is determined by finding all of the Census tracts that fall within the transmit station or receive station spectrum usage contours, then summing the total population within those tracts. The percentage of the population impacted is determined by dividing the summation of population in the Census tracts that fall within the spectrum usage contours by the total U.S. population from the 2010 Census.

5.3 Percentage of Geographical Availability Calculation

The percentage of geographic availability represents the area as a percentage of the contiguous United States that was geographically untouched by the spectrum usage contours. Geographical availability does not take into account US&P frequency assignments which can operate inside or outside of the spectrum usage contours. A spectrum usage contour is denoted as a polygon R_n and the set of spectrum usage contours was queried by frequency and a search radius that encompasses all of the contiguous United States. The contiguous United States was defined as a polygon denoted as S.[37] The percentage of geographic availability calculation is described below.

The union set of aggregate spectrum usage contour polygons was calculated using Equation 5-1.

$$C_u = R_1 \cup R_2 \cup R_3 \cup \ldots \quad (5\text{-}1)$$

[36] Census tracts are statistical subdivisions of a county or equivalent entity that are updated prior to each decennial census as part of the Census Bureau's Participant Statistical Areas Program. Census tract boundaries are updated every 10 years and are based on the decennial census. In this analysis the files dated 2015 are being used. The information on census tracts is available on the Census website: *https://ask.census.gov/faq.php?id=5000&faqId=10472*.

[37] The polygon for the United States is *available at* https://www.census.gov/geo/maps-data/data/cbf/cbf_nation.html.

Equation 5-1 represents the total area covered by the spectrum usage contours.

The set difference of the United States polygon and the union of the spectrum usage contour polygons were calculated using Equation 5-2.

$$S - C_u \qquad (5\text{-}2)$$

Equation 5-2 represents the total areas of the contiguous United States that were not covered by the spectrum usage contours.

The areas of $S - C_u$ and S were computed using the area of a polygon on a sphere shown below:[38]

$$R^2 \sum [(\lambda_{k+2} - \lambda_k) \sin (\varphi_{k+1})]/2 \qquad (5\text{-}3)$$

The indexing for the summation is performed from k = 1 to n. The parameters φ_k and λ_k represent latitudes and longitudes respectively of the k^{th} coordinates that define the boundary of the polygon, and n + 1 and n + 2 wrap around so that $\lambda_{n+1} = \lambda_1$ and similarly for $\lambda_{n+2} = \lambda_2$. The same indexing holds for φ. The radius of the Earth in meters is R.

If $S - C_u$ is complex, meaning a polygon or multi-set of polygons with holes, use the area of a polygon on a sphere to subtract the area from internal "hole polygons" using Equation 5-4 as shown in Figure 5-1.

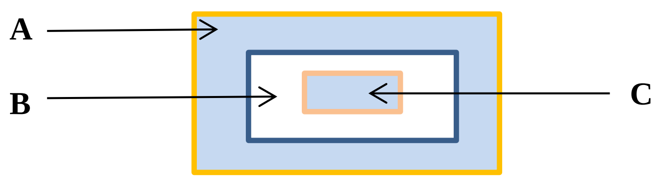

Figure 5-1. Calculation of Geographic Availability

$$\text{Area } (S - C_u) = \text{Area (A)} - \text{Area (B)} + \text{Area (C)} \qquad (5\text{-}4)$$

The percentage of the area of geographic availability was computed as shown in Equation 5-5.

$$[\text{Area } (S - C_u)/\text{Area(S)}] \times 100 \qquad (5\text{-}5)$$

[38] National Aeronautics and Space Administration, Jet Propulsion Laboratory, JPL Publication 07-3, *Some Algorithms for Polygons on a Sphere* (June 2007) at 7, *available at* http://trs-new.jpl.nasa.gov/dspace/handle/2014/40409.

6. OVERVIEW OF FEDERAL OPERATIONS

6.1 Introduction

This section provides an overview of the federal operations in the 1300-1390 MHz, 1675-1695 MHz, 2700-2900 MHz, 2900-3100, and 3100-3550 MHz bands.

6.2 Overview of Federal Systems

Table 6-1 shows the federal agencies that have frequency assignments for systems that operate in the quantitative assessment bands.

Table 6-1. Federal Agencies Operating in Quantitative Assessment Bands

Quantitative Assessment Frequency Band (MHz)	Federal Agencies with Frequency Assignments in the Quantitative Assessment Frequency Band
1300-1390	AF, AR, DHS, DOC, FAA, MC, N, NASA, USCG
1675-1695	AF, AR, DOC, MC, N, NASA
2700-2900	AF, AR, DOC, DOE, FAA, MC, N, NASA
2900-3100	AF, AR, USCG, DHS, DOC, DOE, FAA, N, NASA, DOT
3100-3550	AF, AR, N, MC

The following paragraphs provide an overview of the federal operations in bands under consideration in the quantitative assessment. A more detailed description of the federal operations in these bands is provided at www.spectrum.gov.

6.2.1 1300-1390 MHz Band. The 1300-1390 MHz band is comprised of two sub-bands: 1300-1350 MHz and 1350-1390 MHz. The 1300-1350 MHz sub-band is allocated on a primary basis for the federal aeronautical radionavigation service with a secondary allocation for the radiolocation service. The 1350-1390 MHz sub-band is allocated on a primary basis for the federal radiolocation, fixed, and mobile services.

The predominant federal systems operating in the 1300-1350 MHz frequency range are the long-range radar systems operated to support ATC in the NAS, border surveillance, early warning missile detection, and drug interdiction.[39] The allocation for the aeronautical radionavigation service ends at 1350 MHz, limiting the operation of the long-range radars by the FAA to the 1300-1350 MHz sub-band.[40] The long-range air surveillance radars operate as a joint activity of the FAA, DOD, and DHS via frequency authorizations held by the FAA. The radars support ATC, defense and homeland security missions. The data from the long-range radar

[39] Long-range radars are operated in this portion of the radio frequency spectrum because the effects of rain and fog on radar target detection are very low, the external background noise levels are low, and high-power transmitter tubes operate very efficiently. These factors are important to achieve the long-range detection of different size aircraft as well as other targets.

[40] As specified in international footnote 5.334, in Canada and the United States, the 1350-1370 MHz band is allocated to the aeronautical radionavigation service on a primary basis.

systems is also used by the DOD, DHS, and Department of Energy (DOE) in performing their missions.

There is a large diversity in the types of systems that operate in the 1350-1390 MHz portion of the band compared to the 1300-1350 MHz portion. While the FAA operates a small number of long-range radars in the 1350-1390 MHz portion of the band, the DOD (Air Force, Army, Marine Corps, and Navy) is the predominant user. The types of systems operated by the DOD include: fixed and transportable high-power tactical radar systems, transportable tactical communication systems, vehicular and portable communication systems, aeronautical telemetry systems, tactical air-to-ground communications systems, and airborne test and training systems. NASA and DHS operate a limited number of radar systems in the band. The DOD operates the Nuclear Detonation Detection System (NDS) in the 1378.55-1383.55 MHz band segment.[41] There are also radio astronomy sites operating in the 1350-1390 MHz portion of the band on an unprotected basis.

The fixed and transportable radar systems operating in the 1300-1390 MHz band are characterized by high-power transmitted signals and high gain antennas. The radar antennas rotate 360 degrees, radiating in all directions around the location of the radar. The transportable tactical radar and communication systems can be authorized to operate over a large geographic area (*e.g.*, radius of operation in excess of 100 kilometers) employing antennas that can be pointing in any direction. The combination of high transmitted power, high antenna gain, and large operational areas results in significant geographic areas where there are high signal levels that can be received by other terrestrial users operating in the band.

6.2.2 1675-1695 MHz Band. The 1675-1695 MHz band is allocated on a primary basis to federal and non-federal meteorological aids (radiosondes) and meteorological-satellite (space-to-Earth) services.[42] The DOC Geostationary Operational Environmental Satellites (GOES) series of satellites operate in this band, transmitting weather and other meteorological data to earth station receivers for further processing and distribution. Non-federal entities such as universities, private sector weather forecasters, and others also employ receive-only stations for reception of meteorological-satellite service downlink transmissions. The DOC GOES meteorological data is also transmitted directly to federal and non-federal end-users.

For the GOES-Legacy, there are certain signals such as GOES VARiable (GVAR), multi-use data link (MDL), and Sensor Data (SD) in the 1675-1695 MHz frequency band. The overall bandwidth requirement for all GOES-R links in this band are approximately the same as GOES-Legacy links although GOES-R links provide significantly more data by using more efficient techniques. GOES-NEXT (Next Generation) will have an increase in total bandwidth requirements in the 1675-1695 MHz band. GOES-R has a different frequency distribution than GOES-Legacy. DOC recently modified the design for the GOES-R,S,T,U Data Collection Platform Reports (DCPR) system to accommodate Advanced Wireless Service-3 sharing in 1695-1710 MHz. While the original design included 400 kHz channels centered on 1694.5 MHz and 1694.8 MHz, the DCPR will now operate from 1679.7 to 1680.4 MHz, relaying near-real

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[41] The purpose of the NDS is to broadcast nuclear detonation data to a variety of fixed and mobile stations.

[42] The 1675-1695 MHz band is used internationally for environmental sensing.

time hemisphere data from approximately 27,000 data collection platforms (DCP). DCPRs are used to manage water use and predict flooding, for Tsunami warning facilities, and for up to about 4,000 Remote Automatic Weather Stations (RAWS) which largely address rural firefighting. The total cost, including launch vehicles, for the GOES-R Satellite Program is $8.5 billion in current year dollars and the current procurement schedule would result in October 2016 satellite launch. GOES-NEXT will require emissions in the 1676-1692 MHz band to meet high resolution requirements for GOES Rebroadcast (GRB) and DCPR signals.

The DCPR transponder is a bent-pipe, receiving signals from the DCPs in 401.7-402.4 MHz, and then downlinked in the 1675-1695 MHz band. End users are composed of many federal, state, and local agencies required to monitor environmental and earth resources for a variety of purposes, that include: meteorological analysis and forecasting, river forecast, tsunami warnings, flood warnings, reservoir management, dam monitoring, water quality monitoring, fire potential, navigation, irrigation control, seismic monitoring, and other highly variable phenomena where observations must be collected frequently and in real-time. The bandwidth requirements for this signal have remained the same in comparison to the comparable function of the previous generation of GOES missions.

The GRB on GOES-R replaces the current GVAR system and provides users with a variety of enhanced data and products at a much higher data rate (approximately 31 megabytes per second as compared to the current data rate of 2.11 megabytes per second), including a stream of GOES-R processed instrument data, other DOC products, and related information to the weather research and earth sciences community. The GRB signal is downlinked in the 1675-1695 MHz band. This signal requires an increase in the bandwidth in comparison to the comparable function of the previous generation of GOES missions.

The GOES telemetry and command subsystem provides the functional interface between the spacecraft and ground command and control. It is composed of both radio frequency and digital (baseband) segments. Telemetry parameters describing the status, configuration, and health of the spacecraft payload and subsystems are downlinked to the Command and Data Acquisition (CDA) station and sent to the Satellite Operations Center. Commands are received onboard the spacecraft in another frequency band for controlling mission operations and managing expendable resources. This signal is downlinked in the 1675-1695 MHz band. The bandwidth requirements for this signal have decreased in comparison to the comparable function of the previous generation of GOES missions.

The EMWIN is designed to provide vital data to the nation's emergency management community. The DOC provides a broadcast of live weather and civil emergency information to computers across the United States, the Caribbean, South America, and over most of the Pacific and Atlantic Oceans. EMWIN has been made available by the DOC in cooperation with the National Environmental Satellite Data and Information Service (NESDIS) since 1995. The EMWIN delivers weather warnings in all weather conditions. The EMWIN system's primary use is warning products and other processed data (graphics and imagery) that are needed by emergency managers. EMWIN's flexibility and low cost allows it to be used by even small emergency management units anywhere in the United States. The EMWIN signal is transmitted from GOES satellites using the 1675-1695 MHz band. The EMWIN signal requires an increase in the bandwidth in comparison to the comparable function of the previous generation of GOES missions.

The High Rate Information Transmission (HRIT) is an enhanced replacement of the current Low Rate Information Transmission on the current GOES satellites and will be initiated on GOES-R. The data rate will be 400 kilobytes per second instead of the current 256 kilobytes per second. The HRIT signal is transmitted in the 1675-1695 MHz band. The HRIT signal requires an increase in the bandwidth requirements in comparison to the comparable function of the previous generation of GOES missions.

The GOES-R and GOES-NEXT will provide continuous coverage (24 hours per day and 7 days a week).[43] Table 6-2 and Table 6-3 provide information on both GOES-R and GOES-NEXT frequency and bandwidth requirements and any changes associated with the link. The main earth stations planned for GOES-R geographic coverage includes sites located at Wallops, VA; Fairmont, WV; and Suitland, MD. The differences between planned systems and current GOES-Legacy systems are a change in the back up locations from Greenbelt, MD and Fairbanks, AK to Fairmont, WV.

Table 6-2. DOC GOES-R Spectrum Usage in 1675-1695 MHz Band

Lower Frequency (MHz)	Upper Frequency (MHz)	Frequency Change GOES-Legacy to GOES-R (MHz)	Bandwidth Change GOES-Legacy to GOES-R (MHz)	Link Purpose
1679.7	1680.1	1694.5 to 1679.9	No Change	DCPR Domestic
1680	1680.4	1694.8 to 1680.2	No Change	DCPR International
1681.705	1691.495	1685.7 to 1686.6	Increase from 4.22 (GVAR) to 9.79	GRB
1681.15	1692.05	1685.7 to 1686.6	Increase from 4.22 (GVAR) to 10.9	GRB
1692.996	1693.004	1694 to 1693	Decrease from 0.016 to 0.008	Telemetry to CDA
1693.495	1694.705	1692.7 to 1694.1	Increase from 0.027 to 1.21	HRIT/EMWIN

Table 6-3. DOC GOES-NEXT Spectrum Usage in 1675-1695 MHz Band

Lower Frequency (MHz)	Upper Frequency (MHz)	Frequency Change GOES-R to GOES-NEXT (MHz)	Bandwidth Change GOES-R to GOES-NEXT (MHz)	Link Purpose
1675.05	1675.45	1679.9 to 1675.25	No Change	DCPR
1675.35	1675.75	1680.2 to 1675.55	No Change	DCPR
1676	1692	1686.6 to 1684	Increase from 9.79/10.9 to 16	GRB
1692.996	1693.004	1693 to 1693	No Change	Telemetry to

[43] A Stage 4 (operational) spectrum certification review has been granted for GOES-R. GOES-NEXT has a Stage 1 (conceptual) spectrum certification.

				CDA
1693.5	1694.85	1694.1 to 1694.1	Increase from 1.21 to 1.5	HRIT/EMWIN

The federal agencies use the 1675-1683 MHz portion of the band to transmit meteorological data from radiosondes to ground stations for weather forecasting. Radiosondes are small, expendable instrument packages carried aloft by a weather balloon. Radiosondes operate in the Meteorological Aids service providing atmospheric observation data essential for weather forecasting and research. The DOC releases about 70,000 radiosondes each year at 92 observation stations throughout the United States and its territories. The 400.15-406 MHz and the 1675-1683 MHz bands are both allocated and used for radiosonde meteorological aids operations. The DOC is in the process of relocating radiosonde systems operating in the 1675-1683 MHz frequency range to the 400.15-406 MHz frequency range. The DOC will expand the use of radiosondes operating in the frequency range 400.15-406 MHz, and not require use of the 1675-1683 MHz band in the future. Radiosonde operations are critical to the DOC mission; therefore, harmful interference in the 400.15-406 MHz frequency band could impact the DOC mission to understand and predict changes in climate and weather. Radiosondes will continue operating in the 1675-1680 MHz portion of the band until the transition to 400 MHz is completed in 2021.

6.2.3 2700-2900 MHz Band. The 2700-2900 MHz band is allocated on a primary basis for the federal meteorological aids service and aeronautical radionavigation service, and on a secondary basis for the federal radiolocation service. The 2700-2900 MHz band is used by federal agencies for operating various types of radar systems that perform missions critical to safe and reliable ATC and accurate weather monitoring in the United States. This includes airport surveillance radar (ASR) systems and meteorological radars. The ASR systems are operated by the FAA and the DOD to monitor national airspace for cooperative and non-cooperative targets in and around airports.[44] The ASRs also can have some limited weather monitoring functions. A network of Next Generation Radar (NEXRAD) systems are operated by the DOC in the band 2700-2900 MHz that provide quantitative and automated real-time information on storms, precipitation, hurricanes, and other important weather information (rainfall amounts and rates, wind velocity, wind direction, hail, snow) with higher spatial and temporal resolution than previous weather radar systems. The NEXRAD systems are operated throughout the United States by DOC, FAA, and DOD. All of the radar systems operating in this band have tuning capabilities; however, any re-tuning effort would require replacement components with new technology.[45] Apart from the quantitative assessment, the 2700-3100 MHz frequency range is under consideration as a target for potential relocation of surveillance capabilities from various bands, including1300-1350 MHz, as part of the SENSR program. The DOD operates the tactical equivalent of the FAA ASR in the band. The ASR and NEXRAD systems operate at fixed locations. The DOD tactical ATC radar systems operate at fixed locations or are transportable operating over a specified geographic area.

[44] The ASR (also referred to as terminal radars) systems in the 2700-2900 MHz band are used for control of aircraft during departure and landing.

[45] For NEXRAD, retuning requires contracting efforts for engineering and production of replacement tuning components.

The radars operating in the 2700-2900 MHz band are characterized by high-power transmitted signals and high gain antennas. The radar antennas rotate 360 degrees, radiating in all directions around the location of the radar. The combination of high transmitted power and high antenna gain results in large geographic areas where there are high signal levels that can be received by other terrestrial users operating in the band. The transportable operation of the DOD radars can also impact sharing with other terrestrial users over large geographic areas.

6.2.4 2900-3100 MHz Band. The 2900-3100 MHz band is allocated on a primary basis for the federal radiolocation service and on a secondary basis for the non-federal radiolocation service. The band is also allocated on a primary basis for the federal and non-federal maritime radionavigation service. The federal agencies use the 2900-3100 MHz band for operating various types of radar systems that perform missions critical to safe and reliable maritime navigation and accurate weather monitoring in the United States. Federal and commercial vessels operate radar systems and positioning aids in this band for maritime radionavigation for the safe transportation of people and goods, and to facilitate the flow of commerce. The DOD operates tactical ATC, artillery and rocket tracking, air search and surveillance, and range safety radars in the 2900-3100 MHz band.

The DOC NEXRAD system uses this band when operation in the 2700-2900 MHz band is not possible due to spectrum congestion. Apart from this quantitative assessment, the 2700-3100 MHz frequency range is under consideration as a target for potential relocation of surveillance capabilities from various bands, including 1300-1350 MHz, as part of the SENSR program.

The Navy, Department of Transportation's (DOT) Saint Lawrence Seaway Development Corporation (SLSDC) and Maritime Administration (MARAD), and United States Coast Guard (USCG) operate navigation radar systems and positioning aids in the 2900-3100 MHz band. The USCG and SLSDC Radar Beacon (RACON) systems that work with shipborne navigation radars to electronically identify maritime obstructions and navigation points operate in this band. RACON systems are used to identify navigation hazards to ships traveling, for example, along the Saint Lawrence Seaway.[46]

The radar systems operating in this band are characterized by high-power transmitted signals and high gain antennas. The radar antennas rotate 360 degrees, radiating in all directions around the location of the radar. The transportable tactical radar systems can be authorized to operate over a large geographic area (*e.g.*, radius of operation in excess of 100 kilometers) employing antennas that can be pointing in any direction. The shipborne radars can operate anywhere along the coast and in-land waterways. The combination of high transmitted power, high antenna gain, and the large operational areas results in significant geographic areas where there are high signal levels that can be received by other terrestrial users operating in the band.

6.2.5 3100-3550 MHz Band. The 3100-3550 MHz band is allocated on a primary basis for the federal radiolocation service and on a secondary basis for the non-federal radiolocation

[46] *See* DOT, *Economic Impacts of the Great Lakes-St. Lawrence Seaway* (2011), *available at* http://www.seaway.dot.gov/publications/economic-impact-study-0 (highlighting the economic importance of this waterway to the U.S. economy).

service. There are also secondary allocations for federal and non-federal Earth exploration-satellite (active) and space research (active) services. The DOD operates high-powered air defense radar systems on fixed, mobile, shipborne, and airborne platforms in this band. These tunable radar systems are used in conjunction with weapons control systems for the detection and tracking of air and surface targets. The DOD also operates radar systems used for fleet air defense, missile and gunfire control, bomb scoring, battlefield weapon locations, tactical ATC, and range safety. The ground-based, airborne, and shipborne radar systems operating in the band are characterized by high-power transmitted signals and high gain antennas. The radar antennas rotate 360 degrees, radiating in all directions around the location of the radar. The transportable tactical radar systems can be authorized to operate over a large geographic area (*e.g.*, radius of operation in excess of 100 kilometers) employing antennas that can be pointing in any direction. The combination of high transmitted power, high antenna gain, and the large operational areas results in significant geographic areas where there are high signal levels that can be received by other terrestrial users operating in the band. The airborne and shipborne radar operating in the band can also impact terrestrial users over significant geographic areas. This band is critical to military radar operations supporting national defense.

7. CALCULATION OF TOTAL SPECTRUM USAGE

7.1 Introduction

This section presents the calculation of Total Spectrum Usage for the quantitative assessments. The quantitative assessments were performed in 5 megahertz band segments across the 1300-1390 MHz, 1675-1695 MHz, 2700-2900 MHz, 2900-3100 MHz, and 3100-3550 MHz frequency bands.[47] For each 5 megahertz band segment, the frequency usage, geographic usage, and estimated time usage is described. Total Spectrum Usage is based on the aggregation of the spectrum usage contours for all the applicable agencies to represent overall usage as it relates to geography and population based on NTIA's tool. The frequency usage is described in terms of the number of frequency assignments that fall within each 5 megahertz band segment.[48] The geographic usage is described in terms of the percentage of the population impacted by the transmit and receive station spectrum usage contours and the percentage of the geographic area that is available (*e.g.*, not covered by spectrum usage contours).[49] The time usage is described using the agency provided estimates for the time a station is actually being used to perform its mission.[50]

Experimental stations used for research and development, testing, and calibration were not included in the quantitative assessments since, while an important requirement for the agencies, they operate on a non-interference basis and will continue to do so in the future.

7.2 Total Spectrum Usage in Quantitative Assessment Frequency Bands

The agency GMF frequency assignment and spectrum certification data was used to generate the contours describing spectrum (frequency and bandwidth) usage, geographic usage, and time usage for the transmit and receive stations in the quantitative assessment bands.[51]

7.2.1 1300-1390 MHz Band. Total Spectrum Usage of the 1300-1390 MHz band is presented in Table 7-1. The corresponding spectrum usage contour plots are provided in Appendix A.

[47] A 5 megahertz band segment was selected because it represents the minimum amount of contiguous spectrum currently under consideration for wireless broadband services. *See Ten-Year Plan* at 7.

[48] The number of assignments, authorized by NTIA, cannot be considered independently since many systems use the entire band, and in some cases the number of assignments does not represent the number of equipment in use. Multiple pieces of radio equipment, and sometimes hundreds of devices, can operate under a single frequency assignment.

[49] Geographic usage does not take into account US&P frequency assignments.

[50] The time usage values presented in this section are based on the individual frequency assignments in each 5 megahertz band segment and do not take into account aggregate time usage.

[51] The December 2015 GMF was used for the quantitative assessment results presented in this report.

Table 7-1. Total Spectrum Usage in the 1300-1390 MHz Band

Band Segment (MHz)	Frequency Usage	Geographic Usage	Estimated Time Usage
1300-1305	48 frequency assignments for transmit stations spaced across the band segment. 1 airborne transmit station operating in the band segment.	Population Impacted: 63.7% Geographic Availability: 45.1% Figure A-1	18 stations 50-100% 0 stations 10-50% 30 stations 1-10% 1 station less than 1%
1305-1310	47 frequency assignments for transmit stations spaced across the band segment.	Population Impacted: 75.3% Geographic Availability: 45.8% Figure A-2	25 stations 50-100% 0 stations 10-50% 22 stations 1-10% 0 stations less than 1%
1310-1315	45 frequency assignments for transmit stations spaced across the band segment.	Population Impacted: 77.2% Geographic Availability: 48.4% Figure A-3	30 stations 50-100% 0 stations 10-50% 15 stations 1-10% 0 stations less than 1%
1315-1320	61 frequency assignments for transmit stations spaced across the band segment.	Population Impacted: 67.6% Geographic Availability: 44.8% Figure A-4	31 stations 50-100% 0 stations 10-50% 30 stations 1-10% 0 stations less than 1%
1320-1325	65 frequency assignments for transmit stations spaced across the band segment.	Population Impacted: 74.2% Geographic Availability: 39.2% Figure A-5	31 stations 50-100% 0 stations 10-50% 34 stations 1-10% 0 stations less than 1%
1325-1330	55 frequency assignments for transmit stations spaced across the band segment.	Population Impacted: 78.0% Geographic Availability: 32.0% Figure A-6	35 stations 50-100% 0 stations 10-50% 20 stations 1-10% 0 stations less than 1%
1330-1335	53 frequency assignments for transmit stations spaced across the band segment.	Population Impacted: 69.6% Geographic Availability: 38.3% Figure A-7	31 stations 50-100% 0 stations 10-50% 22 stations 1-10% 0 stations less than 1%
1335-1340	50 frequency assignments for transmit stations spaced across the band segment.	Population Impacted: 65.5% Geographic Availability: 48.2% Figure A-8	24 stations 50-100% 0 stations 10-50% 26 stations 1-10% 0 stations less than 1%
1340-1345	58 frequency assignments for transmit stations spaced across the band segment.	Population Impacted: 85.5% Geographic Availability: 25.1% Figure A-9	37 stations 50-100% 0 stations 10-50% 21 stations 1-10% 0 stations less than 1%
1345-1350	69 frequency assignments for transmit stations spaced across the band segment. 1 airborne transmit station operating in the band segment.	Population Impacted: 85.5% Geographic Availability: 28.4% Figure A-10	24 stations 50-100% 0 stations 10-50% 45 stations 1-10% 1 stations less than 1%
1350-1355	63 frequency assignments for transmit stations spaced across the band segment. 7 airborne transmit stations operating in the band segment.	Population Impacted: 86.6% Geographic Availability: 30.7% Figure A-11	24 stations 50-100% 0 stations 10-50% 45 stations 1-10% 1 station less than 1%
1355-1360	62 frequency assignments for transmit stations spaced across the band segment. 6 airborne transmit stations operating in the band segment.	Population Impacted: 51.4% Geographic Availability: 64.6% Figure A-12	11 stations 50-100% 0 stations 10-50% 56 stations 1-10% 1 station less than 1%
1360-1365	59 frequency assignments for transmit stations spaced across the band segment.	Population Impacted: 56.0% Geographic Availability: 62.6% Figure A-13	13 stations 50-100% 0 stations 10-50% 51 stations 1-10%

Band Segment (MHz)	Frequency Usage	Geographic Usage	Estimated Time Usage
	7 airborne transmit stations operating in the band segment.		2 stations less than 1%
1365-1370	86 frequency assignments for transmit stations spaced across the band segment. 22 airborne transmit stations operating in the band segment.	Population Impacted: 56.5% Geographic Availability: 63.5% Figure A-14	6 stations 50-100% 0 stations 10-50% 99 stations 1-10% 3 stations less than 1%
1370-1375	163 frequency assignments for transmit stations spaced across the band segment. 38 airborne transmit stations operating in the band segment.	Population Impacted: 64.5% Geographic Availability: 59.1% Figure A-15	3 stations 50-100% 0 stations 10-50% 196 stations 1-10% 2 stations less than 1%
1375-1380	189 frequency assignments for transmit stations spaced across the band segment. 27 airborne transmit stations operating in the band segment.	Population Impacted: 67.9% Geographic Availability: 58.9% Figure A-16	2 stations 50-100% 0 stations 10-50% 211 stations 1-10% 3 stations less than 1%
1380-1385	198 frequency assignments for transmit stations spaced across the band segment. 53 airborne transmit stations operating in the band segment.	Population Impacted: 65.4% Geographic Availability: 58.8% Figure A-17	1 stations 50-100% 0 stations 10-50% 248 stations 1-10% 2 stations less than 1%
1385-1390	144 frequency assignments for transmit stations spaced across the band segment. 62 airborne transmit stations operating in the band segment.	Population Impacted: 62.6% Geographic Availability: 60.6% Figure A-18	1 stations 50-100% 0 stations 10-50% 204 stations 1-10% 1 station less than 1%

7.2.2 1675-1695 MHz Band. Total Spectrum Usage of the 1675-1695 MHz band is presented in Table 7-2. Table 7-3 shows Total Spectrum Usage removing the radiosonde receive stations that will be migrating to the 400 MHz frequency range. The corresponding spectrum usage contour plots are provided in Appendix B.

Table 7-2. Total Spectrum Usage in the 1675-1695 MHz Band[a]

Band Segment (MHz)	Frequency Usage	Geographic Usage	Estimated Time Usage
1675-1680	313 frequencies for receive stations in the band segment.	Population Impacted: 39.9% Geographic Availability: 79.0% Figure B-1	313 stations: 50 to 100%
1680-1685	200 frequencies for receive stations in the band segment.	Population Impacted: 38.5% Geographic Availability: 79.6% Figure B-2	200 stations: 50 to 100%
1685-1690	40 frequencies for receive stations in the band segment.	Population Impacted: 4 % Geographic Availability: 99.2 % Figure B-3	40 stations: 50 to 100%
1690-1695	38 frequencies for receive stations in the band segment.	Population Impacted: 4.3% Geographic Availability: 99.0% Figure B-4	38 stations: 50 to 100%
Note a: DOC provides data (forecasts and warnings) to non-federal end users. The impact to non-federal users is not included in the quantitative assessment. The impact to non-federal users will require further study.			

Table 7-3. Total Spectrum Usage in the 1675-1695 MHz Band[a] (Radiosonde Receive Stations Removed)

Band Segment (MHz)	Frequency Usage	Geographic Usage	Estimated Time Usage
1675-1680	32 frequencies for receive stations in the band segment.	Population Impacted: 3.2% Geographic Availability: 98.7% Figure B-5	32 stations: 50 to 100%
1680-1685	11 frequencies for receive stations in the band segment.	Population Impacted: 1.2% Geographic Availability: 99.5% Figure B-6	11 stations: 50 to 100%
1685-1690	39 frequencies for receive stations in the band segment.	Population Impacted: 4. % Geographic Availability: 99.2 % Figure B-7	39 stations: 50 to 100%
1690-1695	37 frequencies for receive stations in the band segment.	Population Impacted: 4.3% Geographic Availability: 99.0% Figure B-8	37 stations: 50 to 100%
Note a: DOC provides data (forecasts and warnings) to non-federal end users. The impact to non-federal users is not included in the quantitative assessment. The impact to non-federal users will require further study.			

7.2.3 2700-2900 MHz Band. Total Spectrum Usage of the 2700-2900 MHz band is presented in Table 7-4. The corresponding spectrum usage contour plots are provided in Appendix C.

Table 7-4. Total Spectrum Usage in the 2700-2900 MHz Band

Band Segment (MHz)	Frequency Usage	Geographic Usage[a]	Estimated Time Usage
2700-2705	45 frequency assignments for transmit stations spaced across the band segment.	Population Impacted: 55.0% Geographic Availability: 73.2% Figure C-1	35 stations 50-100% 2 stations 10-50% 8 stations 1-10% 0 stations Less than 1%
2705-2710	80 frequency assignments for transmit stations spaced across the band segment.	Population Impacted: 74.7% Geographic Availability: 54.9% Figure C-2	68 stations 50-100% 0 stations 10-50% 12 stations 1-10% 0 stations Less than 1%
2710-2715	82 frequency assignments for transmit stations spaced across the band segment.	Population Impacted: 71.6% Geographic Availability: 54.9% Figure C-3	64 stations 50-100% 0 stations 10-50% 17 stations 1-10% 1 stations Less than 1%
2715-2720	84 frequency assignments for transmit stations spaced across the band segment.	Population Impacted: 61.6% Geographic Availability: 66.6% Figure C-4	50 stations 50-100% 4 stations 10-50% 28 stations 1-10% 2 stations Less than 1%
2720-2725	70 frequency assignments for transmit stations spaced across the band segment.	Population Impacted: 55.6% Geographic Availability: 66.9% Figure C-5	51 stations 50-100% 4 stations 10-50% 13 stations 1-10% 2 stations Less than 1%
2725-2730	57 frequency assignments for transmit stations spaced across the band segment.	Population Impacted: 73.5% Geographic Availability: 60.5% Figure C-6	49 stations 50-100% 0 stations 10-50% 7 stations 1-10% 1 stations Less than 1%

Band Segment (MHz)	Frequency Usage	Geographic Usage[a]	Estimated Time Usage
2730-2735	53 frequency assignments for transmit stations spaced across the band segment.	Population Impacted: 72.8% Geographic Availability: 61.6% Figure C-7	45 stations 50-100% 0 stations 10-50% 7 stations 1-10% 1 stations Less than 1%
2735-2740	52 frequency assignments for transmit stations spaced across the band segment.	Population Impacted: 64.2% Geographic Availability: 68.9% Figure C-8	45 stations 50-100% 2 stations 10-50% 4 stations 1-10% 1 stations Less than 1%
2740-2745	60 frequency assignments for transmit stations spaced across the band segment.	Population Impacted: 67.9% Geographic Availability: 64.9% Figure C-9	53 stations 50-100% 3 stations 10-50% 3 stations 1-10% 1 stations Less than 1%
2745-2750	71 frequency assignments for transmit stations spaced across the band segment.	Population Impacted: 72.4% Geographic Availability: 55.3% Figure C-10	62 stations 50-100% 2 stations 10-50% 7 stations 1-10% 0 stations Less than 1%
2750-2755	50 frequency assignments for transmit stations spaced across the band segment.	Population Impacted: 63.2% Geographic Availability: 58.7% Figure C-11	44 stations 50-100% 0 stations 10-50% 6 stations 1-10% 0 stations Less than 1%
2755-2760	42 frequency assignments for transmit stations spaced across the band segment.	Population Impacted: 59.7% Geographic Availability: 70.4% Figure C-12	31 stations 50-100% 4 stations 10-50% 7 stations 1-10% 0 stations Less than 1%
2760-2765	57 frequency assignments for transmit stations spaced across the band segment.	Population Impacted: 68.6% Geographic Availability: 62.4% Figure C-13	38 stations 50-100% 6 stations 10-50% 13 stations 1-10% 0 stations Less than 1%
2765-2770	61 frequency assignments for transmit stations spaced across the band segment.	Population Impacted: 60.6% Geographic Availability: 67.1% Figure C-14	45 stations 50-100% 2 stations 10-50% 13 stations 1-10% 1 stations Less than 1%
2770-2775	55 frequency assignments for transmit stations spaced across the band segment.	Population Impacted: 55.6% Geographic Availability: 65.7% Figure C-15	48 stations 50-100% 0 stations 10-50% 5 stations 1-10% 2 stations Less than 1%
2775-2780	56 frequency assignments for transmit stations spaced across the band segment.	Population Impacted: 49.6% Geographic Availability: 64.4% Figure C-16	49 stations 50-100% 0 stations 10-50% 4 stations 1-10% 3 stations Less than 1%
2780-2785	58 frequency assignments for transmit stations spaced across the band segment.	Population Impacted: 52.8% Geographic Availability: 69.8% Figure C-17	47 stations 50-100% 0 stations 10-50% 10 stations 1-10% 1 stations Less than 1%
2785-2790	68 frequency assignments for transmit	Population Impacted: 63.9%	47 stations 50-100%

Band Segment (MHz)	Frequency Usage	Geographic Usage[a]	Estimated Time Usage
	stations spaced across the band segment.	Geographic Availability: 68.8% Figure C-18	0 stations 10-50% 17 stations 1-10% 4 stations Less than 1%
2790-2795	58 frequency assignments for transmit stations spaced across the band segment.	Population Impacted: 72.8% Geographic Availability: 71.3% Figure C-19	41 stations 50-100% 3 stations 10-50% 10 stations 1-10% 4 stations Less than 1%
2795-2800	52 frequency assignments for transmit stations spaced across the band segment. 1 US&P transmit station operating in the band segment.	Population Impacted: 64.9% Geographic Availability: 68.5% Figure C-20	34 stations 50-100% 3 stations 10-50% 15 stations 1-10% 1 stations Less than 1%
2800-2805	63 frequency assignments for transmit stations spaced across the band segment. 1 US&P transmit station operating in the band segment.	Population Impacted: 65.4% Geographic Availability: 67.7% Figure C-21	39 stations 50-100% 2 stations 10-50% 22 stations 1-10% 1 stations Less than 1%
2805-2810	72 frequency assignments for transmit stations spaced across the band segment. 1 US&P transmit station operating in the band segment.	Population Impacted: 60.1% Geographic Availability: 67.1% Figure C-22	46 stations 50-100% 3 stations 10-50% 21 stations 1-10% 3 stations Less than 1%
2810-2815	61 frequency assignments for transmit stations spaced across the band segment. 1 US&P transmit station operating in the band segment.	Population Impacted: 62.2% Geographic Availability: 66.6% Figure C-23	52 stations 50-100% 3 stations 10-50% 4 stations 1-10% 3 stations Less than 1%
2815-2820	56 frequency assignments for transmit stations spaced across the band segment. 1 US&P transmit station operating in the band segment.	Population Impacted: 63.8% Geographic Availability: 68.5% Figure C-24	50 stations 50-100% 3 stations 10-50% 3 stations 1-10% 1 stations Less than 1%
2820-2825	51 frequency assignments for transmit stations spaced across the band segment. 1 US&P transmit station operating in the band segment.	Population Impacted: 70.9% Geographic Availability: 66.4% Figure C-25	44 stations 50-100% 0 stations 10-50% 5 stations 1-10% 3 stations Less than 1%
2825-2830	60 frequency assignments for transmit stations spaced across the band segment. 1 US&P transmit station operating in	Population Impacted: 67.5% Geographic Availability: 62.1% Figure C-26	45 stations 50-100% 2 stations 10-50% 12 stations 1-10% 2 stations Less than 1%

Band Segment (MHz)	Frequency Usage	Geographic Usage[a]	Estimated Time Usage
	the band segment.		
2830-2835	62 frequency assignments for transmit stations spaced across the band segment. 1 US&P transmit station operating in the band segment.	Population Impacted: 63.1% Geographic Availability: 65.2% Figure C-27	39 stations 50-100% 12 stations 10-50% 10 stations 1-10% 2 stations Less than 1%
2835-2840	56 frequency assignments for transmit stations spaced across the band segment. 1 US&P transmit station operating in the band segment.	Population Impacted: 63.1% Geographic Availability: 67.2% Figure C-28	41 stations 50-100% 9 stations 10-50% 6 stations 1-10% 1 stations Less than 1%
2840-2845	61 frequency assignments for transmit stations spaced across the band segment. 1 US&P transmit station operating in the band segment.	Population Impacted: 65.6% Geographic Availability: 62.7% Figure C-29	47 stations 50-100% 3 stations 10-50% 12 stations 1-10% 0 stations Less than 1%
2845-2850	53 frequency assignments for transmit stations spaced across the band segment. 1 US&P transmit station operating in the band segment.	Population Impacted: 62.7% Geographic Availability: 66.9% Figure C-30	40 stations 50-100% 2 stations 10-50% 12 stations 1-10% 0 stations Less than 1%
2850-2855	41 frequency assignments for transmit stations spaced across the band segment. 1 US&P transmit station operating in the band segment.	Population Impacted: 54.2% Geographic Availability: 69.2% Figure C-31	38 stations 50-100% 0 stations 10-50% 4 stations 1-10% 0 stations Less than 1%
2855-2860	55 frequency assignments for transmit stations spaced across the band segment. 1 US&P transmit station operating in the band segment.	Population Impacted: 44.6% Geographic Availability: 69.7% Figure C-32	40 stations 50-100% 6 stations 10-50% 10 stations 1-10% 0 stations Less than 1%
2860-2865	65 frequency assignments for transmit stations spaced across the band segment. 1 US&P transmit station operating in the band segment.	Population Impacted: 54.8% Geographic Availability: 64.3% Figure C-33	45 stations 50-100% 8 stations 10-50% 13 stations 1-10% 0 stations Less than 1%
2865-2870	74 frequency assignments for transmit stations spaced across the band segment. 1 US&P transmit station operating in	Population Impacted: 67.9% Geographic Availability: 55.6% Figure C-34	58 stations 50-100% 2 stations 10-50% 13 stations 1-10% 2 stations Less than 1%

Band Segment (MHz)	Frequency Usage	Geographic Usage[a]	Estimated Time Usage
	the band segment.		
2870-2875	84 frequency assignments for transmit stations spaced across the band segment. 1 US&P transmit station operating in the band segment.	Population Impacted: 69.8% Geographic Availability: 51.8% Figure C-35	59 stations 50-100% 4 stations 10-50% 19 stations 1-10% 3 stations Less than 1%
2875-2880	84 frequency assignments for transmit stations spaced across the band segment. 1 US&P transmit station operating in the band segment.	Population Impacted: 66.1% Geographic Availability: 60.4% Figure C-36	59 stations 50-100% 4 stations 10-50% 21 stations 1-10% 1 stations Less than 1%
2880-2885	74 frequency assignments for transmit stations spaced across the band segment. 1 US&P transmit station operating in the band segment.	Population Impacted: 64.5% Geographic Availability: 58.0% Figure C-37	69 stations 50-100% 0 stations 10-50% 6 stations 1-10% 0 stations Less than 1%
2885-2890	81 frequency assignments for transmit stations spaced across the band segment. 1 US&P transmit station operating in the band segment.	Population Impacted: 70.6% Geographic Availability: 47.9% Figure C-38	76 stations 50-100% 0 stations 10-50% 6 stations 1-10% 0 stations Less than 1%
2890-2895	69 frequency assignments for transmit stations spaced across the band segment. 1 US&P transmit station operating in the band segment.	Population Impacted: 67.3% Geographic Availability: 52.6% Figure C-39	64 stations 50-100% 0 stations 10-50% 6 stations 1-10% 0 stations Less than 1%
2895-2900	155 frequency assignments for transmit stations spaced across the band segment. 2 US&P transmit stations operating in the band segment.	Population Impacted: 74.5% Geographic Availability: 47.0% Figure C-40	133 stations 50-100% 2 stations 10-50% 22 stations 1-10% 0 stations Less than 1%
Note a: Geographic usage does not take into account US&P frequency assignments. Systems authorized under a US&P assignment can operate anywhere (*e.g.*, inside or outside of the spectrum usage contours) and are not represented on the spectrum usage contours in the appendices. US&P assignments must be taken into account in the sharing feasibility studies.			

7.2.4 2900-3100 MHz Band. Total Spectrum Usage of the 2900-3100 MHz band is presented in Table 7-5. The corresponding spectrum usage contour plots are provided in Appendix D.

Table 7-5. Total Spectrum Usage in the 2900-3100 MHz Band

Band Segment (MHz)	Frequency Usage	Geographic Usage[a]	Estimated Time Usage
2900-2905	128 frequency assignments for transmit stations spaced across the band segment. 2 US&P transmit stations operating in the band segment.	Population Impacted: 60.2% Geographic Availability: 57.9% Figure D-1	107 stations 50-100% 0 stations 10-50% 23 stations 1-10% 0 stations Less than 1%
2905-2910	116 frequency assignments for transmit stations spaced across the band segment. 2 US&P transmit stations operating in the band segment.	Population Impacted: 43.9% Geographic Availability: 71.3% Figure D-2	97 stations 50-100% 0 stations 10-50% 21 stations 1-10% 0 stations Less than 1%
2910-2915	114 frequency assignments for transmit stations spaced across the band segment. 2 US&P transmit stations operating in the band segment.	Population Impacted: 43.9% Geographic Availability: 71.3% Figure D-3	98 stations 50-100% 0 stations 10-50% 18 stations 1-10% 0 stations Less than 1%
2915-2920	115 frequency assignments for transmit stations spaced across the band segment. 2 US&P transmit stations operating in the band segment.	Population Impacted: 43.3% Geographic Availability: 72.8% Figure D-4	97 stations 50-100% 0 stations 10-50% 20 stations 1-10% 0 stations Less than 1%
2920-2925	113 frequency assignments for transmit stations spaced across the band segment. 2 US&P transmit stations operating in the band segment.	Population Impacted: 42.8% Geographic Availability: 73.2% Figure D-5	95 stations 50-100% 0 stations 10-50% 20 stations 1-10% 0 stations Less than 1%
2925-2930	119 frequency assignments for transmit stations spaced across the band segment. 2 US&P transmit stations operating in the band segment.	Population Impacted: 43.8% Geographic Availability: 72.3% Figure D-6	96 stations 50-100% 0 stations 10-50% 24 stations 1-10% 1 stations Less than 1%
2930-2935	122 frequency assignments for transmit stations spaced across the band segment. 2 US&P transmit stations operating in the band segment.	Population Impacted: 44.4% Geographic Availability: 71.7% Figure D-7	98 stations 50-100% 0 stations 10-50% 25 stations 1-10% 1 stations Less than 1%
2935-2940	122 frequency assignments for transmit stations spaced across the band segment. 2 US&P transmit stations operating in the band segment.	Population Impacted: 44.8% Geographic Availability: 70.9% Figure D-8	98 stations 50-100% 0 stations 10-50% 26 stations 1-10% 0 stations Less than 1%

Band Segment (MHz)	Frequency Usage	Geographic Usage[a]	Estimated Time Usage
2940-2945	123 frequency assignments for transmit stations spaced across the band segment. 2 US&P transmit stations operating in the band segment.	Population Impacted: 47.7% Geographic Availability: 70.2% Figure D-9	100 stations 50-100% 0 stations 10-50% 25 stations 1-10% 0 stations Less than 1%
2945-2950	117 frequency assignments for transmit stations spaced across the band segment. 2 US&P transmit stations operating in the band segment.	Population Impacted: 47.1% Geographic Availability: 71.5% Figure D-10	99 stations 50-100% 0 stations 10-50% 20 stations 1-10% 0 stations Less than 1%
2950-2955	114 frequency assignments for transmit stations spaced across the band segment. 2 US&P transmit stations operating in the band segment.	Population Impacted: 46.5% Geographic Availability: 72.2% Figure D-11	97 stations 50-100% 0 stations 10-50% 19 stations 1-10% 0 stations Less than 1%
2955-2960	116 frequency assignments for transmit stations spaced across the band segment. 2 US&P transmit stations operating in the band segment.	Population Impacted: 46.5% Geographic Availability: 72.1% Figure D-12	97 stations 50-100% 0 stations 10-50% 21 stations 1-10% 0 stations Less than 1%
2960-2965	115 frequency assignments for transmit stations spaced across the band segment. 2 US&P transmit stations operating in the band segment.	Population Impacted: 43.7% Geographic Availability: 69.4% Figure D-13	95 stations 50-100% 0 stations 10-50% 22 stations 1-10% 0 stations Less than 1%
2965-2970	119 frequency assignments for transmit stations spaced across the band segment. 2 US&P transmit stations operating in the band segment.	Population Impacted: 43.7% Geographic Availability: 69.1% Figure D-14	95 stations 50-100% 0 stations 10-50% 26 stations 1-10% 0 stations Less than 1%
2970-2975	119 frequency assignments for transmit stations spaced across the band segment. 2 US&P transmit stations operating in the band segment.	Population Impacted: 43.5% Geographic Availability: 72.6% Figure D-15	95 stations 50-100% 0 stations 10-50% 26 stations 1-10% 0 stations Less than 1%
2975-2980	120 frequency assignments for transmit stations spaced across the band segment. 2 US&P transmit stations operating in the band segment.	Population Impacted: 44.1% Geographic Availability: 67.5% Figure D-16	95 stations 50-100% 0 stations 10-50% 27 stations 1-10% 0 stations Less than 1%
2980-2985	119 frequency assignments for	Population Impacted: 44.1%	95 stations 50-100%

Band Segment (MHz)	Frequency Usage	Geographic Usage[a]	Estimated Time Usage
	transmit stations spaced across the band segment. 2 US&P transmit stations operating in the band segment.	Geographic Availability: 67.5% Figure D-17	0 stations 10-50% 26 stations 1-10% 0 stations Less than 1%
2985-2990	125 frequency assignments for transmit stations spaced across the band segment. 2 US&P transmit stations operating in the band segment.	Population Impacted: 45.7% Geographic Availability: 65.9% Figure D-18	102 stations 50-100% 0 stations 10-50% 25 stations 1-10% 0 stations Less than 1%
2990-2995	127 frequency assignments for transmit stations spaced across the band segment. 2 US&P transmit stations operating in the band segment.	Population Impacted: 45.7% Geographic Availability: 65.9% Figure D-19	102 stations 50-100% 0 stations 10-50% 27 stations 1-10% 0 stations Less than 1%
2995-3000	130 frequency assignments for transmit stations spaced across the band segment. 2 US&P transmit stations operating in the band segment.	Population Impacted: 46.2% Geographic Availability: 68.0% Figure D-20	102 stations 50-100% 1 stations 10-50% 29 stations 1-10% 0 stations Less than 1%
3000-3005	130 frequency assignments for transmit stations spaced across the band segment. 2 US&P transmit stations operating in the band segment.	Population Impacted: 46.3% Geographic Availability: 67.4% Figure D-21	102 stations 50-100% 1 stations 10-50% 29 stations 1-10% 0 stations Less than 1%
3005-3010	122 frequency assignments for transmit stations spaced across the band segment. 1 US&P transmit station operating in the band segment.	Population Impacted: 45.0% Geographic Availability: 67.3% Figure D-22	97 stations 50-100% 0 stations 10-50% 26 stations 1-10% 0 stations Less than 1%
3010-3015	120 frequency assignments for transmit stations spaced across the band segment. 1 US&P transmit station operating in the band segment.	Population Impacted: 45.0% Geographic Availability: 67.3% Figure D-23	97 stations 50-100% 0 stations 10-50% 24 stations 1-10% 0 stations Less than 1%
3015-3020	120 frequency assignments for transmit stations spaced across the band segment. 2 US&P transmit stations operating in the band segment.	Population Impacted: 46.2% Geographic Availability: 70.3% Figure D-24	97 stations 50-100% 0 stations 10-50% 25 stations 1-10% 0 stations Less than 1%
3020-3025	130 frequency assignments for transmit stations spaced across the	Population Impacted: 47.5% Geographic Availability: 69.9%	98 stations 50-100% 0 stations 10-50%

Band Segment (MHz)	Frequency Usage	Geographic Usage[a]	Estimated Time Usage
	band segment. 2 US&P transmit stations operating in the band segment.	Figure D-25	34 stations 1-10% 0 stations Less than 1%
3025-3030	132 frequency assignments for transmit stations spaced across the band segment. 2 US&P transmit stations operating in the band segment.	Population Impacted: 48.1% Geographic Availability: 68.9% Figure D-26	98 stations 50-100% 0 stations 10-50% 36 stations 1-10% 0 stations Less than 1%
3030-3035	133 frequency assignments for transmit stations spaced across the band segment. 2 US&P transmit stations operating in the band segment.	Population Impacted: 48.1% Geographic Availability: 68.9% Figure D-27	98 stations 50-100% 0 stations 10-50% 37 stations 1-10% 0 stations Less than 1%
3035-3040	137 frequency assignments for transmit stations spaced across the band segment. 2 US&P transmit stations operating in the band segment.	Population Impacted: 57.4% Geographic Availability: 67.2% Figure D-28	97 stations 50-100% 0 stations 10-50% 37 stations 1-10% 5 stations Less than 1%
3040-3045	136 frequency assignments for transmit stations spaced across the band segment. 2 US&P transmit stations operating in the band segment.	Population Impacted: 57.4% Geographic Availability: 67.2% Figure D-29	97 stations 50-100% 0 stations 10-50% 36 stations 1-10% 5 stations Less than 1%
3045-3050	141 frequency assignments for transmit stations spaced across the band segment. 2 US&P transmit stations operating in the band segment.	Population Impacted: 59.7% Geographic Availability: 66.2% Figure D-30	98 stations 50-100% 0 stations 10-50% 37 stations 1-10% 8 stations Less than 1%
3050-3055	142 frequency assignments for transmit stations spaced across the band segment. 2 US&P transmit stations operating in the band segment.	Population Impacted: 59.7% Geographic Availability: 66.2% Figure D-31	98 stations 50-100% 0 stations 10-50% 38 stations 1-10% 8 stations Less than 1%
3055-3060	138 frequency assignments for transmit stations spaced across the band segment. 2 US&P transmit stations operating in the band segment.	Population Impacted: 59.7% Geographic Availability: 66.1% Figure D-32	97 stations 50-100% 0 stations 10-50% 38 stations 1-10% 5 stations Less than 1%
3060-3065	135 frequency assignments for transmit stations spaced across the band segment.	Population Impacted: 57.4% Geographic Availability: 67.2%	97 stations 50-100% 0 stations 10-50% 35 stations 1-10%

Band Segment (MHz)	**Frequency Usage**	**Geographic Usage[a]**	**Estimated Time Usage**
	2 US&P transmit stations operating in the band segment.	Figure D-33	5 stations Less than 1%
3065-3070	128 frequency assignments for transmit stations spaced across the band segment. 2 US&P transmit stations operating in the band segment.	Population Impacted: 47.5% Geographic Availability: 69.9% Figure D-34	97 stations 50-100% 0 stations 10-50% 33 stations 1-10% 0 stations Less than 1%
3070-3075	129 frequency assignments for transmit stations spaced across the band segment. 2 US&P transmit stations operating in the band segment.	Population Impacted: 47.5% Geographic Availability: 69.9% Figure D-35	97 stations 50-100% 0 stations 10-50% 34 stations 1-10% 0 stations Less than 1%
3075-3080	125 frequency assignments for transmit stations spaced across the band segment. 2 US&P transmit stations operating in the band segment.	Population Impacted: 46.9% Geographic Availability: 70.8% Figure D-36	96 stations 50-100% 0 stations 10-50% 31 stations 1-10% 0 stations Less than 1%
3080-3085	115 frequency assignments for transmit stations spaced across the band segment. 2 US&P transmit stations operating in the band segment.	Population Impacted: 45.1% Geographic Availability: 72.3% Figure D-37	95 stations 50-100% 0 stations 10-50% 22 stations 1-10% 0 stations Less than 1%
3085-3090	112 frequency assignments for transmit stations spaced across the band segment. 1 US&P transmit station operating in the band segment.	Population Impacted: 42.8% Geographic Availability: 73.2% Figure D-38	95 stations 50-100% 0 stations 10-50% 18 stations 1-10% 0 stations Less than 1%
3090-3095	120 frequency assignments for transmit stations spaced across the band segment. 1 US&P transmit station operating in the band segment.	Population Impacted: 44.9% Geographic Availability: 72.3% Figure D-39	95 stations 50-100% 0 stations 10-50% 26 stations 1-10% 0 stations Less than 1%
3095-3100	151 frequency assignments for transmit stations spaced across the band segment. 2 US&P transmit stations operating in the band segment.	Population Impacted: 64.5% Geographic Availability: 45.6% Figure D-40	94 stations 50-100% 0 stations 10-50% 57 stations 1-10% 2 stations Less than 1%
Note a: Geographic usage does not take into account US&P frequency assignments. Systems authorized under a US&P assignment can operate anywhere (*e.g.*, inside or outside of the spectrum usage contours) and are not represented on the spectrum usage contours in the appendices. US&P assignments must be taken into account in the sharing feasibility studies.			

7.2.5 3100-3550 MHz Band. Total Spectrum Usage of the 3100-3550 MHz band is presented in Table 7-6. The corresponding spectrum usage contour plots are provided in Appendix E.

Table 7-6. Total Spectrum Usage in the 3100-3550 MHz Band

Band Segment (MHz)	Frequency Usage	Geographic Usage[a]	Estimated Time Usage
3100-3105	150 frequency assignments for transmit stations spaced across the band segment. 2 US&P transmit stations operating in the band segment.	Population Impacted: 64.5% Geographic Availability: 45.6% Figure E-1	94 stations 50-100% 0 stations 10-50% 56 stations 1-10% 2 stations Less than 1%
3105-3110	43 frequency assignments for transmit stations spaced across the band segment. 1 US&P transmit station operating in the band segment.	Population Impacted: 58.9% Geographic Availability: 57.6% Figure E-2	0 stations 50-100% 0 stations 10-50% 42 stations 1-10% 2 stations Less than 1%
3110-3115	36 frequency assignments for transmit stations spaced across the band segment. 1 US&P transmit station operating in the band segment.	Population Impacted: 58.9% Geographic Availability: 57.6% Figure E-3	0 stations 50-100% 0 stations 10-50% 35 stations 1-10% 2 stations Less than 1%
3115-3120	35 frequency assignments for transmit stations spaced across the band segment. 1 US&P transmit station operating in the band segment.	Population Impacted: 58.9% Geographic Availability: 57.6% Figure E-4	0 stations 50-100% 0 stations 10-50% 34 stations 1-10% 2 stations Less than 1%
3120-3125	34 frequency assignments for transmit stations spaced across the band segment. 1 US&P transmit station operating in the band segment.	Population Impacted: 58.9% Geographic Availability: 57.7% Figure E-5	0 stations 50-100% 0 stations 10-50% 33 stations 1-10% 2 stations Less than 1%
3125-3130	35 frequency assignments for transmit stations spaced across the band segment. 1 US&P transmit station operating in the band segment.	Population Impacted: 58.9% Geographic Availability: 57.7% Figure E-6	0 stations 50-100% 0 stations 10-50% 34 stations 1-10% 2 stations Less than 1%
3130-3135	35 frequency assignments for transmit stations spaced across the band segment. 1 US&P transmit station operating in the band segment.	Population Impacted: 58.9% Geographic Availability: 57.6% Figure E-7	0 stations 50-100% 0 stations 10-50% 34 stations 1-10% 2 stations Less than 1%

Band Segment (MHz)	Frequency Usage	Geographic Usage[a]	Estimated Time Usage
3135-3140	35 frequency assignments for transmit stations spaced across the band segment. 1 US&P transmit station operating in the band segment.	Population Impacted: 58.9% Geographic Availability: 57.6% Figure E-8	0 stations 50-100% 0 stations 10-50% 34 stations 1-10% 2 stations Less than 1%
3140-3145	65 frequency assignments for transmit stations spaced across the band segment. 1 US&P transmit station operating in the band segment.	Population Impacted: 78.0% Geographic Availability: 35.7% Figure E-9	0 stations 50-100% 0 stations 10-50% 64 stations 1-10% 2 stations Less than 1%
3145-3150	67 frequency assignments for transmit stations spaced across the band segment. 1 US&P transmit station operating in the band segment.	Population Impacted: 78.0% Geographic Availability: 35.7% Figure E-10	0 stations 50-100% 0 stations 10-50% 66 stations 1-10% 2 stations Less than 1%
3150-3155	37 frequency assignments for transmit stations spaced across the band segment. 1 US&P transmit station operating in the band segment.	Population Impacted: 58.9% Geographic Availability: 57.6% Figure E-11	0 stations 50-100% 0 stations 10-50% 36 stations 1-10% 2 stations Less than 1%
3155-3160	35 frequency assignments for transmit stations spaced across the band segment. 1 US&P transmit station operating in the band segment.	Population Impacted: 58.9% Geographic Availability: 57.6% Figure E-12	0 stations 50-100% 0 stations 10-50% 34 stations 1-10% 2 stations Less than 1%
3160-3165	35 frequency assignments for transmit stations spaced across the band segment. 1 US&P transmit station operating in the band segment.	Population Impacted: 58.9% Geographic Availability: 57.6% Figure E-13	0 stations 50-100% 1 stations 10-50% 33 stations 1-10% 2 stations Less than 1%
3165-3170	34 frequency assignments for transmit stations spaced across the band segment. 1 US&P transmit station operating in the band segment.	Population Impacted: 58.9% Geographic Availability: 57.6% Figure E-14	0 stations 50-100% 0 stations 10-50% 33 stations 1-10% 2 stations Less than 1%
3170-3175	34 frequency assignments for transmit stations spaced across the band segment. 1 US&P transmit station operating in the band segment.	Population Impacted: 58.9% Geographic Availability: 57.6% Figure E-15	0 stations 50-100% 0 stations 10-50% 33 stations 1-10% 2 stations Less than 1%
3175-3180	37 frequency assignments for	Population Impacted: 60.2%	0 stations 50-100%

Band Segment (MHz)	Frequency Usage	Geographic Usage[a]	Estimated Time Usage
	transmit stations spaced across the band segment. 1 US&P transmit station operating in the band segment.	Geographic Availability: 56.7% Figure E-16	0 stations 10-50% 33 stations 1-10% 5 stations Less than 1%
3180-3185	38 frequency assignments for transmit stations spaced across the band segment. 1 US&P transmit station operating in the band segment.	Population Impacted: 60.2% Geographic Availability: 56.7% Figure E-17	0 stations 50-100% 1 stations 10-50% 33 stations 1-10% 5 stations Less than 1%
3185-3190	34 frequency assignments for transmit stations spaced across the band segment. 1 US&P transmit station operating in the band segment.	Population Impacted: 58.9% Geographic Availability: 57.6% Figure E-18	0 stations 50-100% 0 stations 10-50% 33 stations 1-10% 2 stations Less than 1%
3190-3195	38 frequency assignments for transmit stations spaced across the band segment. 3 airborne transmit stations operating in the band segment. 1 US&P transmit station operating in the band segment.	Population Impacted: 59.6% Geographic Availability: 57.3% Figure E-19	0 stations 50-100% 0 stations 10-50% 38 stations 1-10% 4 stations Less than 1%
3195-3200	38 frequency assignments for transmit stations spaced across the band segment. 3 airborne transmit stations operating in the band segment. 1 US&P transmit station operating in the band segment.	Population Impacted: 59.6% Geographic Availability: 57.3% Figure E-20	0 stations 50-100% 0 stations 10-50% 38 stations 1-10% 4 stations Less than 1%
3200-3205	36 frequency assignments for transmit stations spaced across the band segment. 3 airborne transmit stations operating in the band segment. 1 US&P transmit station operating in the band segment.	Population Impacted: 59.5% Geographic Availability: 57.5% Figure E-21	0 stations 50-100% 0 stations 10-50% 38 stations 1-10% 2 stations Less than 1%
3205-3210	37 frequency assignments for transmit stations spaced across the band segment. 3 airborne transmit stations operating in the band segment. 1 US&P transmit station operating in	Population Impacted: 59.5% Geographic Availability: 57.5% Figure E-22	0 stations 50-100% 1 stations 10-50% 38 stations 1-10% 2 stations Less than 1%

Band Segment (MHz)	Frequency Usage	Geographic Usage[a]	Estimated Time Usage
	the band segment.		
3210-3215	35 frequency assignments for transmit stations spaced across the band segment. 3 airborne transmit stations operating in the band segment. 1 US&P transmit station operating in the band segment.	Population Impacted: 59.0% Geographic Availability: 57.6% Figure E-23	0 stations 50-100% 0 stations 10-50% 37 stations 1-10% 2 stations Less than 1%
3215-3220	63 frequency assignments for transmit stations spaced across the band segment. 3 airborne transmit stations operating in the band segment. 1 US&P transmit station operating in the band segment.	Population Impacted: 78.3% Geographic Availability: 35.7% Figure E-24	0 stations 50-100% 0 stations 10-50% 65 stations 1-10% 2 stations Less than 1%
3220-3225	64 frequency assignments for transmit stations spaced across the band segment. 3 airborne transmit stations operating in the band segment. 1 US&P transmit station operating in the band segment.	Population Impacted: 78.3% Geographic Availability: 35.7% Figure E-25	0 stations 50-100% 0 stations 10-50% 65 stations 1-10% 3 stations Less than 1%
3225-3230	37 frequency assignments for transmit stations spaced across the band segment. 3 airborne transmit stations operating in the band segment. 1 US&P transmit station operating in the band segment.	Population Impacted: 59.9% Geographic Availability: 56.5% Figure E-26	0 stations 50-100% 1 stations 10-50% 37 stations 1-10% 3 stations Less than 1%
3230-3235	38 frequency assignments for transmit stations spaced across the band segment. 3 airborne transmit stations operating in the band segment. 1 US&P transmit station operating in the band segment.	Population Impacted: 59.9% Geographic Availability: 56.5% Figure E-27	0 stations 50-100% 1 stations 10-50% 38 stations 1-10% 3 stations Less than 1%
3235-3240	37 frequency assignments for transmit stations spaced across the band segment. 3 airborne transmit stations operating in the band segment.	Population Impacted: 59.9% Geographic Availability: 56.5% Figure E-28	0 stations 50-100% 0 stations 10-50% 38 stations 1-10% 3 stations Less than 1%

Band Segment (MHz)	Frequency Usage	Geographic Usage[a]	Estimated Time Usage
	1 US&P transmit station operating in the band segment.		
3240-3245	36 frequency assignments for transmit stations spaced across the band segment. 3 airborne transmit stations operating in the band segment. 1 US&P transmit station operating in the band segment.	Population Impacted: 59.0% Geographic Availability: 57.6% Figure E-29	0 stations 50-100% 0 stations 10-50% 38 stations 1-10% 2 stations Less than 1%
3245-3250	37 frequency assignments for transmit stations spaced across the band segment. 3 airborne transmit stations operating in the band segment. 1 US&P transmit station operating in the band segment.	Population Impacted: 59.0% Geographic Availability: 57.6% Figure E-30	0 stations 50-100% 0 stations 10-50% 39 stations 1-10% 2 stations Less than 1%
3250-3255	41 frequency assignments for transmit stations spaced across the band segment. 3 airborne transmit stations operating in the band segment. 1 US&P transmit station operating in the band segment.	Population Impacted: 69.6% Geographic Availability: 46.8% Figure E-31	0 stations 50-100% 0 stations 10-50% 42 stations 1-10% 3 stations Less than 1%
3255-3260	40 frequency assignments for transmit stations spaced across the band segment. 3 airborne transmit stations operating in the band segment. 1 US&P transmit station operating in the band segment.	Population Impacted: 69.6% Geographic Availability: 46.8% Figure E-32	0 stations 50-100% 0 stations 10-50% 41 stations 1-10% 3 stations Less than 1%
3260-3265	34 frequency assignments for transmit stations spaced across the band segment. 3 airborne transmit stations operating in the band segment. 1 US&P transmit station operating in the band segment.	Population Impacted: 59.0% Geographic Availability: 57.6% Figure E-33	0 stations 50-100% 0 stations 10-50% 36 stations 1-10% 2 stations Less than 1%
3265-3270	34 frequency assignments for transmit stations spaced across the band segment.	Population Impacted: 59.0% Geographic Availability: 57.6% Figure E-34	0 stations 50-100% 0 stations 10-50% 36 stations 1-10%

Band Segment (MHz)	Frequency Usage	Geographic Usage[a]	Estimated Time Usage
	3 airborne transmit stations operating in the band segment. 1 US&P transmit station operating in the band segment.		2 stations Less than 1%
3270-3275	35 frequency assignments for transmit stations spaced across the band segment. 3 airborne transmit stations operating in the band segment. 1 US&P transmit station operating in the band segment.	Population Impacted: 59.8% Geographic Availability: 57.0% Figure E-35	0 stations 50-100% 0 stations 10-50% 36 stations 1-10% 3 stations Less than 1%
3275-3280	36 frequency assignments for transmit stations spaced across the band segment. 3 airborne transmit stations operating in the band segment. 1 US&P transmit station operating in the band segment.	Population Impacted: 60.2% Geographic Availability: 56.7% Figure E-36	0 stations 50-100% 0 stations 10-50% 36 stations 1-10% 4 stations Less than 1%
3280-3285	36 frequency assignments for transmit stations spaced across the band segment. 3 airborne transmit stations operating in the band segment. 1 US&P transmit station operating in the band segment.	Population Impacted: 59.5% Geographic Availability: 57.3% Figure E-37	0 stations 50-100% 0 stations 10-50% 36 stations 1-10% 4 stations Less than 1%
3285-3290	35 frequency assignments for transmit stations spaced across the band segment. 3 airborne transmit stations operating in the band segment. 1 US&P transmit station operating in the band segment.	Population Impacted: 59.5% Geographic Availability: 57.3% Figure E-38	0 stations 50-100% 0 stations 10-50% 36 stations 1-10% 3 stations Less than 1%
3290-3295	35 frequency assignments for transmit stations spaced across the band segment. 3 airborne transmit stations operating in the band segment. 1 US&P transmit station operating in the band segment.	Population Impacted: 59.0% Geographic Availability: 57.2% Figure E-39	0 stations 50-100% 0 stations 10-50% 37 stations 1-10% 2 stations Less than 1%
3295-3300	36 frequency assignments for transmit stations spaced across the	Population Impacted: 59.0% Geographic Availability: 57.2%	0 stations 50-100% 0 stations 10-50%

Band Segment (MHz)	Frequency Usage	Geographic Usage[a]	Estimated Time Usage
	band segment. 3 airborne transmit stations operating in the band segment. 1 US&P transmit station operating in the band segment.	Figure E-40	38 stations 1-10% 2 stations Less than 1%
3300-3305	34 frequency assignments for transmit stations spaced across the band segment. 1 US&P transmit station operating in the band segment.	Population Impacted: 58.9% Geographic Availability: 57.6% Figure E-41	0 stations 50-100% 0 stations 10-50% 33 stations 1-10% 2 stations Less than 1%
3305-3310	59 frequency assignments for transmit stations spaced across the band segment. 1 US&P transmit station operating in the band segment.	Population Impacted: 77.5% Geographic Availability: 35.9% Figure E-42	0 stations 50-100% 0 stations 10-50% 58 stations 1-10% 2 stations Less than 1%
3310-3315	59 frequency assignments for transmit stations spaced across the band segment. 1 US&P transmit station operating in the band segment.	Population Impacted: 77.5% Geographic Availability: 35.9% Figure E-43	0 stations 50-100% 0 stations 10-50% 58 stations 1-10% 2 stations Less than 1%
3315-3320	34 frequency assignments for transmit stations spaced across the band segment. 1 US&P transmit station operating in the band segment.	Population Impacted: 58.9% Geographic Availability: 57.7% Figure E-44	0 stations 50-100% 0 stations 10-50% 33 stations 1-10% 2 stations Less than 1%
3320-3325	34 frequency assignments for transmit stations spaced across the band segment. 1 US&P transmit station operating in the band segment.	Population Impacted: 58.9% Geographic Availability: 57.6% Figure E-45	0 stations 50-100% 0 stations 10-50% 33 stations 1-10% 2 stations Less than 1%
3325-3330	36 frequency assignments for transmit stations spaced across the band segment. 1 US&P transmit station operating in the band segment.	Population Impacted: 58.9% Geographic Availability: 57.5% Figure E-46	0 stations 50-100% 0 stations 10-50% 35 stations 1-10% 2 stations Less than 1%
3330-3335	40 frequency assignments for transmit stations spaced across the band segment. 1 US&P transmit station operating in the band segment.	Population Impacted: 68.8% Geographic Availability: 47.4% Figure E-47	0 stations 50-100% 0 stations 10-50% 39 stations 1-10% 2 stations Less than 1%

Band Segment (MHz)	**Frequency Usage**	**Geographic Usage[a]**	**Estimated Time Usage**
3335-3340	37 frequency assignments for transmit stations spaced across the band segment. 1 US&P transmit station operating in the band segment.	Population Impacted: 68.8% Geographic Availability: 47.6% Figure E-48	0 stations 50-100% 0 stations 10-50% 36 stations 1-10% 2 stations Less than 1%
3340-3345	35 frequency assignments for transmit stations spaced across the band segment. 3 airborne transmit stations operating in the band segment. 3 US&P transmit stations operating in the band segment.	Population Impacted: 66.5% Geographic Availability: 51.1% Figure E-49	0 stations 50-100% 0 stations 10-50% 39 stations 1-10% 2 stations Less than 1%
3345-3350	34 frequency assignments for transmit stations spaced across the band segment. 3 airborne transmit stations operating in the band segment. 3 US&P transmit stations operating in the band segment.	Population Impacted: 60.2% Geographic Availability: 55.6% Figure E-50	0 stations 50-100% 0 stations 10-50% 38 stations 1-10% 2 stations Less than 1%
3350-3355	33 frequency assignments for transmit stations spaced across the band segment. 3 airborne transmit stations operating in the band segment. 3 US&P transmit stations operating in the band segment.	Population Impacted: 60.2% Geographic Availability: 55.7% Figure E-51	0 stations 50-100% 0 stations 10-50% 37 stations 1-10% 2 stations Less than 1%
3355-3360	38 frequency assignments for transmit stations spaced across the band segment. 3 airborne transmit stations operating in the band segment. 3 US&P transmit stations operating in the band segment.	Population Impacted: 69.5% Geographic Availability: 46.6% Figure E-52	0 stations 50-100% 0 stations 10-50% 42 stations 1-10% 2 stations Less than 1%
3360-3365	38 frequency assignments for transmit stations spaced across the band segment. 2 US&P transmit stations operating in the band segment.	Population Impacted: 68.7% Geographic Availability: 47.8% Figure E-53	0 stations 50-100% 0 stations 10-50% 38 stations 1-10% 2 stations Less than 1%
3365-3370	37 frequency assignments for transmit stations spaced across the band segment.	Population Impacted: 67.9% Geographic Availability: 49.5% Figure E-54	0 stations 50-100% 0 stations 10-50% 37 stations 1-10%

Band Segment (MHz)	Frequency Usage	Geographic Usage[a]	Estimated Time Usage
	2 US&P transmit stations operating in the band segment.		2 stations Less than 1%
3370-3375	35 frequency assignments for transmit stations spaced across the band segment. 2 US&P transmit stations operating in the band segment.	Population Impacted: 61.4% Geographic Availability: 54.5% Figure E-55	0 stations 50-100% 0 stations 10-50% 35 stations 1-10% 2 stations Less than 1%
3375-3380	53 frequency assignments for transmit stations spaced across the band segment. 2 US&P transmit stations operating in the band segment.	Population Impacted: 75.5% Geographic Availability: 38.3% Figure E-56	0 stations 50-100% 0 stations 10-50% 53 stations 1-10% 2 stations Less than 1%
3380-3385	53 frequency assignments for transmit stations spaced across the band segment. 2 airborne transmit stations operating in the band segment. 4 US&P transmit stations operating in the band segment.	Population Impacted: 75.5% Geographic Availability: 38.3% Figure E-57	0 stations 50-100% 0 stations 10-50% 57 stations 1-10% 2 stations Less than 1%
3385-3390	34 frequency assignments for transmit stations spaced across the band segment. 2 airborne transmit stations operating in the band segment. 4 US&P transmit stations operating in the band segment.	Population Impacted: 58.9% Geographic Availability: 57.0% Figure E-58	0 stations 50-100% 1 stations 10-50% 37 stations 1-10% 2 stations Less than 1%
3390-3395	33 frequency assignments for transmit stations spaced across the band segment. 2 airborne transmit stations operating in the band segment. 4 US&P transmit stations operating in the band segment.	Population Impacted: 59.0% Geographic Availability: 57.0% Figure E-59	0 stations 50-100% 0 stations 10-50% 37 stations 1-10% 2 stations Less than 1%
3395-3400	24 frequency assignments for transmit stations spaced across the band segment. 2 airborne transmit stations operating in the band segment. 4 US&P transmit stations operating in the band segment.	Population Impacted: 45.4% Geographic Availability: 74.9% Figure E-60	0 stations 50-100% 0 stations 10-50% 28 stations 1-10% 2 stations Less than 1%

Band Segment (MHz)	**Frequency Usage**	**Geographic Usage**[a]	**Estimated Time Usage**
3400-3405	24 frequency assignments for transmit stations spaced across the band segment. 2 US&P transmit stations operating in the band segment.	Population Impacted: 42.8% Geographic Availability: 76.0% Figure E-61	0 stations 50-100% 0 stations 10-50% 24 stations 1-10% 2 stations Less than 1%
3405-3410	12 frequency assignments for transmit stations spaced across the band segment. 1 US&P transmit station operating in the band segment.	Population Impacted: 35.5% Geographic Availability: 81.1% Figure E-62	0 stations 50-100% 0 stations 10-50% 11 stations 1-10% 2 stations Less than 1%
3410-3415	19 frequency assignments for transmit stations spaced across the band segment. 1 US&P transmit station operating in the band segment.	Population Impacted: 42.3% Geographic Availability: 76.8% Figure E-63	0 stations 50-100% 0 stations 10-50% 18 stations 1-10% 2 stations Less than 1%
3415-3420	18 frequency assignments for transmit stations spaced across the band segment. 1 US&P transmit station operating in the band segment.	Population Impacted: 42.3% Geographic Availability: 76.8% Figure E-64	0 stations 50-100% 0 stations 10-50% 17 stations 1-10% 2 stations Less than 1%
3420-3425	12 frequency assignments for transmit stations spaced across the band segment.	Population Impacted: 19.0% Geographic Availability: 84.9% Figure E-65	0 stations 50-100% 0 stations 10-50% 10 stations 1-10% 2 stations Less than 1%
3425-3430	38 frequency assignments for transmit stations spaced across the band segment.	Population Impacted: 76.3% Geographic Availability: 39.3% Figure E-66	0 stations 50-100% 0 stations 10-50% 36 stations 1-10% 2 stations Less than 1%
3430-3435	37 frequency assignments for transmit stations spaced across the band segment.	Population Impacted: 76.3% Geographic Availability: 39.3% Figure E-67	0 stations 50-100% 0 stations 10-50% 35 stations 1-10% 2 stations Less than 1%
3435-3440	11 frequency assignments for transmit stations spaced across the band segment.	Population Impacted: 19.0% Geographic Availability: 85.0% Figure E-68	0 stations 50-100% 0 stations 10-50% 9 stations 1-10% 2 stations Less than 1%
3440-3445	12 frequency assignments for transmit stations spaced across the band segment.	Population Impacted: 35.6% Geographic Availability: 81.1% Figure E-69	0 stations 50-100% 0 stations 10-50% 10 stations 1-10% 2 stations Less than 1%
3445-3450	17 frequency assignments for transmit stations spaced across the band segment.	Population Impacted: 43.1% Geographic Availability: 76.6% Figure E-70	0 stations 50-100% 0 stations 10-50% 15 stations 1-10%

Band Segment (MHz)	Frequency Usage	Geographic Usage[a]	Estimated Time Usage
			2 stations Less than 1%
3450-3455	18 frequency assignments for transmit stations spaced across the band segment.	Population Impacted: 43.1% Geographic Availability: 76.6% Figure E-71	0 stations 50-100% 0 stations 10-50% 16 stations 1-10% 2 stations Less than 1%
3455-3460	13 frequency assignments for transmit stations spaced across the band segment.	Population Impacted: 37.2% Geographic Availability: 80.1% Figure E-72	0 stations 50-100% 0 stations 10-50% 11 stations 1-10% 2 stations Less than 1%
3460-3465	11 frequency assignments for transmit stations spaced across the band segment. 2 airborne transmit stations operating in the band segment. 2 US&P transmit stations operating in the band segment.	Population Impacted: 21.6% Geographic Availability: 83.9% Figure E-73	0 stations 50-100% 0 stations 10-50% 13 stations 1-10% 2 stations Less than 1%
3465-3470	15 frequency assignments for transmit stations spaced across the band segment. 2 airborne transmit stations operating in the band segment. 2 US&P transmit stations operating in the band segment.	Population Impacted: 44.9% Geographic Availability: 75.8% Figure E-74	0 stations 50-100% 0 stations 10-50% 17 stations 1-10% 2 stations Less than 1%
3470-3475	15 frequency assignments for transmit stations spaced across the band segment. 2 airborne transmit stations operating in the band segment. 2 US&P transmit stations operating in the band segment.	Population Impacted: 44.9% Geographic Availability: 75.8% Figure E-75	0 stations 50-100% 0 stations 10-50% 17 stations 1-10% 2 stations Less than 1%
3475-3480	11 frequency assignments for transmit stations spaced across the band segment. 2 airborne transmit stations operating in the band segment. 2 US&P transmit stations operating in the band segment.	Population Impacted: 21.6% Geographic Availability: 83.9% Figure E-76	0 stations 50-100% 0 stations 10-50% 13 stations 1-10% 2 stations Less than 1%
3480-3485	11 frequency assignments for transmit stations spaced across the band segment.	Population Impacted: 19.0% Geographic Availability: 85.0% Figure E-77	0 stations 50-100% 0 stations 10-50% 9 stations 1-10% 2 stations Less than 1%

Band Segment (MHz)	Frequency Usage	Geographic Usage[a]	Estimated Time Usage
3485-3490	37 frequency assignments for transmit stations spaced across the band segment.	Population Impacted: 75.4% Geographic Availability: 39.2% Figure E-78	0 stations 50-100% 0 stations 10-50% 35 stations 1-10% 2 stations Less than 1%
3490-3495	37 frequency assignments for transmit stations spaced across the band segment.	Population Impacted: 75.4% Geographic Availability: 39.2% Figure E-79	0 stations 50-100% 0 stations 10-50% 35 stations 1-10% 2 stations Less than 1%
3495-3500	11 frequency assignments for transmit stations spaced across the band segment.	Population Impacted: 19.0% Geographic Availability: 85.0% Figure E-80	0 stations 50-100% 0 stations 10-50% 9 stations 1-10% 2 stations Less than 1%
3500-3505	11 frequency assignments for transmit stations spaced across the band segment. 2 airborne transmit stations operating in the band segment. 2 US&P transmit stations operating in the band segment.	Population Impacted: 21.6% Geographic Availability: 83.9% Figure E-81	1 stations 50-100% 0 stations 10-50% 12 stations 1-10% 2 stations Less than 1%
3505-3510	0 frequency assignments for transmit stations spaced across the band segment. 2 airborne transmit stations operating in the band segment. 2 US&P transmit stations operating in the band segment.	Population Impacted: 9.7% Geographic Availability: 97.5% Figure E-82	1 stations 50-100% 0 stations 10-50% 3 stations 1-10% 0 stations Less than 1%
3510-3515	0 frequency assignments for transmit stations spaced across the band segment. 2 airborne transmit stations operating in the band segment. 2 US&P transmit stations operating in the band segment.	Population Impacted: 9.7% Geographic Availability: 97.5% Figure E-83	1 stations 50-100% 0 stations 10-50% 3 stations 1-10% 0 stations Less than 1%
3515-3520	0 frequency assignments for transmit stations spaced across the band segment. 2 airborne transmit stations operating in the band segment. 2 US&P transmit stations operating in the band segment.	Population Impacted: 9.7% Geographic Availability: 97.5% Figure E-84	1 stations 50-100% 0 stations 10-50% 3 stations 1-10% 0 stations Less than 1%
3520-3525	0 frequency assignments for transmit stations spaced across the band	Population Impacted: 0.0000% Geographic Availability: 100.0000%	0 stations 50-100% 0 stations 10-50% 0 stations 1-10%

Band Segment (MHz)	Frequency Usage	Geographic Usage[a]	Estimated Time Usage
	segment.	Figure E-85	0 stations Less than 1%
3525-3530	0 frequency assignments for transmit stations spaced across the band segment.	Population Impacted: 0.0000% Geographic Availability: 100.0000% Figure E-86	0 stations 50-100% 0 stations 10-50% 0 stations 1-10% 0 stations Less than 1%
3530-3535	0 frequency assignments for transmit stations spaced across the band segment.	Population Impacted: 0.0000% Geographic Availability: 100.0000% Figure E-87	0 stations 50-100% 0 stations 10-50% 0 stations 1-10% 0 stations Less than 1%
3535-3540	0 frequency assignments for transmit stations spaced across the band segment.	Population Impacted: 0.0000% Geographic Availability: 100.0000% Figure E-88	0 stations 50-100% 0 stations 10-50% 0 stations 1-10% 0 stations Less than 1%
3540-3545	0 frequency assignments for transmit stations spaced across the band segment.	Population Impacted: 0.0000% Geographic Availability: 100.0000% Figure E-89	0 stations 50-100% 0 stations 10-50% 0 stations 1-10% 0 stations Less than 1%
3545-3550	0 frequency assignments for transmit stations spaced across the band segment.	Population Impacted: 0.0000% Geographic Availability: 100.0000% Figure E-90	0 stations 50-100% 0 stations 10-50% 0 stations 1-10% 0 stations Less than 1%
Note a: Geographic usage does not take into account US&P frequency assignments. Systems authorized under a US&P assignment can operate anywhere (*e.g.*, inside or outside of the spectrum usage contours) and are not represented on the spectrum usage contours in the appendices. US&P assignments must be taken into account in the sharing feasibility studies.			

8. RESULTS OF QUANTITATIVE ASSESSMENTS

8.1 Introduction

This section presents the results of the quantitative assessments for the: 1300-1390 MHz, 1675-1695 MHz, 2700-2900 MHz, 2900-3100 MHz, and 3100-3550 MHz bands. To the extent the applicable agencies provided responses on projections for future spectrum usage, potential access to non-federal spectrum, and risks to mission requirements, this information was used in conjunction with Total Spectrum Usage calculations. Based on the quantitative assessments, potential sharing opportunities are identified.

In order to identify potential frequency, geographic, and time sharing opportunities in a band, NTIA developed criteria and applied it to the assignment data used in the quantitative assessment (see Table 1-1). The quantitative assessment data is one input for consideration of potential sharing opportunities, but other factors would have to be considered in any detailed feasibility assessment before any conclusions could be reached. Pursuant to the President's 2013 memorandum, in identifying spectrum bands with the greatest potential to be shared, NTIA and the Spectrum Policy Team are to consider the number and nature of federal and non-federal systems in the band, the technical suitability of the band for shared use, international implications, any potential for relocating federal systems to comparable spectrum or otherwise enabling comparable capabilities, and other factors NTIA and the Spectrum Policy Team deem relevant based on consultation with agencies and other stakeholders. These include, for example, the need to take into account mission requirements that can impact federal and non-federal users.

In general, frequency sharing is possible when there is no frequency overlap. For frequency sharing opportunities, the criterion is applied where no assignments fall within a 5 megahertz segment. Geographic sharing is possible when the impact to population is low and the available geographic area is high. In considering geographic sharing opportunities based on the quantitative assessment, the criterion is based on the percentage of population impacted being less than 60 percent and the percentage of geographic area available exceeding 50 percent.[52] Time sharing may be possible when systems are using the spectrum for a low percentage of time. For time sharing opportunities, the criterion is applied where the estimated time usage within 70 percent of the 5 megahertz segments in a frequency band is less than 10 percent.

8.2 1300-1390 MHz Band

8.2.1 Total Spectrum Usage. Total Spectrum Usage in Table 7-1 for the 1300-1350 MHz portion of the band shows the number of frequency assignments across each of the 5 megahertz band segments range from 45 to 68. Based on the aggregation of the frequency usage data, and the criteria NTIA developed, the heavy and diverse use of the band will limit the

[52] US&P assignments were not included in the contours used to assess geographic sharing opportunities. Systems authorized under a US&P assignment have the potential to operate anywhere in the United States but can only be at a single location at a given period of time, which are undetermined. The feasibility studies assessing potential sharing opportunities will have to take US&P operations into account.

opportunities for frequency sharing in the 1300-1350 MHz frequency range. The aggregate geographic usage component of Total Spectrum Usage shows that large percentages of the population can be impacted, ranging from 63.7 percent to 85.5 percent across the 5 megahertz band segments. The percentage of geographic area available in the 5 megahertz band segments ranged from 24.6 percent to 47.1 percent. Geographic sharing opportunities in the 1300-1350 MHz frequency range will be limited according to the quantitative assessment. The long-range surveillance radars operated by the FAA, with DOD and DHS, support ATC safety-of-life functions in the NAS and operate essentially 100 percent of the time, eliminating any potential opportunities for time sharing in the 1300-1350 MHz frequency range as long as these systems remain in the band. Other tactical systems that also operate in the band could have an impact on potential sharing opportunities.

Total Spectrum Usage in Table 7-1 for the 1350-1390 MHz portion of the band shows the number of frequency assignments in the 5 megahertz band segments range from 69 to 251. There are also a large number of frequency assignments for airborne transmit stations in the 1350-1390 MHz sub-band. Based on the aggregation of the frequency usage data, and the criteria NTIA developed, there are no opportunities for frequency sharing in the 1350-1390 MHz frequency range exist. The aggregate geographic usage component of Total Spectrum Usage shows that large percentages of the population can be impacted, ranging from 51.3 percent to 86.2 percent across the 5 megahertz band segments. The percentage of geographic area available ranged from 24.6 percent to 64.3 percent in the 5 megahertz band segments. The geographic sharing opportunities in the 1350-1390 MHz frequency range are limited according to the quantitative assessment. Many of the transmit stations show a time usage ranging from 1 percent to 10 percent. With the exception of the small number of FAA long-range surveillance radar systems, there is an opportunity for time sharing with the terrestrial and airborne systems operating in the 1365-1390 MHz frequency range.

8.2.2 Projections for Future Spectrum Usage. As discussed in Sections 1.4.2 and 1.4.4, an interagency activity is developing plans to analyze the feasibility of moving the aeronautical long-range radar capabilities from existing spectrum allocations, including the 1300-1350 MHz band, into the 2700-3100 MHz band, as part of the SENSR capability. Such a potential relocation from the 1300-1350 MHz band is contingent on the development, funding and outcome of the feasibility study.

The National Aeronautics and Space Administration (NASA) operates a limited number of terrestrial radar systems in the band and can vacate the frequency band as long as suitable frequency assignments can be accommodated within the 1215-1300 MHz frequency range.

DHS plans to continue operating its terrestrial and tethered aerostat radar systems for the foreseeable future. DHS does plan on deploying new systems in the 1350-1390 MHz portion of the band. At this time, DHS is not planning to make any changes to the mission requirements that the systems operating in 1300-1390 MHz band support. DHS anticipates that they will require continued access to the 1350-1390 MHz band at a limited number of locations to support its mission requirements for the foreseeable future.

The USCG is experimenting with unmanned aircraft system (UAS) in the 1300-1390 MHz band. However, final development may be in a different frequency band. The geographical area for UAS operations will most likely be United States and Possessions (US&P). UAS development may take several years to become fully operational. The USCG plans on submitting a request for spectrum support to NTIA once the technology has been developed. DHS and other federal agencies that are responsible for rescue and security operations may benefit from the USCG UAS. The USCG spectrum usage for UAS may increase in the 1300-1390 MHz band; however, the actual percentage increase in the spectrum usage will depend on the final system development.

The Army reported that at the present time it does not plan to design new systems in the 1300-1390 MHz band. Modifications to the existing systems may not require additional spectrum within the 1300-1390 MHz band. Based on the current information that is available, the Army anticipates that the present spectrum requirements in the 1300-1390 MHz band are expected to remain unchanged.

The Navy and Marine Corps reported that they plan on continuing to operate systems in the 1350-1390 MHz band. It is anticipated that they will need additional frequencies in the band to support future operations. They also have plans to expand the geographic areas where they operate. The Navy and Marine Corps also expect that the time of usage for their systems will increase in the future.

The Air Force reported that they do not foresee any changes to the geographic use, spectrum requirements, or time of usage for its systems operating in this band. For the foreseeable future, the Air Force also does not anticipate any relocation of systems from the band or modifications that would impact the geographic usage, frequency/bandwidth requirements, or time usage for its systems operating in the 1300-1390 MHz band.

8.2.3 Federal Access to Non-Federal Spectrum. The federal agencies with operations in this band did not identify non-federal spectrum that could be used to help fulfill their missions.

8.2.4 Risks to Agency Mission Requirements. The long-range radars in the 1300-1350 MHz band support safety-of-life applications, and as such, any risks of harmful interference are not acceptable. At this time, the FAA is exploring the feasibility of making changes to the mission requirements for the long-range radars operating in the 1300-1350 MHz portion of the band. It is too early in the SENSR program to determine how it may impact systems in the future. Ultimately other measures would be necessary in order to enable sharing in the band, including consideration of potential relocation of major widely deployed systems to other bands if feasible. A detailed study of the feasibility of relocating systems out of the band would have numerous factors to consider beyond the results of the quantitative assessment.

8.3 1675-1695 MHz Band

8.3.1 Total Spectrum Usage. Total Spectrum Usage in Table 7-2 shows a significant number of meteorological-satellite and radiosonde receive stations in the 1675-1685 MHz portion of the band across each of the 5 megahertz band segments and a much smaller number in the 1685-1695 MHz portion of the band. In the 1675-1680 MHz portion of the band, there are 313 receive stations and in the 1680-1685 MHz portion of the band there are 200 receive stations. In the 1685-1690 MHz portion of the band, there are 40 receive stations and in the 1690-1695 MHz portion of the band there are 38 receive stations. Based on the quantitative assessment aggregation of the frequency usage data, no opportunities for frequency sharing in the 1675-1695 MHz band exist. The aggregate geographic usage component of Total Spectrum Usage shows that the percentage of population impacted ranged from 3.99 percent to 39.8 percent.[53] The percentage of geographic area available is high across the 1675-1695 MHz band ranging from 79 percent to 99.2 percent. There are geographic sharing opportunities with federal receive stations in the 1675-1695 MHz band, contingent upon the successful completion of a feasibility study.

The DOC is in the process of relocating radiosonde systems in the 1675-1695 MHz band to the 400.15-406 MHz band. Total Spectrum Usage in Table 7-3 and the spectrum usage contours plots in Appendix B as shown do not include the radiosonde receive stations. As shown in Table 7-3, the migration of the radiosondes to the 400.15-406 MHz band will significantly improve the opportunities for geographic sharing. However, a sharing feasibility study needs to be performed to assess the potential impact to GOES receive stations that will remain in the 1675-1695 MHz band.

The frequency, geographic, and time usage for the 1675-1695 MHz band shown in Table 7-2 and Table 7-3 does not reflect non-federal use of the band.

8.3.2 Projections for Future Spectrum Usage. The DOC provided information describing projected frequency and bandwidth plans for the GOES-R and GOES-NEXT meteorological-satellites. The overall bandwidth requirements for GOES-R are the same as the legacy GOES satellites. GOES-NEXT will increase the total bandwidth requirements in the 1675-1695 MHz band.

The Army reported that at the present time it does not plan to design new systems for the 1675-1695 MHz band. Modifications to the existing systems will not require additional spectrum within the 1675-1695 MHz band. Based on the current information that is available, the Army anticipates that its present spectrum requirements in the 1675-1695 MHz band are expected to remain unchanged.

The Navy and Marine Corps reported that at the present time they do not plan to design new systems for the 1675-1695 MHz band. Modifications to the existing systems will not require additional spectrum within the 1675-1695 MHz band. Based on the currently available information, the Navy anticipates that its present spectrum requirements in the 1675-1695 MHz band are expected to remain unchanged.

The Air Force does not anticipate changes to the geographic use, spectrum requirements, or time of usage for its system operating in the 1675-1695 MHz band. For the foreseeable future, the Air Force does not anticipate any relocation of systems from the band or

[53] Many of the receive stations in the 1685-1695 MHz band operate at the same location, so the number of spectrum usage contours shown in Appendix B are less than the number of receive stations shown in Table 7-3.

modifications that would impact the geographic usage, frequency/bandwidth requirements, or time usage for its system operating in the 1675-1695 MHz band.

8.3.3 Federal Access to Non-Federal Spectrum. DOC did not identify specific non-federal frequency bands that could be used to satisfy its mission, but will work with NTIA and the FCC in analyzing non-federal bands that meet its technical and logistical requirements.

8.3.4 Risks to Agency Mission Requirements. The signals from the DOC meteorological-satellites in the 1675-1695 MHz band are used by federal and non-federal entities. Since the non-federal users do not need to register or receive FCC authorization for their receive sites, data is not available to predict the impact of sharing with the non-federal users in the 1675-1695 MHz band.[54] Many of the public safety uses are for mobile or transportable meteorological-satellite earth station receivers (*e.g.*, EMWIN), for which it is not possible to establish geographic sharing arrangements. The impact to federal and non-federal users must be taken into account when considering sharing in the 1675-1695 MHz band.

8.4 2700-2900 MHz Band

8.4.1 Total Spectrum Usage. Total Spectrum Usage in Table 7-4 shows the number of frequency assignments in the 5 megahertz band segments range from 42 to 157. Nine percent of the frequency assignments in this band authorize operation across the entire band.[55] Based on the aggregation of the frequency usage data, and the criteria NTIA developed, no opportunities for frequency sharing in the 2700-2900 MHz band exist. The aggregate geographic usage component of Total Spectrum Usage shows that large percentages of the population can be impacted, ranging from 44.6 percent to as high as 74.7 percent across 5 megahertz band segments, as some systems have the flexibility to operate across the entire band (*e.g.*, band assignments). The percentage of geographic area available ranged from 48.5 percent to 75.3 percent, across 5 megahertz band segments in the 2700-2900 MHz band. Based on the quantitative assessment data, and the criteria NTIA developed, geographic sharing opportunities in the 2700-2900 MHz band are limited. The ATC and NEXRAD radars support safety-of-life functions and are operating essentially 100 percent of the time, eliminating any potential opportunities for time sharing in the 2700-2900 MHz band.

8.4.2 Projections for Future Spectrum Usage. The FAA and the DOC have no plans to expand or terminate usage of the ASR and NEXRAD radar systems that operate in the 2700-2900 MHz band. The FAA and DOC initially evaluated the feasibility of replacing the NEXRAD and ASR systems with a MPAR system in the 2700-3100 MHz frequency range. As stated in Section 1.4.2 and 1.4.4, the FAA and DOC effort has evolved into an ongoing interagency activity that also includes DOD and DHS to develop plans to analyze the feasibility of relocating the aeronautical long-range radar systems from existing spectrum allocations, including the 1300-1350 MHz band, into the 2700-2900 MHz band as part of the SENSR capability. SENSR could facilitate interagency spectrum sharing in the 2700-3100 MHz

[54] *Fast Track Report* at 3-22.

[55] In the GMF, a frequency assignment that authorizes operation of a system across the entire band is referred to as a band assignment.

frequency range and enable commercial broadband access in the 1300-1350 MHz band, based on the results of the feasibility study. Details of how the feasibility study will be conducted are still under development among the impacted federal agencies, including the determination of the SENSR spectrum requirements. The Army reported that at the present time it does not plan to design new systems in the 2700-2900 MHz band. Modifications to the existing systems will not require additional spectrum within the 2700-2900 MHz band. Based on the current information that is available, the Army anticipates that its present spectrum requirements in the 2700-2900 MHz band are expected to remain unchanged.

The Navy and Marine Corps reported that they plan on continuing to operate systems in the 2700-2900 MHz band. It is anticipated that they will need additional frequencies in the band to support future operations. They also have plans to expand the geographic areas where their systems operate. The Navy and Marine Corps also expect that the time of usage for their systems will increase in the future.

The Air Force does not anticipate changes to the geographic use, spectrum requirements, or time of usage for its systems operating in this band. For the foreseeable future, the Air Force does not anticipate any relocation of systems from the band or modifications that would impact the geographic usage, frequency/bandwidth requirements, or time usage for its systems operating in the 2700-2900 MHz band.

NASA has limited operations in the 2700-2900 MHz band that are anticipated to continue indefinitely.

8.4.3 Federal Access to Non-Federal Spectrum. There are no non-federal ATC systems in the 2700-2900 MHz frequency band that can aid the FAA in performing its mission. As for using existing operating systems and sharing data, the FAA currently shares system data from the NEXRAD weather radar systems operated by the DOC as well as data with radar systems operated by the DOD and DHS. The FAA currently shares data from the FAA systems with every other federal agency that can benefit from this data.

The federal agencies operating radar systems in the 2700-2900 MHz band did not identify non-federal frequency bands that could be used to aid in supporting their missions to perform ATC, weather prediction, and national security.

8.4.4 Risks to Agency Mission Requirements. NEXRAD is used to warn the public about dangerous weather. 160 operational NEXRAD radar systems are deployed throughout the United States. Meteorologists use NEXRAD to provide severe weather and flash flood warnings; air traffic safety and flow control; resource protection at military bases; and management of water, agriculture, and forest resources. NEXRAD is critical to the DOC mission; therefore, harmful interference in the 2700-3000 MHz frequency band could impact the ability of the DOC to provide accurate weather information to the public. The potential loss of these essential mission requirements that can impact federal and non-federal users alike must be taken into account when considering the risks of sharing in this band to ensure current and future protection of these capabilities.

In general, non-radar (*e.g.*, communication) systems and radar systems operated by the FAA in the 2700-2900 MHz frequency band are incompatible. The radar systems operated by the FAA provide aeronautical radionavigation and meteorological services that support safety-of-life applications (*e.g.*, air traffic control operations within the national airspace system). Therefore, any risk of harmful interference is unacceptable. At this time, the FAA is not planning to make any changes to the mission requirements that the radar systems operating in this band support.

8.5 2900-3100 MHz Band

8.5.1 Total Spectrum Usage. Total Spectrum Usage in Table 7-5 shows that the number of frequency assignments for transmit stations in the 5 megahertz band segments, with the exception of the 2900-2905 MHz segment, ranges from 113 to 153. In this band, 52 percent of the frequency assignments authorize operations across the entire band. There are frequency assignments for shipborne transmit stations and US&P transmit stations in the band. Based on the aggregation of the frequency usage data, there are no opportunities for frequency sharing in the 2900-3100 MHz band. The aggregate geographic usage component of Total Spectrum Usage shows that the percentage of population impacted ranged from 42.8 percent to 64.5 percent. The US&P assignments are not represented in the geographic usage. The percentage of geographic area available ranged from 45.6 percent to 73.2 percent. Based on the quantitative assessment and the criteria NTIA developed, geographic sharing opportunities may exist in the 2900-3100 MHz band, contingent upon the successful completion of a sharing feasibility study. In each of the 5 megahertz band segments, approximately half of the transmit stations have time of usage percentages ranging from 50 percent to 100 percent, limiting time sharing opportunities in the 2900-3100 MHz band. Looking forward, a significant change in the quantitative assessment frequency and geographic usage data would occur if implementation of the SENSR capability in this band is found to be feasible, from a technical, operational, and cost perspective, as part of the relocation feasibility assessment of the 1300-1350 MHz band.

8.5.2 Projections for Future Spectrum Usage. DOT's MARAD has two frequency assignments in the 2900-3100 MHz band for radars operating on two Merchant Marine training vessels with the Merchant Marine Academy at Kings Point, New York. The 2900-3100 MHz band is used by federal and non-federal entities. There are no changes expected in the operation of the maritime radars for the foreseeable future in light of the non-federal usage of this band and the critical training mission they fulfill. For the foreseeable future, the maritime radars will continue to operate in the band, with no new systems or expansion of service anticipated. If equipment upgrades are needed, they will be off-the-shelf units as direct replacements.

DOT's SLDSC has RACONs operating in the Saint Lawrence River in the 2900-3100 MHz band. The 2900-3100 MHz band is used by both federal and non-federal users. No changes are expected in the service provided by these RACONs for the foreseeable future in light of the non-federal usage of this band and the critical nature of the operation of the RACONs. These RACONs will continue to operate in the band, with no new systems or expansion of service anticipated. If equipment upgrades are needed, they will be off-the-shelf units as direct replacements.

The Army reported that at the present time it does not plan to design new systems for the 2900-3100 MHz band. Modifications to the existing systems will not require additional spectrum within the 2900-3100 MHz band. Based on the currently available information, the Army projects that its present spectrum requirements for the 2900-3100 MHz band are expected to remain unchanged.

The Navy and Marine Corps anticipates they will need additional frequencies in the band to support future operations. They also have plans to expand the geographic areas where their systems operate. The Navy and Marine Corps also expect that the time of usage for their systems will increase in the future.

The Air Force does not anticipate changes to the geographic use, spectrum requirements, or time of usage for their systems operating in this band. For the foreseeable future, the Air Force does not anticipate any relocation of systems from the band or modifications that would impact the geographic usage, frequency/bandwidth requirements, or time usage for their systems operating in the 2900-3100 MHz band.

NASA, DOT, and DHS will continue to operate systems in the 2900-3100 MHz band for the foreseeable future. There are no plans for new systems or the expansion of existing systems. The geographic usage of this band will be impacted by the final disposition of the SENSR program through the ongoing and planned interagency evaluation of the feasibility of consolidating various radar systems from the 1300-1350 MHz and other bands into the 2700-3100 MHz frequency range.

8.5.3 Federal Access to Non-Federal Spectrum. The federal agencies did not identify non-federal spectrum that could be used to fulfill their missions.

8.5.4 Risks to Agency Mission Requirements. Meteorologists use NEXRAD to provide severe weather and flash flood warnings, air traffic safety and flow control; resource protection at military bases; and management of water, agriculture, and forest resources. NEXRAD is critical to the DOC mission; therefore, harmful interference in the 2700-3000 MHz frequency band could impact the ability of the DOC mission to provide accurate weather information to the public.

In general, non-radar (*e.g.*, communication) systems and radar systems operated by the FAA in the 2900-3100 MHz frequency band are incompatible. The radar systems operated by the FAA in those frequency bands provide aeronautical radionavigation and meteorological services that support safety-of-life applications (*e.g.*, air traffic control operations with the national airspace system). Therefore, any risk of harmful interference is unacceptable for the mission that the FAA performs.

At this time the federal agencies have no plans to make changes to the mission requirements that the radar systems operating in the 2900-3100 MHz band support.

8.6 3100-3550 MHz Band

8.6.1 Total Spectrum Usage. Total Spectrum Usage in Table 7-5 shows that in the 3100-3505 MHz portion of the band, the number of frequency assignments in the 5 megahertz band segments range from 0 to 68. In the 3505-3550 MHz portion of the band, the number of frequency assignments range in 5 megahertz band segments from 1 to 4. Thirty-three percent of the frequency assignments in this band authorize operation across the entire band, recognizing that some systems have the capability to operate across the entire band (*e.g.*, band assignments), recognizing that some systems have the capability to operate across the band. In addition, a small number of US&P frequency assignments can operate in segments of the band. Based on the aggregation of the frequency usage data, and the criteria NTIA developed, potential opportunities exist for frequency sharing, particularly in the 3505-3550 MHz portion of the band. The percentage of the population impacted ranged from 0 percent to 78.3 percent. The percentage of geographic area available ranged from 35.7 percent to 100 percent. Based on the quantitative assessment data and the criteria NTIA developed, geographic sharing opportunities may exist, particularly in the upper 45 MHz portion of the band. In each of the 5 megahertz band segments, the transmit stations have usage percentages ranging from 1 percent to 10 percent, indicating that time sharing opportunities may exist in the 3100-3550 MHz band. The sharing opportunities are contingent upon the successful completion of a feasibility study, which would take into account the US&P operations in the band.

8.6.2 Projections for Future Spectrum Usage. The Army reported that at the present time, it does not plan to design new systems for the 3100-3550 MHz band. Modifications to the existing systems will not require additional spectrum within the 3100-3550 MHz band. The Army reported that one of its radars operating in this band may be deployed at additional locations in the United States. Based on the current available information, the Army projects that its present spectrum requirements in the 3100-3550 MHz band will remain unchanged.

The Navy and Marine Corps reported that they plan on continuing to operate systems in the 3100-3550 MHz band. It is anticipated that they will need additional frequencies in the band to support future operations. They also have plans to expand the geographic areas where their systems operate. The Navy and Marine Corps also expect that the time of usage for their systems will increase in the future.

The Air Force does not anticipate changes to the geographic use, spectrum requirements, or time of usage for its systems operating in this band. For the foreseeable future, the Air Force does not anticipate any relocation of systems from the band or modifications that would impact the geographic usage, frequency/bandwidth requirements, or time usage for its systems operating in the 3100-3550 MHz band.

8.6.3 Federal Access to Non-Federal Spectrum. The DOD did not identify non-federal spectrum that could be used to fulfill its missions.

8.6.4 Risks to Agency Mission Requirements. The DOD's air, land, maritime, and space operations increasingly depend on electromagnetic spectrum access. The growing requirements to gather, analyze, and share information rapidly; to control an increasing number of automated intelligence, surveillance, and reconnaissance assets; to command geographically dispersed and mobile forces; to gain access into denied areas; and to “train as they fight” requires that the DOD maintain sufficient spectrum access. In 2013, the DOD developed its Electromagnetic Spectrum Strategy that established a framework for how it should rapidly adapt to the changing spectrum environment and to assess and respond to spectrum regulatory changes.[56] One of the objectives of its spectrum strategy is to accelerate the fielding of technologies that enable spectrum sharing access opportunities. The DOD will pursue promising technologies, establish policies, and adopt standards to improve interference mitigation while preserving the capabilities of its systems. The DOD also will identify systems that can share spectrum and/or operate compatibly with systems in adjacent spectrum bands without affecting system effectiveness or compromising operational safety.

[56] Department of Defense Electromagnetic Spectrum Strategy, *A Call to Action* (2013).

APPENDICES