NTIA Report 24-01

Spectrum Pipeline Reallocation Engineering Study Follow-On

TASK 3—IDENTIFYING REGULATORY CONTRAINTS

National Telecommunications and Information Administration
1401 Constitution Ave., NW Washington, DC 20230

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Office of Spectrum Management
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CONTENTS

ABBREVIATIONS/ACRONYMS

dB	Decibel
dBi	Decibels relative to an isotropic antenna
dBm	Decibel (referenced to milliwatts)
EIRP	Effective Isotropic Radiated Power
EMC	Electromagnetic Compatibility
FCC	Federal Communications Commission
FDR	Frequency Dependent Rejection
GHz	Gigahertz
GMF	Government Master File
IF	Intermediate Frequency
I/N	Interference-to-Noise ratio
ITM	Irregular Terrain Model
ITU-R	International Telecommunication Union Radiocommunication Sector
IRAC	Interdepartmental Radio Advisory Committee
MHz	Megahertz
MHz-POP	Megahertz times Population
NOAA	National Oceanic and Atmospheric Administration
NTIA	National Telecommunications and Information Administration
OFR	Off-Tune Frequency Rejection
OSM	Office of Spectrum Management
OTR	On-Tune Rejection
PEA	Partial Economic Area
Rx	Receiver
Tx	Transmitter

EXECUTIVE SUMMARY

The National Telecommunications and Information Administration (NTIA) concludes in this report that it is technically feasible to share the 1675-1680 MHz band used by the National Oceanic and Atmospheric Administration (NOAA) for transmission of time-sensitive satellite data with commercial wireless services. In 2016, the Federal Communications Commission (FCC) issued a Notice of Proposed Rulemaking to consider sharing of the 1675-1680 MHz band between new commercial mobile operators and incumbent NOAA satellite operations.[1] In response, in October 2020, NOAA published the Spectrum Pipeline Reallocation Engineering Study (SPRES) Report (SPRES Report)[2] that studied the potential impact on NOAA operations of possibly sharing spectrum with new commercial operations in the 1675-1680 MHz band. This instant report is intended to address the further study topics suggested in the SPRES Report and concludes that spectrum sharing is possible by employing "coordination zones" around five "DCS" earth stations and then transitioning the remaining earth stations to an alternative distribution method.

Figure 1 shows the current and proposed frequency usage for this band.

[1] *Allocation and Service Rules for the 1675–1680 MHz Band*, Notice of Proposed Rulemaking, 34 FCC Rcd 3552 (2019).

[2] U.S. Department of Commerce. National Oceanic and Atmospheric Administration. National Environmental Satellite Data Information Service, Spectrum Pipeline Reallocation 1675–1680 MHz Engineering Study (SPRES) Program Report. Silver Spring, MD: NESDIS, October 2020 ("SPRES Report"), https://www.fcc.gov/ecfs/document/10906163747708/1.

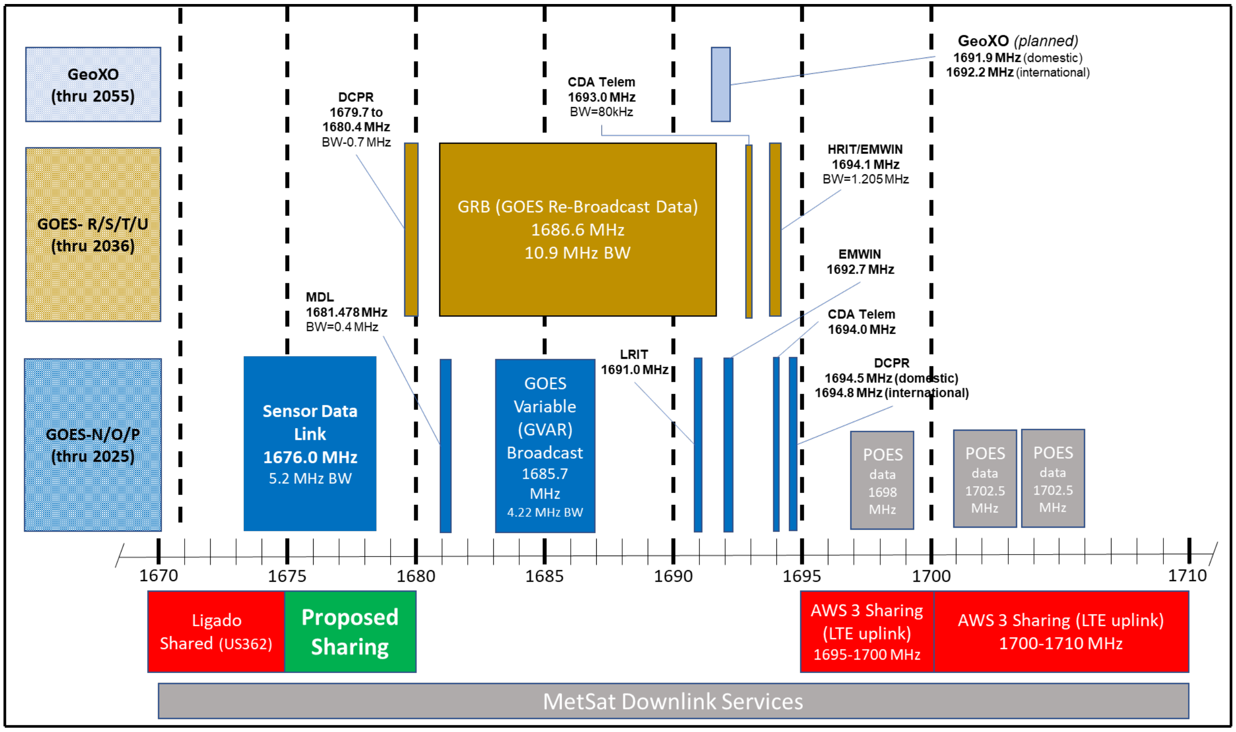

Figure 1: Current and Proposed Frequency Usage

The SPRES Report addressed the impact of sharing on three aspects of NOAA data distribution operations: (1) High-Rate Information Transmission (HRIT); (2) Geostationary Operational Environmental Satellites (GOES) ReBroadcast (GRB); and (3) the Data Collection System (DCS).

> **HRIT**: The SPRES Report found that spectrum sharing presents low risk of causing impacts to HRIT given the frequency separation.
>
> **GRB**: The SPRES Report found that the GRB signal is at some risk of radio-frequency interference (RFI) at the ground stations, more so from commercial base station operations (downlinks) than from commercial user devices (uplinks).
>
> **DCS**: The SPRES Report found that the most significant obstacle to spectrum sharing involves radio-frequency interference from downlink commercial operation to DCS ground stations. If the commercial operations are restricted to uplinks, however, sharing may be manageable with modest protection zones.

To reach a more definitive conclusion regarding the potential for sharing the 1675-1680 MHz band with commercial mobile, the SPRES Report suggested:

> further technical compatibility analysis to determine specific technical limits on commercial mobile operations to insure protection for the key DCS sites and

certain GRB and HRIT sites. This latter work would consider limits on such things as the radiated power and out-of-band emissions of the commercial mobile system's transmitters and any guardband that might be used to limit in-band energy in protection zones around the DCS, GRB, or HRIT receiver sites.[3]

This instant report is intended to address the further study topics suggested in the SPRES Report. NTIA's technical assessment is that sharing the 1675-1680 MHz band with non-federal wireless services is technically feasible. Federal earth stations would be protected from harmful interference by employing "coordination zones" around five DCS ground stations and then transitioning the remaining DCS ground stations to an alternative distribution method. It is estimated that, in such a manner, commercial service could be provided for 80-90 percent of the population of the continental United States.

Protection of Federal Systems from Harmful Interference that Sharing Could Cause. To protect the federal earth stations from harmful interference that otherwise could result from sharing the spectrum, this report provides the methodology to be used in a coordination process, along with the technical characteristics of federal earth station operations. A "coordination zone" would be established as an area in which wireless terrestrial commercial operators would need to coordinate with NTIA before they could deploy a base station within that coordination zone. Commercial operators would need to coordinate for a particular base station only once. Spectrum sharing in these coordination zones would not be time dynamic. Specifically:

- Five DCS ground station locations would be protected using coordination zones. All other DCS ground stations would transition to use an alternative distribution method to maintain access to the DCS data.
- If an alternative distribution method could not be applied to GRB data, an additional 14 GRB locations would be protected using coordination zones.
- No HRIT locations would need to rely on the protection of coordination zones.

To adequately protect federal incumbents, NTIA recommends that the coordination zones be identified on the NTIA website (as was done for the 3.5 GHz Citizens Broadband Radio Service),[4] allowing for future modification of federal coordination zones if changes in non-federal operational use so warrant.

Future Work to Advance Spectrum Sharing. To advance spectrum sharing (at the Hunt Valley DCS location), future efforts could consider whether earth stations could share in the time domain, with potential use of an incumbent informing capability (IIC) optimized for time-based spectrum

[3] SPRES Report at ii.

[4] *See* Letter from Paige Atkins, NTIA, to Julius Knapp, FCC, Docket No. 12-354 (Mar. 24, 2015), https://www.ntia.gov/files/ntia/publications/ntia_letter_docket_no_12-354.pdf (regarding commercial operations in the 3.5 GHz band).

sharing.[5] The IIC can be a near-real-time mechanism to inform non-federal users in a shared spectrum band when incumbent federal systems need to be protected from harmful interference.

[5] *See* NTIA Report, *Incumbent Informing Capability (IIC) for Time-Based Spectrum Sharing* (2021), https://www.ntia.gov/report/2021/ntia-report-incumbent-informing-capability-iic-time-based-spectrum-sharing.

1. INTRODUCTION

1.1 Background

The National Oceanic and Atmospheric Administration's (NOAA), National Environmental Satellite Data and Information Systems (NESDIS) conducted a Spectrum Pipeline Reallocation Engineering Study (SPRES) to provide a range of technical measurements and analysis and enabled objective decisions regarding the ability to accommodate and implement spectrum sharing in the 1675-1680 MHz band.[6] A follow-on study was required to reach a more definitive conclusion on the feasibility and specific implementation details for sharing the 1675-1680 MHz band with commercial wireless services. The Spectrum Pipeline Reallocation Engineering Study Follow-On (SPRES-FO) objective is to conduct further studies to refine the efforts of the SPRES project and determine if sharing the 1675-1680 MHz band with commercial mobile operations can remain an option. This report is part of the SPRES-FO.

1.2 Objective

The objective of this report is to identify regulatory constraints needed to protect mission-critical sites. To support this objective, the model is included to calculate harmful interference.

1.3 Approach

The report considers two possible sharing scenarios to protect the incumbent (current and planned) federal earth stations from harmful interference:

- Status Quo: 37 DCS and GRB locations identified by the NOAA survey. (See Table 1)
- Alternative Distribution Mechanism (ADM)[7,8]: 5 DCS locations to support ADM. (See Table 3)

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[6] *See Allocation and Service Rules for the 1675–1680 MHz Band*, 34 FCC Rcd at 3560 ("We also note that our record will be informed by a study that NOAA is conducting using Spectrum Relocation Fund support, as provided under the Spectrum Pipeline Act, regarding the protection methodology necessary to make this band available on a shared basis with non-federal fixed or mobile (except aeronautical mobile) users").

[7] "*SPRES Projects 3, 4, and 5 considered whether alternative means, specifically using terrestrial networks, of disseminating DCS and GRB data could feasibly reduce or replace the need for the L-band data relay or broadcast for some or all end users. The projects identified the DCP and GRB users' data and performance needs, then evaluated a combination of existing NOAA assets and new distribution/dissemination technologies that may be capable of fulfilling those needs.*" SPRES Report at 87.

[8] The SPRES report looked at allowing for near-real-time (NRT) distribution of the DCS data from key DCS sites to both federal and non-federal users. The assessment included the feasibility of streaming DCS data from key DCS sites with high reliability and low latency to federal and non-federal users.

1.4 Report Structure

The report is organized as follows:

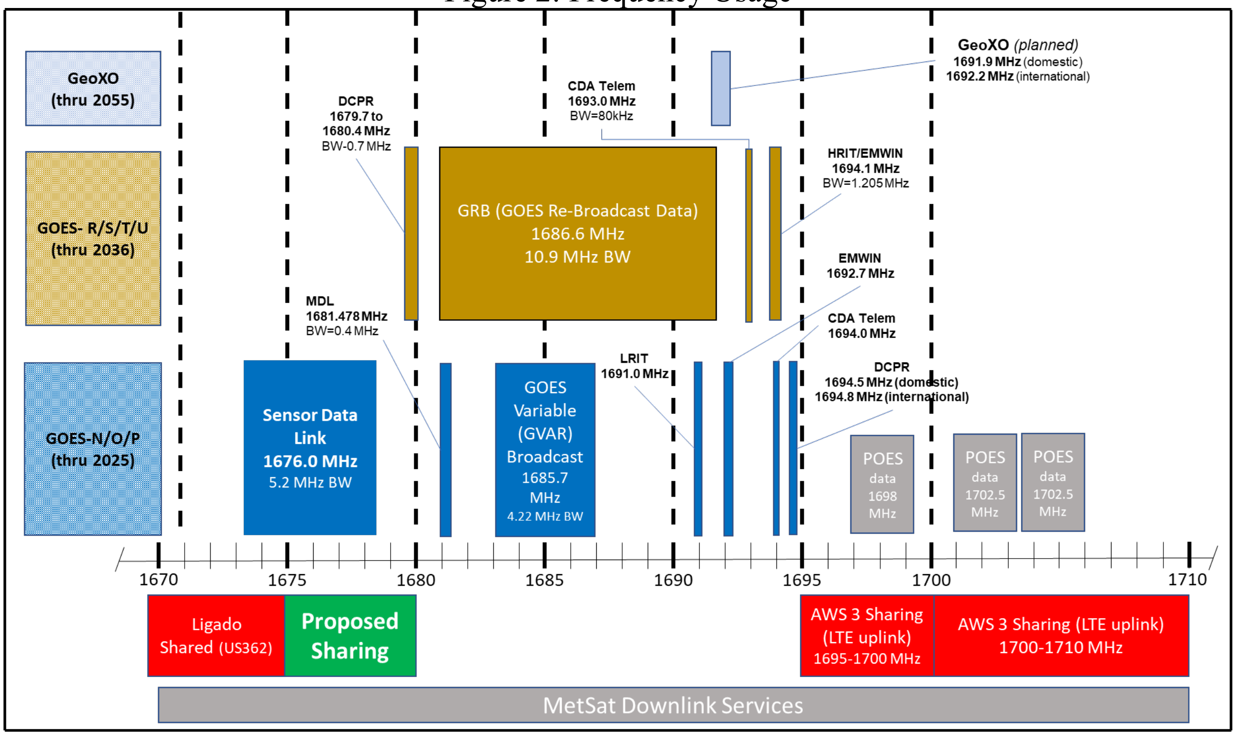
- Section 2: Federal Spectrum Usage in the 1675-1695 MHz band.
- Section 3: Engineering Models and Assumptions using the analysis.
- Section 4: Coordination Zone (Protection) Methodology of Federal systems.
- Section 5: Pathways to Increase Non-Federal Spectrum Access
- Section 6: Discussion on Monitoring

2. FEDERAL SPECTRUM USAGE

2.1 Overview

Figure 2 shows the frequency usage (and systems) that operate in the 1670-1700 MHz band. The proposed sharing band (1675-1680 MHz) that was studied in this report.

Figure 2: Frequency Usage



2.2 1675-1695 MHz

The 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.

That 1675-1680 MHz band is used by NOAA satellites to transmit crucial, time-sensitive data, primarily to geographically diverse, ground-based users. The current NOAA satellite fleet in geostationary orbit, known as Geostationary Operational Environmental Satellites Series R (GOES-R), relies on the 1675–1695 MHz band to collect and disseminate critical, real-time information on weather, hydrologic and other environmental conditions, and solar activity to a broad range of users in the Federal government, state and local agencies, and the private sector. The GOES-R four-satellite constellation will operate through the year 2035, when it is expected to be replaced.

The Data Collection System (DCS) operates at 1679.7-1680.1 MHz. It acquires data from a wide variety of sensors, then formats and retransmits that data to earth stations throughout the United States. The DCS requires high reliability because the data provides critical real-time information about weather, tides, river and reservoir levels, wildfire, and other conditions, and it is used by government agencies and private companies to manage billions of dollars of critical infrastructure. The primary DCS receive site, also used to retransmit the data to other users, is located at Wallops Island, Virginia. There is also a backup facility, the Consolidated Backup Unit (CBU), at Fairmont, West Virginia. Table 1 shows DCS system locations analyzed in this report.

The GOES Rebroadcast (GRB) operates at 1681.15-1692.05 MHz and consists of satellite ground stations, product development facilities, and dissemination infrastructure. It is used to disseminate critical, real-time information for weather, hydrologic, solar activity, and other environmental observations to a broad range of users in federal, state and local government agencies, and the private sector. Table 1 shows GRB system locations analyzed in this report.

The High-Rate Information Transmission (HRIT) operates at 1693.5-1694.7 MHz and transmits near-real-time weather forecasts and warnings via satellite in a form well-suited for emergency managers. The signal incorporates weather event warnings, low-resolution GOES satellite imagery data, DCS messages, and other selected products. The HRIT were not analyzed in this report because, "[t]he SPRES report finds that sharing presents low risk of causing impacts to HRIT given the frequency separation."[9] In some cases, HRIT is used as backup to the Direct Readout Ground Station (DRGS) to receive DCS data.

Note that in Table 1, some locations have multiple receivers (a combination of DCS, GRB, and HRIT). In some cases, HRIT is used as a backup to the DRGS to receive DCS data.

Table 1: DCS and GRB System Locations

City	State	Latitude	Longitude	System Type
Anchorage (Elmendorf AFB)	AK	61.2351	-149.8250	GRB
Anchorage (NWS)	AK	61.1570	-149.9860	GRB
Boise (BOR)	ID	43.6147	-116.2520	DCS HRIT
Boise (NIFC)	ID	43.5669	-116.2090	DCS HRIT
Boulder	CO	39.9908	-105.2640	GRB
Brevard County	FL	28.4280	-80.5963	GRB
Cincinnati	OH	39.1028	-84.5097	DCS HRIT
College Park	MD	38.9719	-76.9252	GRB
Columbus Lake	MS	33.5345	-88.5018	DCS
Fairmont	WV	39.4336	-80.1928	DCS GRB HRIT

[9] SPRES Report.

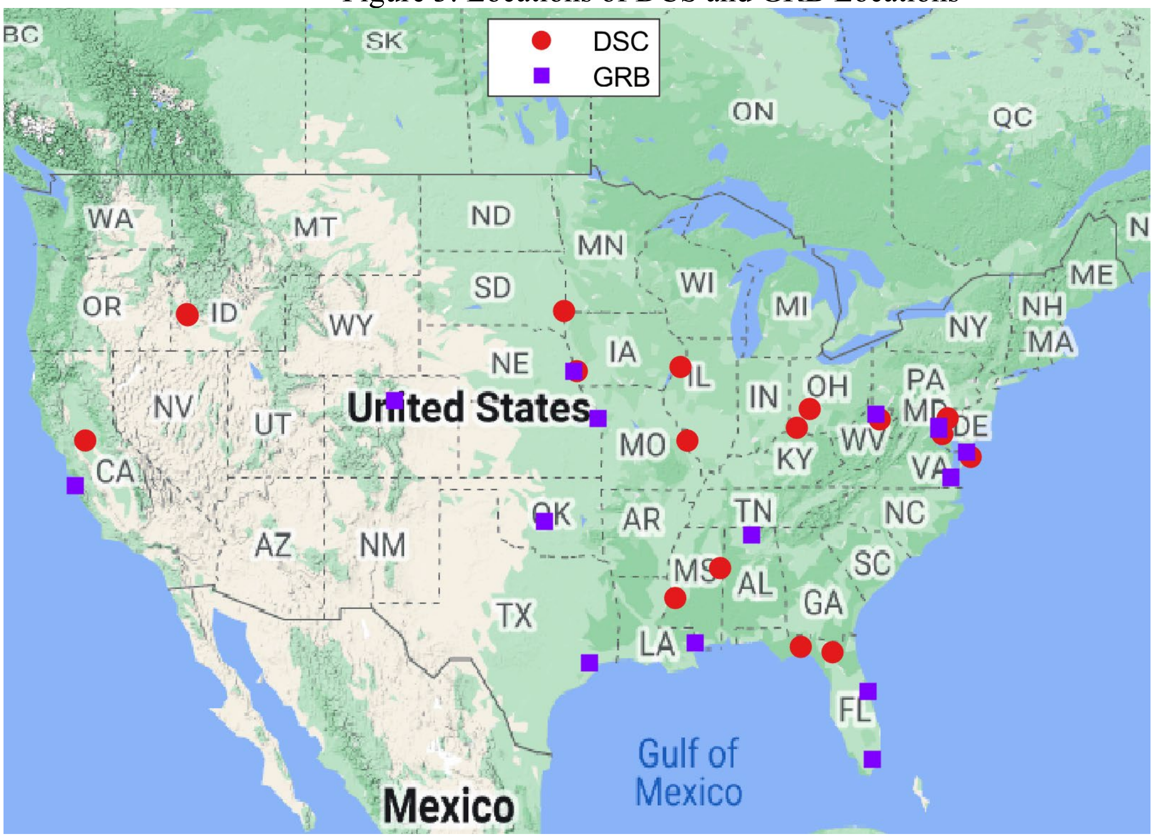
Hancock County	MS	30.3683	-89.6130	GRB
Honolulu (Hickam AFB)	HI	21.3216	-157.9580	GRB
Honolulu (NWS)	HI	21.3658	-157.9630	GRB
Houston	TX	29.5619	-95.0859	GRB
Huntsville	AL	34.6540	-86.6688	GRB
Kansas City	MO	39.2780	-94.6623	GRB
Miami	FL	25.7549	-80.3837	GRB
Monterey	CA	36.5918	-121.8540	GRB
Norfolk	VA	36.9409	-76.3002	GRB
Norman	OK	35.1812	-97.4390	GRB
Omaha (AF)	NE	41.1317	-95.9163	GRB
Omaha (USACE)	NE	41.3488	-95.9595	DCS
Rock Island	IL	41.5161	-90.5645	DCS HRIT
Sacramento	CA	38.5972	-121.5430	DCS
Sioux Falls	SD	43.7351	-96.6255	DCS HRIT
St. Louis	MO	38.5905	-90.2067	DCS HRIT
Suitland	MD	38.8522	-76.9367	DCS HRIT
Vicksburg	MS	32.3463	-90.8361	DCS HRIT
Wallops	VA	37.9465	-75.4621	DCS GRB HRIT
Hunt Valley	MD	39.4794	-76.6606	DCS
Tallahassee	FL	30.4101	-84.3046	DCS
Lake City	FL	30.1950	-82.6530	DCS

Table 2: Combination of Receivers

Receiver Types	Count
DCS	7
DCS/HRIT	7
GRB	20
GRB/HRIT	2
HRIT	5
DCS/GRB/HRIT	3

Figure 3 shows the locations of the DCS and GRB locations (in the contiguous United States).

Figure 3: Locations of DCS and GRB Locations



The following five locations have been identified to support an alternative distribution mechanism.[10]

Table 3: Alternative Distribution Mechanism Locations

City	State	Latitude	Longitude	System Type
Fairmont	WV	39.4336	-80.1928	DCS
Sioux Falls	SD	43.7351	-96.6255	DCS
Suitland	MD	38.8522	-76.9367	DCS
Wallops[11]	VA	37.9465	-75.4621	DCS

[10] SPRES Report at 87.

[11] DADDS is the DCS Administration and Data Distribution System (DADDS). Its function is to provide management of user and platform information, to distribute data to various transmission circuits (i.e. National Weather Service Telecommunications Gateway), to distribute data to Users via the Internet, and to allow Users to view platform information (such as channel and time slot allocations) and contact information (https://www.noaasis.noaa.gov/GOES/GOES_DCS/dadds.html).

Hunt Valley[12]	MD	39.4794	-76.6606	DCS

2.3 Allocation Table

An extract from the United States Table of Frequency Allocations for the 1670-1695 MHz frequency range is shown in Table 4.

Table 4: United States Table of Frequency Allocations[13]

Federal Table	Non-Federal Table	FCC Rule Part(s)
1670-1675 5.341 US211 US362	1670-1675 FIXED MOBILE except aeronautical mobile 5.341 US211 US362	Wireless Communications (27)
1675-1695 METEOROLOGICAL AIDS (radiosonde) METEOROLOGICAL-SATELLITE (space-to-Earth) US88 5.341 US211 US289		

Footnotes:

5.341 In the bands 1 400-1 727 MHz, 101-120 GHz and 197-220 GHz, passive research is being conducted by some countries in a programme for the search for intentional emissions of extraterrestrial origin.

US211 In the bands 1670-1690, 5000-5250 MHz and 10.7-11.7, 15.1365-15.35, 15.4-15.7, 22.5-22.55, 24-24.05, 31.0-31.3, 31.8-32.0, 40.5-42.5, 116-122.25, 123-130, 158.5-164, 167-168, 191.8-200, and 252-265 GHz, applicants for airborne or space station
assignments are urged to take all practicable steps to protect radio astronomy observations in the adjacent bands from harmful interference; however, US74 applies.

US362 The band 1670-1675 MHz is allocated to the meteorological-satellite service (space-to-Earth) on a primary basis for Federal use. Earth station use of this allocation is limited to Wallops Island, VA (37° 56' 44'' N, 75° 27' 37'' W), Fairbanks, AK (64° 58' 22'' N, 147° 30' 04'' W), and Greenbelt, MD (39° 00' 02'' N, 76° 50' 29'' W). Applicants for non-Federal stations within 100 kilometers of the Wallops Island or Fairbanks coordinates and within 65 kilometers of the Greenbelt coordinates shall notify NOAA in accordance with the procedures specified in 47 CFR 1.924.

US88 In the bands 1675-1695 MHz and 1695-1710 MHz, the following provisions shall apply:

[12] Hunt Valley (Microcom) is included to provide support in the case that the receivers at the four alternative distribution mechanism location experience failures with their receivers and require support.

[13] 47 C.F.R. § 2.106.

(a) Non-Federal use of the band 1695-1710 MHz by the fixed and mobile except aeronautical mobile services is restricted to stations in the Advanced Wireless Service (AWS). Base stations that enable AWS mobile and portable stations to operate in the
band 1695-1710 MHz must be successfully coordinated prior to operation as follows:
(i) all base stations within the 27 protection zones listed in paragraph (b) that enable mobiles to operate at a maximum e.i.r.p. of 20 dBm, and
(ii) nationwide for base stations that enable mobiles to operate with a maximum e.i.r.p. greater than 20 dBm, up to a maximum e.i.r.p. of 30 dBm, unless otherwise specified by Commission rule, order, or notice
(b) Forty-seven Federal earth stations located within the protection zones listed below operate on a co-equal, primary basis with AWS operations. All other Federal earth stations operate on a secondary basis . . .

US211 In the bands 1670-1690, 5000-5250 MHz and 10.7-11.7, 15.1365-15.35, 15.4-15.7, 22.5-22.55, 24-24.05, 31.0-31.3, 31.8-32.0, 40.5-42.5, 116-122.25, 123-130, 158.5-164, 167-168, 191.8-200, and 252-265 GHz, applicants for airborne or space station assignments are urged to take all practicable steps to protect radio astronomy observations in the adjacent bands from harmful interference; however, US74 applies.

US289 Earth exploration-satellite service applications, other than the meteorological-satellite service, may also be used in the bands 460-470 MHz and 1690-1695 MHz for space-to-Earth transmissions subject to not causing harmful interference to stations operating in accordance with the Table of Frequency Allocations.

3. ENGINEERING MODELS

3.1 Overview

The objective of this report as recommended by task three of the SPRES report is to to determine specific technical limits on commercial mobile operations to insure protection for the key DCS sites and certain GRB and HRIT sites. The output (of this report) is to identify regulatory constraints needed to protect mission-critical sites. This section describes the engineering models used to identify those constraints in this study.

Table 5 shows the similarities and differences in the simulation parameters between the SPRES report and this report. The simulation inputs for this analysis were chosen to provide an upper bound for the regulatory constraints. The differences between the two studies should be noted: principally, the SPRES study sought to understand the mechanisms affecting spectrum sharing potential for the band, characterize exclusion zones, and identify potential RFI mitigations. This study is meant to identify regulatory constraints needed to protect mission-critical sites, specifically by evaluating coordination zones (rather than the SPRES protection zones), hence some parameters (e.g., Base Station EIRP, Downtilt, and Azimuth pointing) are specified differently between the two studies.

Table 5: Simulation Input Comparison Table

Parameter	SPRES	This Report
Base Station EIRP	63dBm	65dBm
Base Station Downtilt	6-7° (Dense Urban) 4-6° (Urban) 3-5° (Suburban) 2-4° (Rural)	0°
Base Station Azimuth	3 Sectors (120°) (Uniformly Randomized Azimuth)	Azimuth Pointing at Federal Location
Base Station Height	25m (Dense Urban) 35m (Urban) 45m (Suburban) 55m (Rural)	30m
Base Station Location	Randomized Real[14] (Same) [Section 3.6]	
UE Locations	3 Per Base Station Sector (Same) [Section 3.6]	
Downlink Load (%)	100 (Same)	

[14] "The study assumed that 3 UEs per LTE sector were operating simultaneously. This is consistent with 5 MHz LTE network assumptions used in the CMSAC Working Group 3 analysis for their 1755–1850 MHz study. (See "Commerce Spectrum Management Advisory Committee (CSMAC) Working Group 3 (WG 3) Report on 1755-1850 MHz Satellite Control and Electronic Warfare," Table 4.2.1-9, page 27.)"

Propagation Model[15]	Advanced Propagation Model (APM)	Irregular Terrain Model (ITM) [See Section 3.3]
Clutter	ITU-R P.2108/Measurements	ITU-R P.2108 [See Section 3.4]
Receiver Antenna Gain	-10dBi (Same)	
DCS/GRB Threshold	See Table 6 (Same) [See Section 3.2]	
FDR	See Table 7 (Same) [See Section 3.5]	
Monte Carlo Iterations/Percentile	1,000 Iterations (Same) 95th Percentile (Same)	

3.2 SPRES Link Budget

Equation (1) shows the link budget used in the SPRES report (and this report):

$$P_{R_{dBm}} = P_{Tx} + G_{Tx} - L_{Terrain} - L_{Clutter} + G_{Rx} - FDR(\Delta f)_{dB} \qquad (1)$$

where:

$P_{R_{dBm}}$: received power at federal receiver (dBm);

P_{Tx}: Power of the interfering transmitter (dBm);

G_{Tx}: Antenna gain of the interfering transmitter in the direction of the federal system (dBi)

$L_{Terrain}$: is the path loss from a terrain propagation model (dB);

$L_{Clutter}$: is the clutter loss (dB);

G_{Rx}: antenna gain of the federal system (at the horizon, in the direction of the non-federal system) [-10dBi];

$FDR(\Delta f)_{dB}$: is the frequency dependent rejection[16] between the non-federal system and the federal system, in dB.

To take into consideration aggregate interference, power received (in dBm) is convert to Watts [Equation (2)], summed [Equation (3)], and convert back to dBm [Equation (4)].

$$P_{R_{watts}} = 10^{\left(\frac{P_{R_{dBm}} - 30}{10}\right)} \qquad (2)$$

[15] SPRES Report at 244 ("*Project 7 addresses RFI at an aggregate level, thus, distances where the models* [APM/ITM] *deviate present a minimal impact to the analysis.*").

[16] https://www.itu.int/rec/R-REC-SM.337/en.

$$P_{R_{watts_{aggregate}}} = \sum_{k=1}^{n} P_{R_{watts_k}} \quad (3)$$

$$P_{R_{dBm_{aggregate}}} = log_{10}\left(P_{R_{watts_{aggregate}}}\right) + 30 \quad (4)$$

The aggregate power received (at the federal system) is then compared with the harmful interference threshold. Table 6 shows the harmful interference threshold used in the SPRES report.

$$P_{R_{dBm_{aggregate}}} < Threshold_{Aggregate} \quad (5)$$

Table 6: Harmful Interference Thresholds

Parameter	DCS	GRB
Signal Bandwidth [MHz]	0.4	11.0
Receiver Noise Temperature [K]	28.0	22.3
Receiver Noise Temperate [dB-K]	14.5	13.5
Noise Floor [dBm]	-128.1	-114.7
I/N [dB]	-6.0	-6.0
Harmful Inference Threshold (in GOES Bandwidth) [dBm]	**-134.11dBm**	**-120.70dBm**

3.3 Basic Transmission Loss

The Irregular Terrain Model (ITM) point-to-point mode was used to calculate the propagation loss using a 1 arc-second terrain database.[17] For the aggregate interference calculation, the ITM reliability was uniformly randomized from 1%-99%, 1,000 Monte Carlo iterations were randomized, and the 95th percentile was calculated, like the SPRES report.

In ITM, *Reliability* represents the time and location variability. When ITM point-to-point mode is used, where specific latitudes and longitudes are used as inputs, there is no location variability.[18]

[17] *See A Guide to the Use of the ITS Irregular Terrain Model in the Area Prediction Mode* (1982), https://www.ntia.doc.gov/sites/default/files/publications/ntia_82-100_20121129145031_555510_0.pdf (NTIA Report 82-100).

[18] *See* "The ITS Irregular Terrain Model, version 1.2.2, The Algorithm." https://its.ntia.gov/media/50676/itm_alg.pdf

"The second form of output provides the two- or three-dimensional cumulative distribution of attenuation in which time, location, and situation variability are all accounted for. When the point-to-point mode is used on particular, well-defined

For a given path (and especially distance) in ITM, the convention is that the strongest signals (or the lowest basic transmission losses) correspond to the lower quantiles of the cumulative distribution produced by the model. What remains is to decide how to organize the time, location, and situation variability strata into reliability (i.e., corresponding to the notion of adequate service) and confidence. Because, for base station transmitters and a given receiver, each link will involve fixed end points or terminals, location variability can be neglected. For an analysis where all links converge to a single receiver, then situation variability (at the receiver) can be neglected. Thus, the time variability is reflected as the reliability, while leaving the location and situation variabilities at the medians (where the situation variability is a measure of confidence).

To form the cumulative distribution function of the aggregate of interfering signals from many base stations' signals, we make the commonly used assumption that the time variability considered on each individual link is independent of the time variabilities for all the other links. Another limit, which could be considered would be perfect correlation amongst all, or groups (in terms of geographic areas), the individual links' time variabilities, which would over predict the aggregate interfering signal strength at a given quantile. To obtain the aggregate signal strength cumulative distribution function, we then simply convolve the individual paths' probability density functions by the numerical procedure of randomly summing the individual signals using Monte Carlo techniques.

Additional ITM parameters include:

- Polarization: Vertical
- Dielectric constant: 25
- Conductivity: 0.02 S/m
- Confidence: 50%
- Mode of Variability: 13 (broadcast point-to-point)
- Surface Refractivity: value varies by location and was derived by the methods and associated data files in Recommendation ITU-R P.452.[19]
- Climate: value varies by location and was derived by the methods and associated data files in Recommendation ITU-R P.617.[20]
- Frequency: 1675 MHz

Selected text from NTIA Report 82-100 is provided to describe how ITM treats the statistics of radio propagation and how it relates to the input parameters of Reliability and Confidence.

> "*We come now to a discussion of how the ITS irregular terrain model treats the* ***statistics of radio propagation****. As we have mentioned before it seems undeniable that received signal levels are subject to a wide variety of random variations and that proper engineering must*

paths with definitely fixed terminals, there is no location variability, and one must use a two-dimensional description of cumulative distributions."

[19] Recommendation ITU-R P.452-16, *Prediction procedure for the evaluation of interference between stations on the surface of the Earth at frequencies above about 0.1 GHz* (2015), https://www.itu.int/rec/R-REC-P.452/en.

[20] Recommendation ITU-R P.617-4 *Propagation prediction techniques and data required for the design of trans-horizon radio-relay systems* (2017), https://www.itu.int/rec/R-REC-P.617/en.

take these variations into account. Unfortunately, the problem is considerably more complicated than problems of simple random variables one encounters in elementary probability theory."[21]

"*We turn now to a general discussion of the physical phenomenology involved. First, we should note that there is a very important part of the variability that we do not wish to include. This is the short-term or small displacement variability that is usually attributed to multipath propagation. Although it is probably the most dramatic manifestation of how signal levels vary, we exclude it for several reasons.*"[22]

Time Variability

"*If we set out to measure statistics of local medians, the first step that occurs to us is to choose a particular fixed link and record measurements of hourly median received signal levels for 2 or 3 years. The resulting statistics will describe what we call the* ***time variability*** *on that one path. We could characterize these observations in terms of their mean and standard deviation; but, both because the distribution is asymmetric and not easily classified as belonging to any of the standard probability distributions, and because the practicing engineer seems to feel more comfortable with the alternative, we prefer to use the quantiles of the observations. These are the values not exceeded for given fractions of the time and are equivalent to a full description of the cumulative distribution function as described in the elementary texts on statistics.*"[23]

"In considering time variability, it is important to note that we are concerned only with long-term variability, the changes in signal level that may occur during an entire year."[24]

Location Variability

"*Suppose, now, that we make a series of these long-term measurements, choosing sample paths from a single situation. In other words, we keep all system parameters constant, we restrict ourselves to a single area of the earth and keep environmental parameters as nearly constant as is reasonable, and we choose path terminals in a single, consistent way. We still find that the long-term time statistics change from path to path and the variation in these statistics we call* ***location variability****. Of course, if the situation we are concerned with has to do with a single, well-defined link, then it is improper to speak of different paths and hence improper to speak of location variability. But in the broadcast or mobile services, it is natural to consider such changes. The most obvious reason for the observed variability is the accompanying change in the profile of the terrain lying between the two terminals; although the outward—statistical, so to speak—aspects of the terrain may remain constant, the actual*

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[21] NTIA Report 82-100 at 26.

[22] *Id.*at 28.

[23] *Id*. at 29.

[24] *Id*. at 26.

individual profiles, together with other, less obvious, environmental changes, will induce large changes in observed signal level statistics."[25]

Situation Variability

"*Finally, we must ask what effect there is when one changes from situation to situation. It should be no surprise to be told that the statistics we have so painfully collected following the outline above have changed. If we use like appearing situations—that is, if we change operations from one area to another very similar area or if we merely change the sampling scheme somewhat—then the observed changes in the location variability we call* ***situation variability****. In other contexts this last variability is sometimes referred to as "prediction error," for we may have used measurements from the first situation to "predict" the observations from the second. We prefer here to treat the subject as a manifestation of random elements in nature, and hence as something to be described.*"[26]

Reliability and Confidence

"To continue our discussions, we find it convenient here to introduce the term ***reliability****. This is a quantile of that part of the variability which enters into the notion of 'adequate service.' For the individual receiver of a broadcast station, reliability is concerned with a fraction of time. For a broadcaster, however, reliability must be expressed as a twofold quantile involving time and location variability separately. For the remaining variability—always at a higher level in the hierarchy—we use the term* ***confidence****; and we mean this term in the sense that if one makes a large number of engineering decisions based on calculations that use the same confidence level, then, irrespective of what systems or even what types of systems are involved, that same fraction of the decisions should be correct—and, of course, the remainder should be incorrect. Reliability is a measure of the variability that a radio system will observe during the course of its deployment. Confidence will be measurable only in the aggregate of a large number of radio systems. Clearly, differentiation between the two will depend on the point of view one takes. To a broadcaster, confidence will be a measure of the situation variability; to an individual receiver of a broadcast station, it will be a measure of a combined situation and location variability. But the spectrum planner of the broadcast service will not speak of confidence at all; from that point of view all of the variability is observable and is part of the system.*"[27]

3.4 Clutter Loss

For handset/user equipment, the median clutter loss, $L_{Clutter}$, was calculated using Recommendation ITU-R P.2108, section 3.2 (Terrestrial Terminal Within the Clutter). *"A statistical model which can*

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[25] *Id*. at 29-30.

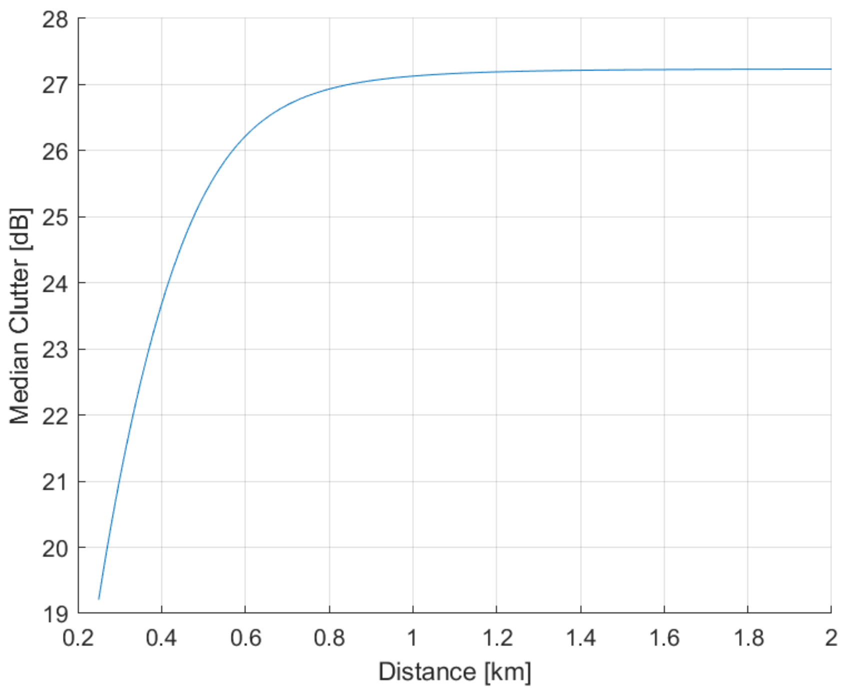
[26] *Id*. at 30.

[27] *Id*. at 36.

be applied for modelling the clutter loss distribution for urban and suburban environments. This correction may be applied to both ends of the path."[28]

Figure 4 shows the median clutter loss, for 1675 MHz, calculated by P.2108. Note that the minimum path length is 0.25 km the clutter correction to be applied at for one end of the path. The clutter loss must not exceed a maximum value calculated for a distance of 2km.

Figure 4: Median Clutter Loss for 1675MHz



Note, in this analysis, base stations were assumed to be above the clutter. A clutter loss value was assumed to be 0dB for base stations.

3.5 Frequency Dependent Rejection

Frequency dependent rejection (FDR) is a measure/calculation of the rejection produced by the receiver intermediate frequency (IF) selectivity curve on an unwanted transmitter emission spectra. A detailed description of how to compute FDR can be found in Recommendation ITU-R SM.337.[29]

The SPRES report modeled the commercial system in the following way:

[28] https://www.itu.int/rec/R-REC-P.2108/en.

[29] Recommendation ITU-R SM.337-6, *Frequency and Distance Separations* (2008), https://www.itu.int/rec/R-REC-SM.337/en.

"For 1675–1680, this means the 5 MHz channel bandwidth includes 4.5 MHz transmission bandwidth and a 250 kHz guard band at each end of the signal, so that the necessary bandwidth (NB) of the LTE signal extends from1675.25–1679.75 MHz. If the LTE-allocated signal spectrum extended from 1670–1680 MHz, the NB is 9 MHz and the guard band would be 500 kHz wide on each side of the band."

The FDR measurements from SPRES Project 6 were derived using a 5 MHz signal, and not a 10 MHz signal. The SPRES report conducted analysis assuming a 5 MHz signal. If a 5G 10 MHz signal is assumed (15 kHz subcarrier spacing (SCS)), then the guard band would be 320 kHz on each side of the band. The occupied bandwidth would be 9.36 MHz (a maximum of 52 potential resource blocks, each 180 kHz wide).

The FDR values used in the SPRES report were used in this report. Table 7 shows those FDR values. Future work will need to further refine the FDR values (see Section 3.5).

Table 7: FDR Values

City	State	System	FDR [dB]
Anchorage	AK	GRB	28.65
Anchorage	AK	GRB	28.65
Boise	ID	DCS	10.14
Boise	ID	DCS	3.60
Boulder	CO	GRB	23.71
Brevard County	FL	GRB	16.55
Cincinnati	OH	DCS	7.24
College Park	MD	GRB	28.65
Columbus Lake	MS	DCS	2.06
Fairmont	WV	GRB	8.96
Fairmont	WV	DCS	3.51
Hancock County	MS	GRB	16.55
Honolulu	HI	GRB	26.18
Honolulu	HI	GRB	23.38
Houston	TX	GRB	16.55
Huntsville	AL	GRB	29.22
Kansas City	MO	GRB	23.71
Miami	FL	GRB	27.28
Monterey	CA	GRB	25.54
Norfolk	VA	GRB	16.55
Norman	OK	GRB	25.16
Omaha	NE	GRB	23.71
Omaha	NE	DCS	3.60
Rock Island	IL	DCS	1.53
Sacramento	CA	DCS	3.60
Sioux Falls	SD	DCS	3.51

St. Louis	MO	DCS	2.76
Suitland	MD	GRB	26.23
Suitland	MD	DCS	3.51
Vicksburg	MS	DCS	2.76
Wallops	VA	GRB	8.96
Wallops	VA	DCS	3.51
Hunt Valley	MD	DCS	3.00 (Placeholder, Not Measured by SPRES)
Tallahassee	FL	DCS	3.00 (Placeholder, Not Measured by SPRES)
Lake City	FL	DCS	3.00 (Placeholder, Not Measured by SPRES)

3.6 Commercial Deployment

Like the SPRES report, the base station tower locations (≈68) used were based on the Commerce Spectrum Management Advisory Committee (CSMAC) Working Group 5 "Randomized Real". The following sections provide details about the commercial deployment was modeled.

A SPRES sensitivity analysis showed that the precise locations of the base stations were not a factor of the coordination zone distance. The SPRES report concluded that the accurate representation of the density of the base stations was a factor in determining the coordination zone distance.

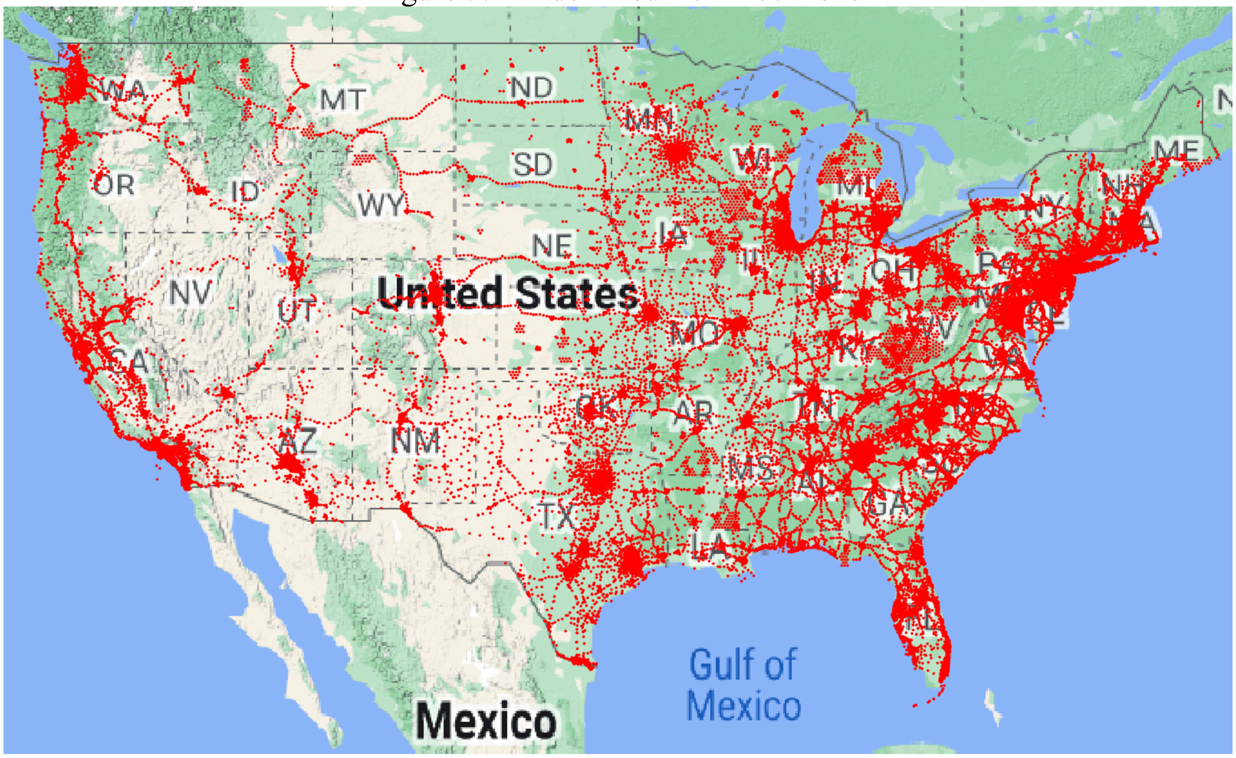
3.6.1 Location

"The randomized real network laydown consisted of a carrier's actual nationwide base station locations that were shifted random distances up to one mile in random directions."[30]

The "Randomized Real" is a set of latitudes and longitudes. Figure 5 shows the locations of the "Randomized Real".

[30] https://ntia.gov/files/ntia/publications/wg5_final_report_posted_03042014.pdf.

Figure 5: Randomized Real Locations



For user equipment (UE), like the SPRES report, "*The study assumed that 3 UEs per LTE sector were operating simultaneously. This is consistent with 5 MHz LTE network assumptions used in the CMSAC Working Group 3 analysis for their 1755–1850 MHz study. (See "Commerce Spectrum Management Advisory Committee (CSMAC) Working Group 3 (WG 3) Report on 1755-1850 MHz Satellite Control and Electronic Warfare," Table 4.2.1-9, page 27.).*"

The SPRES report classified each cell as Dense Urban, Urban, Suburban, or Rural. Based on the assumed footprint of each cell, the UE locations were uniformly randomized within each sector to a distance dictated by the classification of the cell. The SPRES report used the following radius for each location morphology:

- Dense urban: 0.5 km
- Urban: 1 km
- Suburban: 2 km

In this report, the UE locations were uniformly randomized within each base station sector.

In the same way as the SPRES report, the CSMAC UE EIRP cumulative distribution function (CDF) curve[31] was used to simulate the UE EIRP.

[31] https://www.ntia.doc.gov/files/ntia/Working_Group_3_Final.pdf.

Table 8 provides a breakdown of the number of Randomized Real base stations for the Top 30 PEAs.

Table 8: Number of Randomized Real Base Stations in the Top 30 PEAs

PEA	PEA Number	Population	Number of Randomized Real Base Stations
New York, NY	1	25,237,061	6,940
Los Angeles, CA	2	19,410,169	5,193
Chicago, IL	3	9,366,713	2,292
San Francisco, CA	4	9,027,937	2,637
Baltimore, MD-Washington, DC	5	7,842,134	2,236
Philadelphia, PA	6	7,587,252	2,428
Boston, MA	7	6,776,035	1,888
Dallas, TX	8	6,452,472	1,429
Miami, FL	9	6,291,880	1,070
Houston, TX	10	5,891,999	1,247
Atlanta, GA	11	5,435,312	1,480
Detroit, MI	12	5,137,479	1,028
Orlando, FL	13	4,562,642	757
Cleveland, OH	14	4,096,678	647
Phoenix, AZ	15	3,817,117	942
Seattle, WA	16	3,792,218	2,182
Minneapolis-St. Paul, MN	17	3,390,091	803
San Diego, CA	18	3,095,313	912
Portland, OR	19	3,022,643	738
Denver, CO	20	2,789,669	640
Tampa, FL	21	2,783,243	496
Sacramento, CA	22	2,722,415	567
Pittsburgh, PA	23	2,399,667	384
Saint Louis, MO	24	2,396,938	455
Cincinnati, OH	25	2,196,428	355
Las Vegas, NV	26	2,151,455	524
Salt Lake City, UT	27	2,142,152	569
San Antonio, TX	28	1,999,689	312
Jacksonville, FL	29	1,918,264	444
Kansas City, MO	30	1,810,075	403

3.6.2 Antenna Height

The CSMAC working group concluded that when there is 0 dB clutter for base stations, *"Variations in base station antenna heights above ground level had small effects on the predicted required separation distances."* [32]

A sensitivity analysis (for this band) yielded similar results, assuming that base stations are above the terrain clutter. Because the variation of base station antenna height has a small effect on separation distances (to protect the federal receivers), the antenna height for all base stations was set to 30 meters.

3.6.3 Spectrum

The SPRES report modeled the commercial system in the following way:

> *"For 1675–1680, this means the 5 MHz channel bandwidth includes 4.5 MHz transmission bandwidth and a 250 kHz guard band at each end of the signal, so that the necessary bandwidth (NB) of the LTE signal extends from1675.25–1679.75 MHz. If the LTE-allocated signal spectrum extended from 1670–1680 MHz, the NB is 9 MHz and the guard band would be 500 kHz wide on each side of the band."*[33]

If a 5G 10 MHz signal is assumed (15 kHz SCS), then the guard band would be 320 kHz on each side of the band. The occupied bandwidth would be 9.36 MHz (a maximum of 52 potential resource blocks, each 180 kHz wide).

[32] https://ntia.gov/files/ntia/publications/wg5_final_report_posted_03042014.pdf.

[33] SPRES Report at 65.

4. COORDINATION ZONE ANALYSIS

4.1 Overview

This section considers the use of coordination zones as a sharing mechanism. The purpose of coordination is to avoid harmful interference to protected federal operations and missions while expediting access to and maximizing commercial use of the spectrum. The coordination considered each individual site and sector within a market or deployment area. Note that a population within a coordination zone is not excluded from the terrestrial wireless service. A coordination zone is an area in which wireless terrestrial commercial operators would need to coordinate with NTIA before a base station can be deployed within the coordination zone. If harmful interference were to occur, non-federal user information can then be used to identify and prioritize possible sources of harmful interference.

The population impact of the coordination zones is determined from the number of federal systems that remain in, or adjacent, band. The population impact is based on the 2010 U.S. Census population data.[34,35] The population availability for each Partial Economic Area (PEA)[36] was calculated based on the census tract population availability.

The results are provided for the two possible sharing scenarios:

- Current/Status Quo: [Table 1 Locations]
- Alternative Distribution Mechanism: [Table 3 Locations]

4.2 Coordination Zone Methodology

In this section, the coordination zone methodology was illustrated by providing an example of a coordination zone calculation. Similar coordination methodologies are being used in 1670-1675 MHz, 1695-1710 MHz and 1755-1780 MHz (AWS-3),[37] 3.45-3.550 GHz (AMBIT),[38] 3.55-3.65 GHz (CBRS),[39] 3.7-3.98 GHz (C-Band),[40] 5.85-5.925 GHz (DSRC/C-V2X),[41] 37 GHz,[42] and 70/80/90GHz.

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[34] https://www.census.gov/geographies/mapping-files/time-series/geo/tiger-line-file.html.

[35] The population availability analysis was calculated on a census tract availability. If the census tract centroid was within a coordination zone, the entire population of the census tract was considered to be unavailable.

[36] https://www.fcc.gov/oet/maps/areas.

[37] https://docs.fcc.gov/public/attachments/DA-14-1023A1.pdf.

[38] https://ntia.gov/sites/default/files/publications/da_21-645a1-06022021_0.pdf.

[39] https://docs.fcc.gov/public/attachments/FCC-16-55A1.pdf

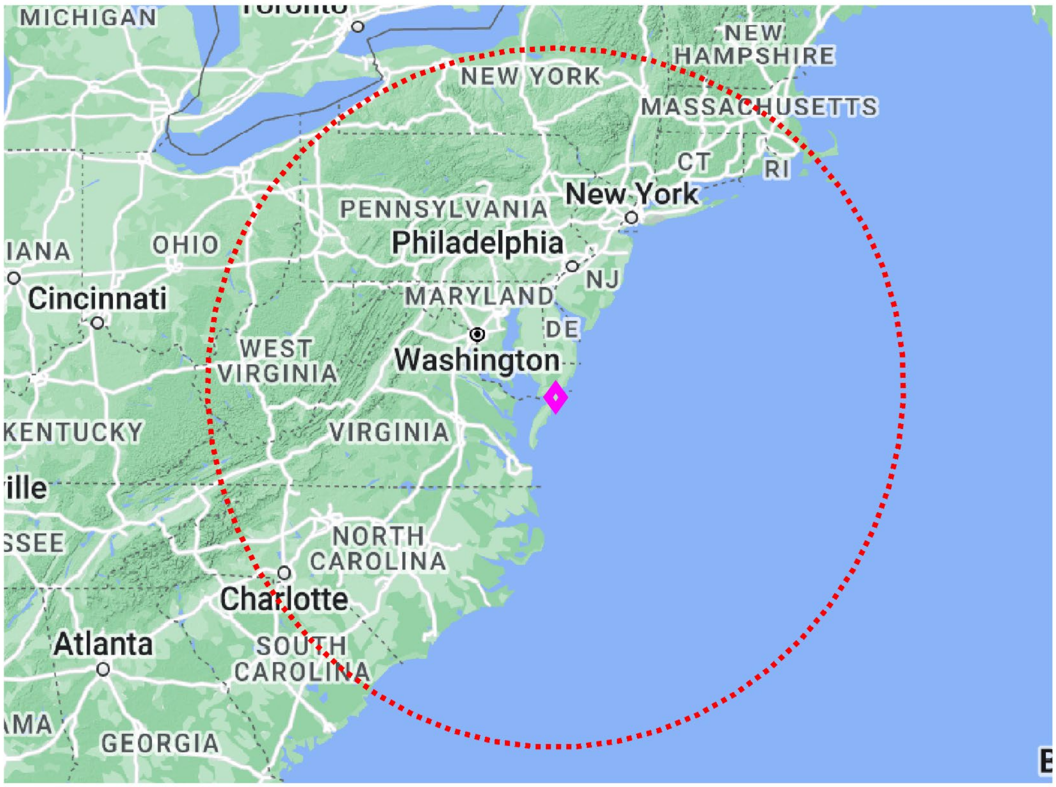
[40] https://docs.fcc.gov/public/attachments/FCC-20-22A1.pdf

[41] https://docs.fcc.gov/public/attachments/FCC-20-164A1.pdf

[42] https://docs.fcc.gov/public/attachments/FCC-24-16A1.pdf

First, the location of the federal system (latitude/longitude) is used to calculate the simulation area. Figure 6 shows an example simulation area, where the federal system is designated with a maroon diamond and the simulation area is designated as a red dashed circle. [43]

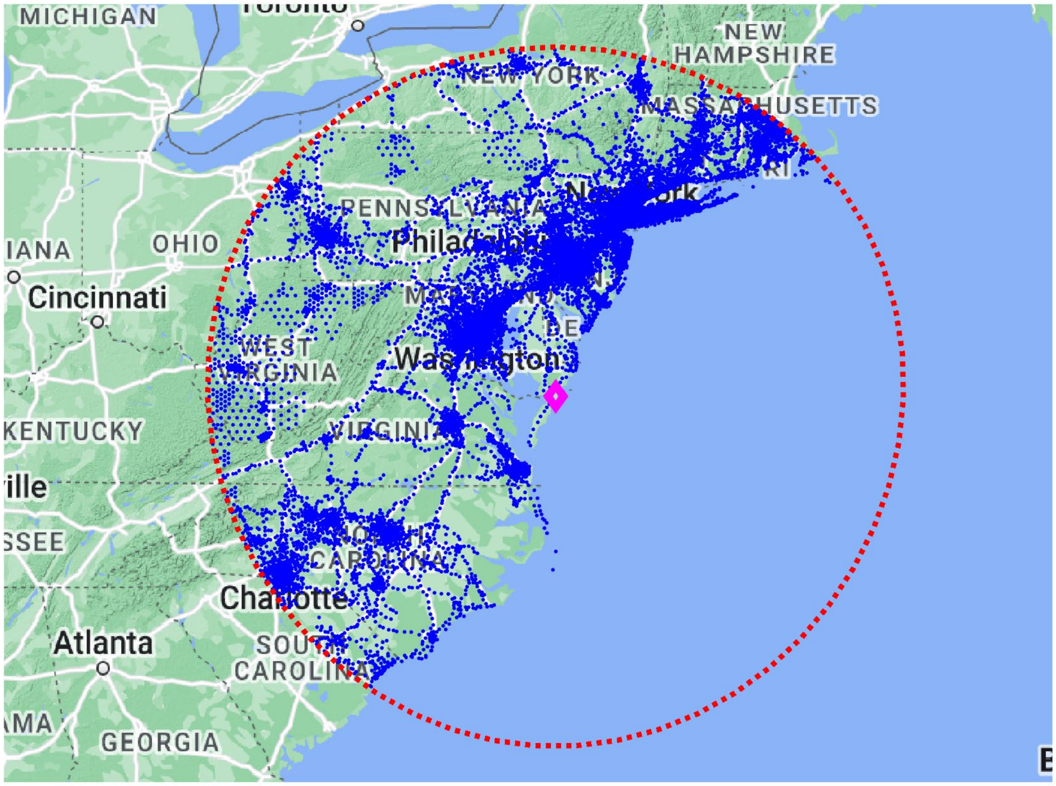
Figure 6: Example Simulation Area



Then base stations/UEs are deployed within the simulation area. Figure 7 shows an example base station deployment, where the base stations are designated with blue dots, the federal system is designated with a maroon diamond, and the simulation area is designated as a red dashed circle. See Section 3.6 for the Commercial Deployment parameters.

[43] Note that after the "initial" analysis, an algorithm checks to see if the simulation area is sufficiently large enough, specifically, determining if the calculated turn off list increases if the simulation area is increased.

Figure 7: Example Base Station Deployment within the Simulation Area

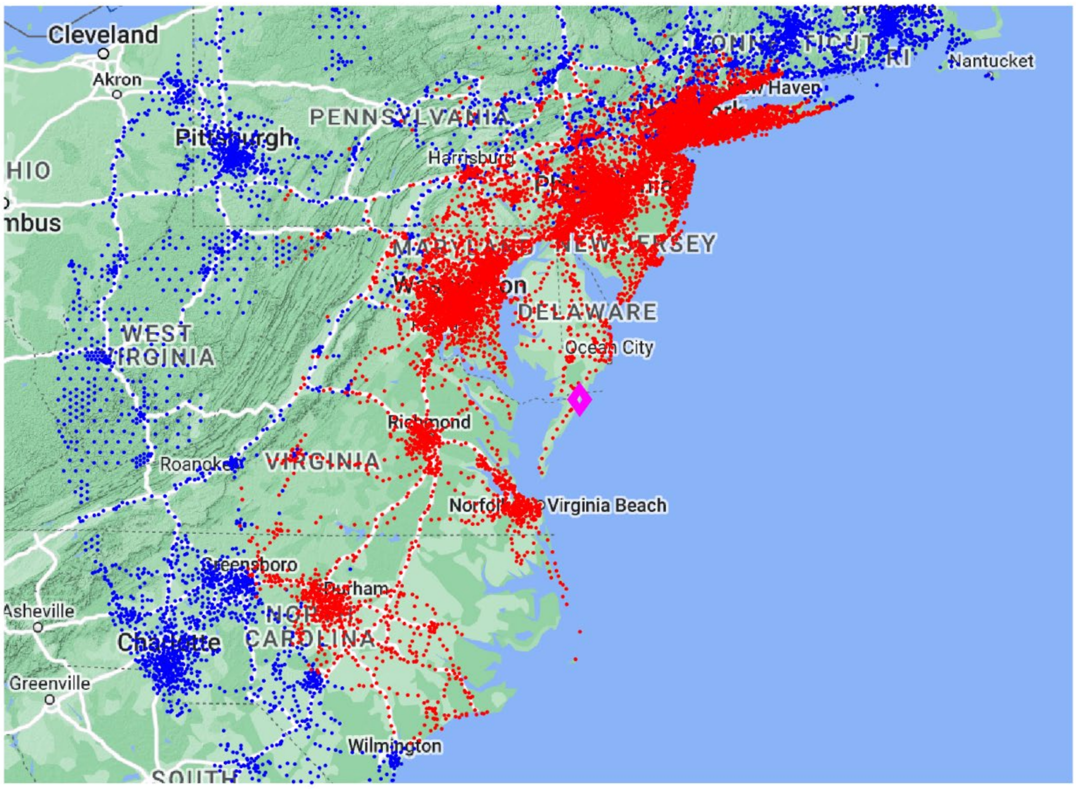


The path loss is calculated between the federal system operational location and the base stations/UE. Section 3.3 describes the basic transmission loss calculation using ITM. If applicable, clutter loss is calculated. See Section 3.4 for the clutter loss calculation.

The aggregate interference is calculated (see Section 3.2), where the ITM Reliability (time variance) is uniformly randomized for 1,000 Monte Carlo iterations. The aggregate interference is then calculated for each Monte Carlo iteration. The turn-off algorithm sorts the interferers based on their contribution to the federal system and attempts to minimize the number of base stations/UEs that would have to be turned off so that the 95th percentile of the aggregate interference is less than the harmful interference threshold.

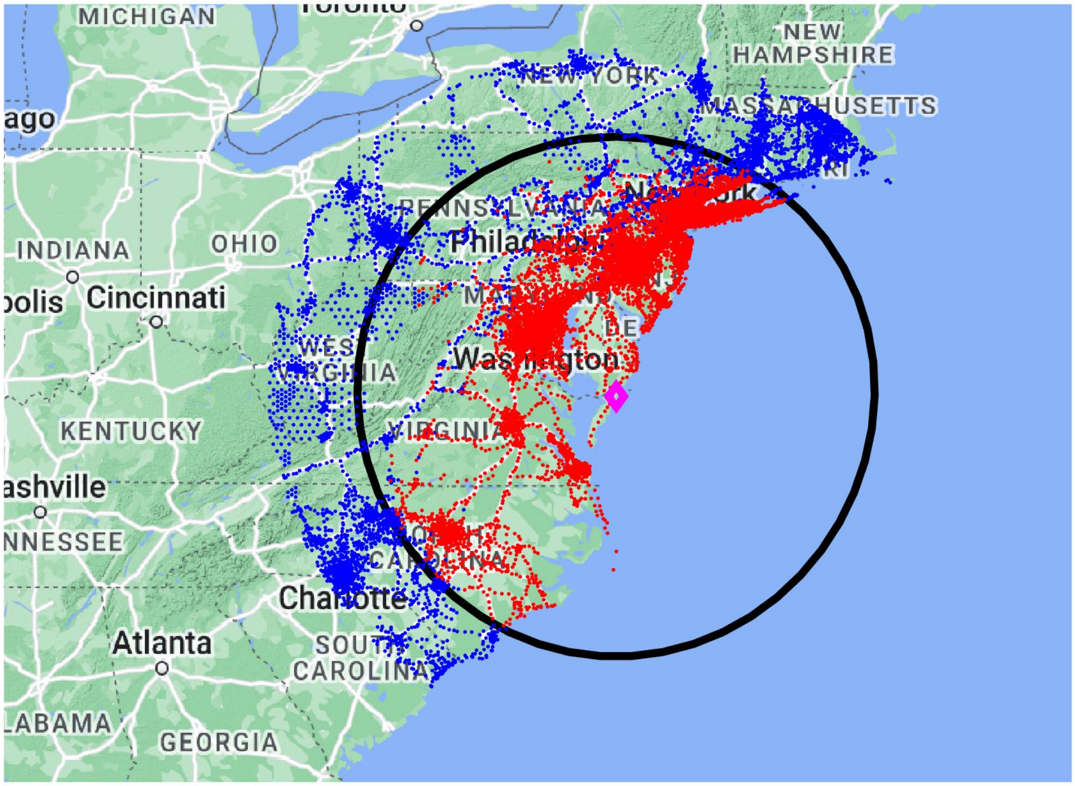
Figure 8 shows an example of the base station turn-off. The red dots are base stations that are turned-off, the blue dots are base stations that are allowed to transmit, and the federal system is designated with a maroon diamond.

Figure 8: Example Base Station Turn-Off



The coordination zone is created from two composite polygons. First, a 1-kilometer circle is created around the receiver. Second, a circle is created around all the base station locations that the calculation determined that needed to be turned off. Figure 9 shows an example coordination zone, where the black circle encompasses all the (red) base station locations from the calculation. Note that there are base stations within the coordination zone that are operating.

Figure 9: Example Coordination Zone



4.3 Population Impact Methodology

This section describes the population impact of the coordination zones. The population inside the coordination zones was calculated based on the 2010 U.S. Census population data.[44] The population availability for each PEA[45] is calculated based on the census tract population availability.[46]

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[44] https://www.census.gov/geographies/mapping-files/time-series/geo/tiger-line-file.html.

[45] https://www.fcc.gov/oet/maps/areas.

[46] https://docs.fcc.gov/public/attachments/FCC-19-43A1_Rcd.pdf

"We propose to license the 1675-1680MHz band on a partial economic area (PEA) basis, which may enable a wide range of bidders to participate in the auction and select the focused geographic areas that are most suited to their planned operations using the 1675-1680 MHz spectrum. We ask commenters to discuss and quantify the economic, technical, and other public interest considerations of licensing on a PEA basis. We also ask commenters to address the costs and benefits of their recommended licensing approach, given that the band will be shared with federal users. For example, to what extent would incumbent federal operations extend across proposed license boundaries and, if they do, is this a relevant factor to consider in adopting such a licensing scheme?"

4.3.1 Census Tract Population Impact Methodology

First, it is determined which census tract[47] centroids[48] is inside the coordination zone.

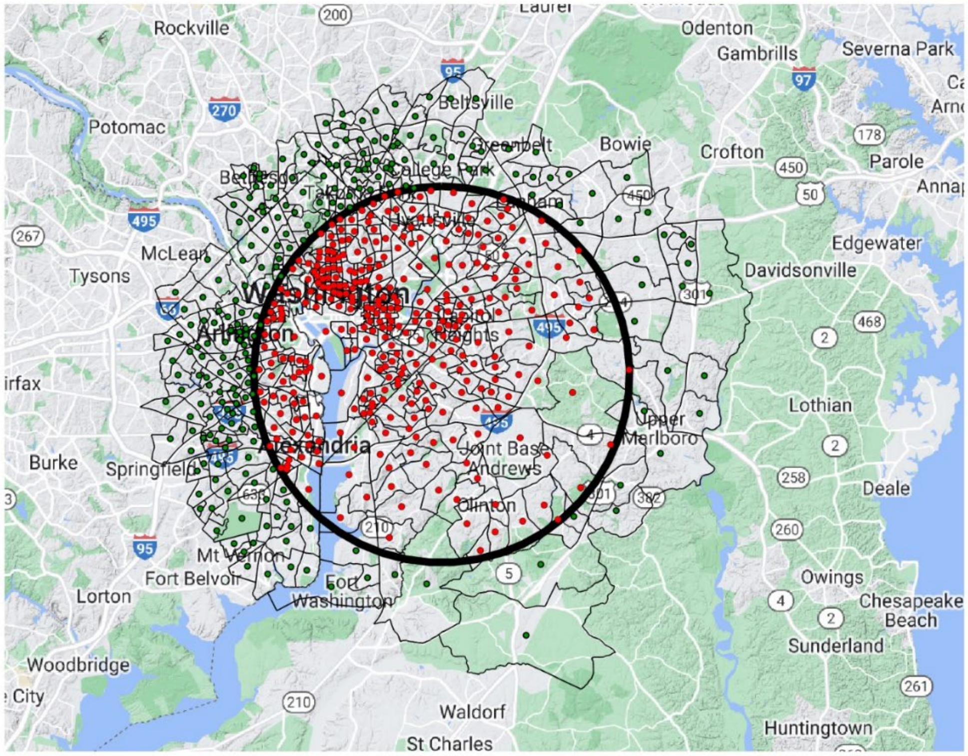
If a partial census tract and the census tract centroid are within the coordination zone, the entire population of the census tract is considered unavailable. If a partial census tract is within the coordination zone, but the census tract centroid is out of the coordination zone, the entire population of the census tract is considered available. The population impact is not considered worst-case, where if any part of the census tract polygon was inside the coordination zone the entire population of the census tract would be considered unavailable.

Figure 10 shows the coordination zone (black circle) around the Suitland, MD DCS. The census tracts are shown. The census tract centroids inside the coordination zone are shown as red dots and those outside the coordination zone are shown as green dots.

[47] Census tracts are statistical subdivisions of a county that aim to have roughly 4,000 inhabitants. Tract boundaries are usually visible features, such as roads or rivers, but they can also follow the boundaries of national parks, military reservations, or American Indian reservations. Tracts are designed to be fairly homogeneous with respect to demographic and economic conditions when they are first established. When a census tract experiences growth and the internal population grows beyond 8,000 persons, the tract is split up.

[48] A centroid is a point located in the geographic center of the polygon it represents and is provided in the Census Tract information.

Figure 10: Census Tract Example



4.3.2 Partial Economic Areas Population Impact Methodology

After it is determined which census tracts centroids are within a coordination zone, the population impact/availability of a PEA is calculated.[49]

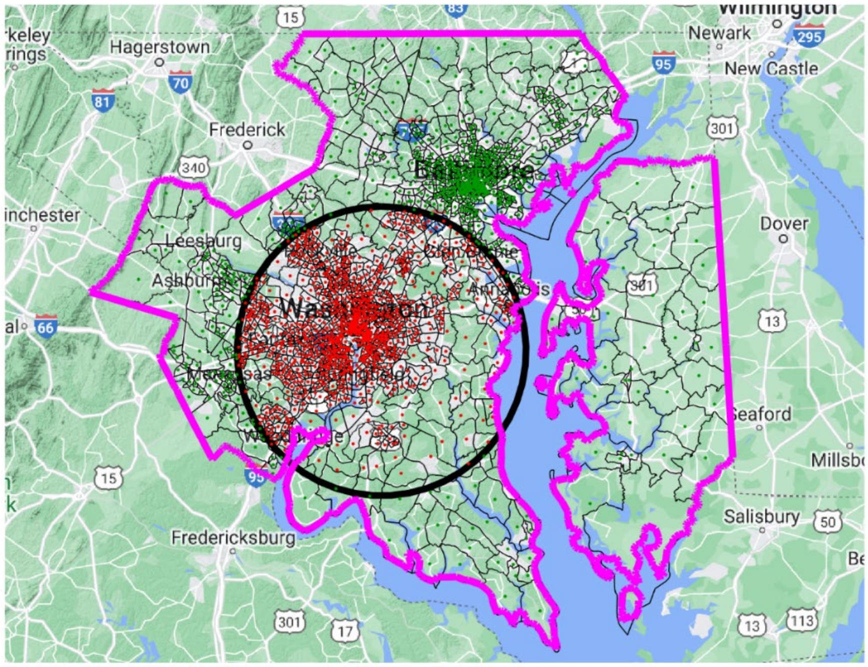
For each PEA, the census tract centroids (within a PEA) are determined to be inside or outside the coordination zone. If a partial census tract and the census tract centroid are within the coordination zone, the entire population of the census tract is considered unavailable. If a partial census tract is within the coordination zone, but the census tract centroid is out of the coordination zone, the entire population of the census tract is considered available. The population impact is not considered worst-case, where if any part of the census tract polygon was inside the coordination zone the entire population of the census tract would be considered unavailable.

[49] https://docs.fcc.gov/public/attachments/FCC-19-43A1_Rcd.pdf

"We propose to license the 1675-1680MHz band on a partial economic area (PEA) basis, which may enable a wide range of bidders to participate in the auction and select the focused geographic areas that are most suited to their planned operations using the 1675-1680 MHz spectrum. We ask commenters to discuss and quantify the economic, technical, and other public interest considerations of licensing on a PEA basis. We also ask commenters to address the costs and benefits of their recommended licensing approach, given that the band will be shared with federal users. For example, to what extent would incumbent federal operations extend across proposed license boundaries and, if they do, is this a relevant factor to consider in adopting such a licensing scheme?"

Figure 11 shows the Baltimore/Washington DC PEA, outlined in pink. The Suitland, MD DCS coordination zone is a shown as a black circle. The census tracts are shown. The census tract centroid inside the coordination zone is shown as red dots and those outside the coordination zone are shown as green dots.

Figure 11: PEA Example



4.4 Discussion on Coordination

It is assumed that when two (or more) coordination zones overlap, commercial deployment within the overlapping area of the two (or more) coordination zones becomes difficult. Overlapping areas of coordination zones (at different locations) is considered a limited deployment coordination zone.

Figure 12 shows the coordination zones for *Status Quo* sharing scenario, where the red areas represent overlapping areas of coordination zones, or the limited deployment coordination zone, and the blue areas represent non-overlapping coordination zones. Figure 13 shows the DCS coordination zones for the *Alternative Distribution Mechanism* (ADM) sharing scenario. Since the ADM was not studied for GRB locations, Figure 14 shows the GRB coordination zones. Figure 15 shows the DCS ADM and GRB coordination zones.

Figure 12: *Status Quo* Coordination Zones (30+ Locations)

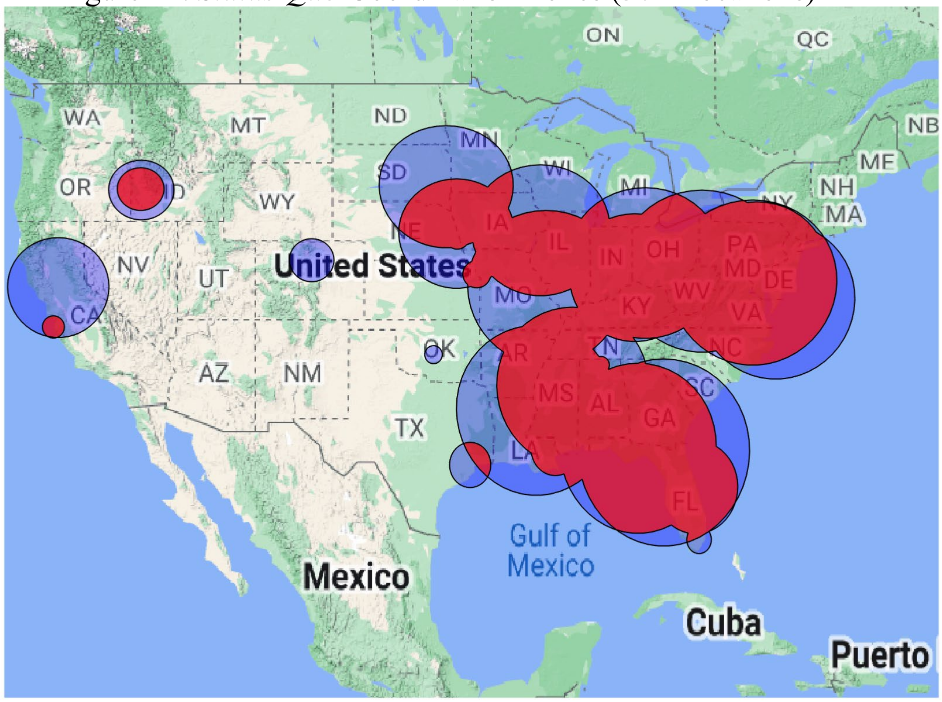


Figure 13: *"Alternative Distribution Mechanism"* Coordination Zones (5 Locations)

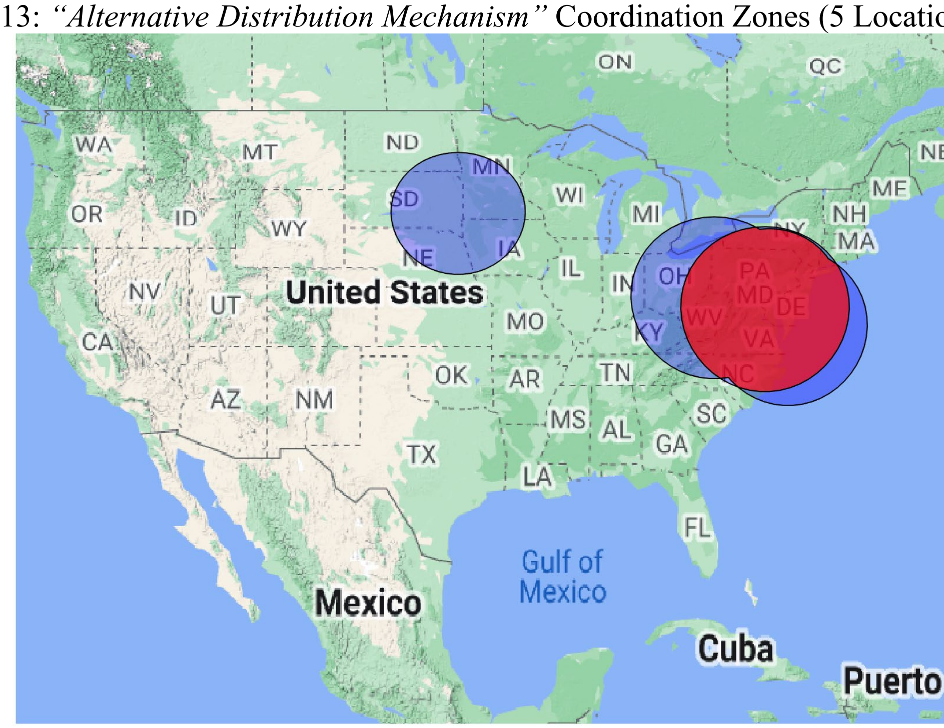


Figure 14: GRB Coordination Zones (15 Locations)

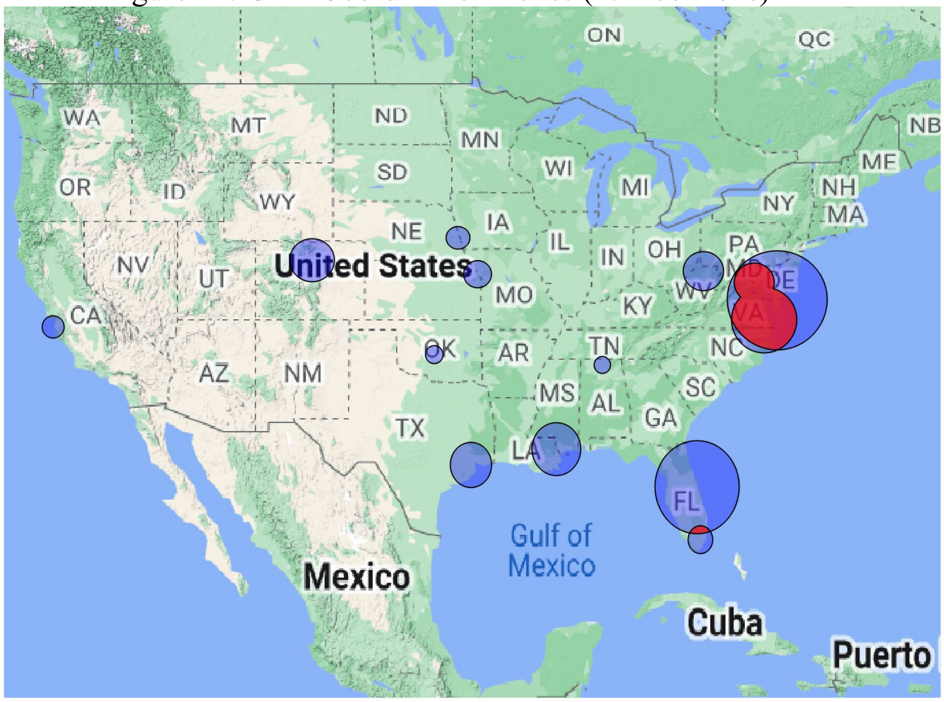


Figure 15: GRB Coordination Zones and DCS ADM (17 Locations)

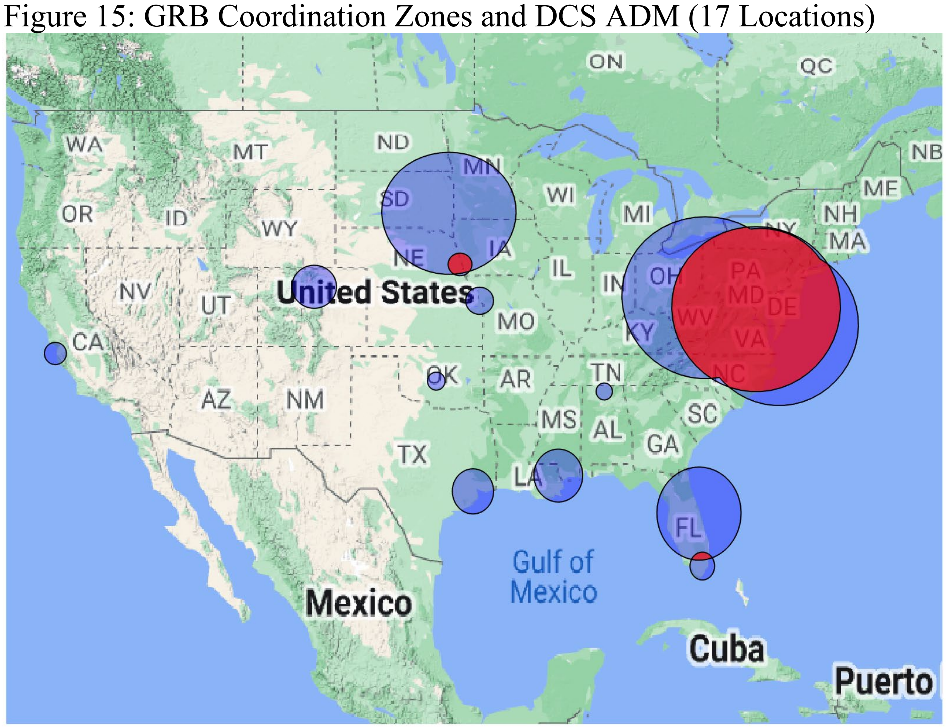


Table 9: Coordination Zone Distance (within the contiguous USA)

Location/System	Coordination Distance [km]
Boise BOR DCS	121
Boise NIFC DCS	169
Boulder GRB	122
Cape Canaveral GRB	264
Cincinnati DCS	362
College Park GRB	48
Columbus Lake DCS	452
Fairmont DCS	459
Fairmont GRB	111
Houston GRB	128
Hunt Valley DCS	388
Huntsville GRB	48
Kansas City GRB	77
Lake City DCS	530
Miami GRB	79
Monterey GRB	63
Norfolk GRB	186
Norman GRB	51
Omaha AF GRB	64
Omaha ACE DCS	310
Rock Island DCS	371
Sacramento DCS	283
Sioux Falls DCS	346
St Louis DCS	438
Stennis GRB	150
Suitland DCS	468
Suitland GRB	111
Tallahassee DCS	482
Vicksburg DCS	482
Wallops DCS	446
Wallops GRB	281

4.5 Partial Economic Areas Population Impact Results

Table 10 shows the population impact of the top 25 PEAs for sharing scenario *Status Quo*. The population impact is shown for non-overlapping coordination zones, overlapping coordination zones, and unencumbered. Figure 16 visualizes the PEA impact, where the PEAs are shaded according to their population availability, with the non-overlapping coordination zones shown as gray.

Table 11 and Figure 17 are the results for the sharing scenario "Alternative Distribution Mechanism."

Table 10: Top 25 PEA Population Impact: Scenario: Status Quo

PEA Name	PEA Number	PEA Population	Population Percentage		
			Non-Overlapping Coordination Zone	Overlapping Coordination Zones	Unencumbered
New York, NY	1	25,237,061	1.6%	92.5%	5.9%
Los Angeles, CA	2	19,410,169	0.0%	0.0%	100.0%
Chicago, IL	3	9,366,713	8.7%	91.3%	0.0%
San Francisco, CA	4	9,027,937	91.8%	8.2%	0.0%
Baltimore, MD-Washington, DC	5	7,842,134	0.0%	100.0%	0.0%
Philadelphia, PA	6	7,587,252	0.0%	100.0%	0.0%
Boston, MA	7	6,776,035	0.0%	0.0%	100.0%
Dallas, TX	8	6,452,472	0.0%	0.0%	100.0%
Miami, FL	9	6,291,880	36.5%	62.9%	0.6%
Houston, TX	10	5,891,999	97.2%	2.8%	0.0%
Atlanta, GA	11	5,435,312	0.4%	99.5%	0.2%
Detroit, MI	12	5,137,479	15.5%	84.5%	0.0%
Orlando, FL	13	4,562,642	0.0%	100.0%	0.0%
Cleveland, OH	14	4,096,678	0.0%	100.0%	0.0%
Phoenix, AZ	15	3,817,117	0.0%	0.0%	100.0%
Seattle, WA	16	3,792,218	0.0%	0.0%	100.0%
Minneapolis-St. Paul, MN	17	3,390,091	97.2%	0.0%	2.8%
San Diego, CA	18	3,095,313	0.0%	0.0%	100.0%
Portland, OR	19	3,022,643	0.0%	0.0%	100.0%
Denver, CO	20	2,789,669	100.0%	0.0%	0.0%
Tampa, FL	21	2,783,243	0.0%	100.0%	0.0%
Sacramento, CA	22	2,722,415	100.0%	0.0%	0.0%
Pittsburgh, PA	23	2,399,667	0.0%	100.0%	0.0%
Saint Louis, MO	24	2,396,938	1.1%	98.9%	0.0%
Cincinnati, OH	25	2,196,428	0.0%	100.0%	0.0%

Figure 16: PEA Impact: Scenario: Status Quo

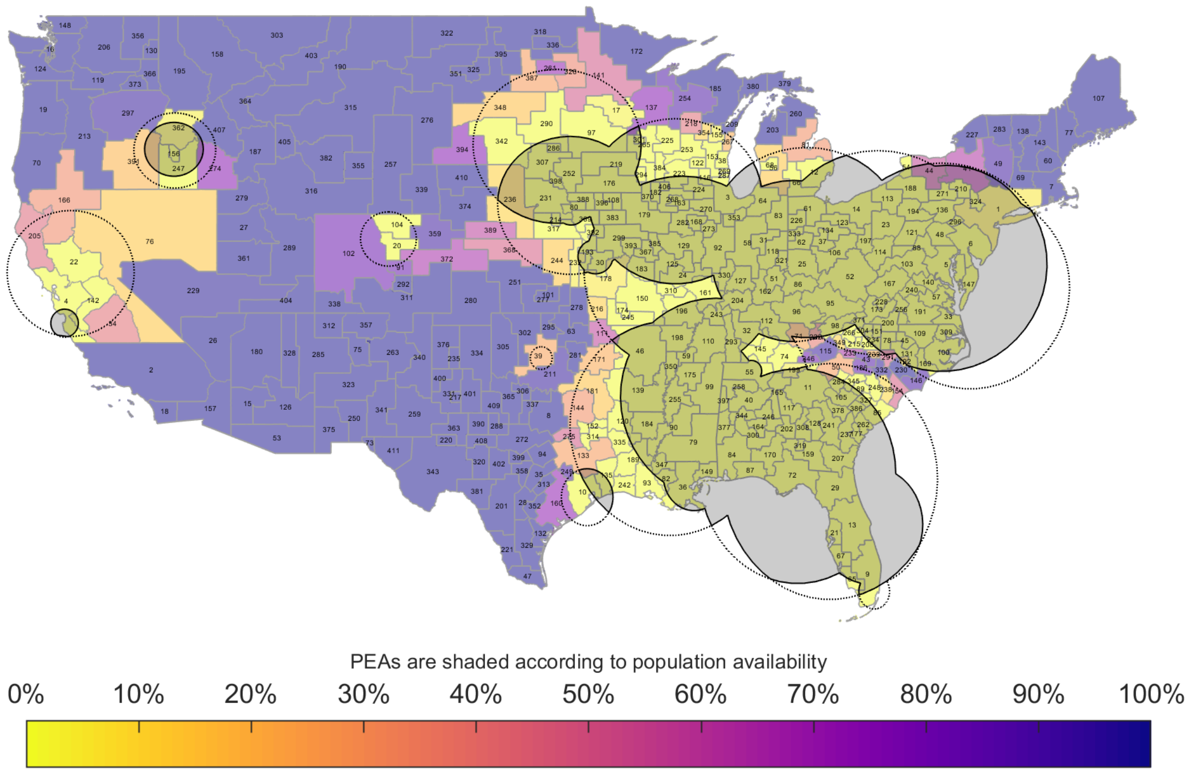
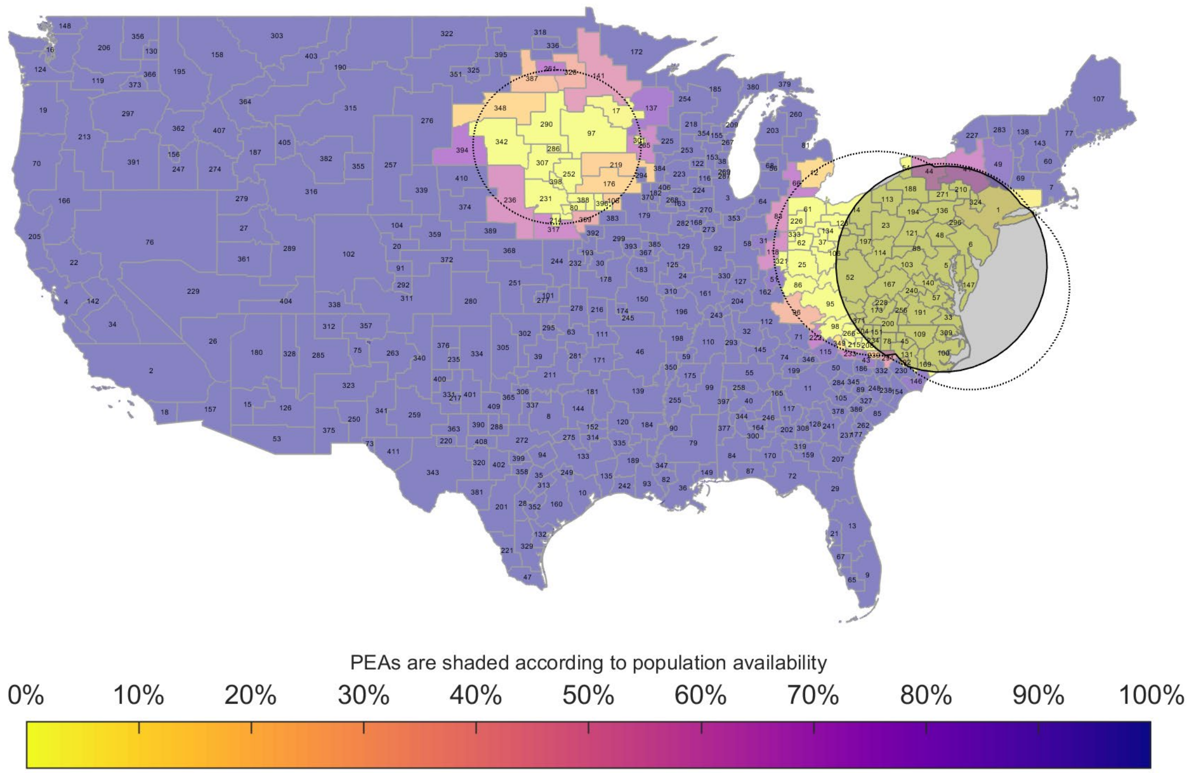


Table 11: Top 25 PEA Population Impact: Scenario: Alternative Distribution Mechanism

PEA Name	PEA Number	PEA Population	Population Percentage		
			Non-Overlapping Coordination Zone	Overlapping Coordination Zones	Unencumbered
New York, NY	1	25,237,061	1.7%	92.4%	5.9%
Los Angeles, CA	2	19,410,169	0.0%	0.0%	100.0%
Chicago, IL	3	9,366,713	0.0%	0.0%	100.0%
San Francisco, CA	4	9,027,937	0.0%	0.0%	100.0%
Baltimore, MD-Washington, DC	5	7,842,134	0.0%	100.0%	0.0%
Philadelphia, PA	6	7,587,252	0.0%	100.0%	0.0%
Boston, MA	7	6,776,035	0.0%	0.0%	100.0%
Dallas, TX	8	6,452,472	0.0%	0.0%	100.0%
Miami, FL	9	6,291,880	0.0%	0.0%	100.0%
Houston, TX	10	5,891,999	0.0%	0.0%	100.0%
Atlanta, GA	11	5,435,312	0.0%	0.0%	100.0%
Detroit, MI	12	5,137,479	84.5%	0.0%	15.5%
Orlando, FL	13	4,562,642	0.0%	0.0%	100.0%
Cleveland, OH	14	4,096,678	57.2%	42.8%	0.0%
Phoenix, AZ	15	3,817,117	0.0%	0.0%	100.0%
Seattle, WA	16	3,792,218	0.0%	0.0%	100.0%
Minneapolis-St. Paul, MN	17	3,390,091	97.2%	0.0%	2.8%
San Diego, CA	18	3,095,313	0.0%	0.0%	100.0%
Portland, OR	19	3,022,643	0.0%	0.0%	100.0%
Denver, CO	20	2,789,669	0.0%	0.0%	100.0%
Tampa, FL	21	2,783,243	0.0%	0.0%	100.0%
Sacramento, CA	22	2,722,415	0.0%	0.0%	100.0%
Pittsburgh, PA	23	2,399,667	0.0%	100.0%	0.0%
Saint Louis, MO	24	2,396,938	0.0%	0.0%	100.0%
Cincinnati, OH	25	2,196,428	100.0%	0.0%	0.0%

Figure 17: PEA Impact: Scenario: Alternative Distribution Mechanism



5.PATHS TO INCREASED SPECTRUM SHARING

5.1 Overview

In this section, options to increasing spectrum sharing in the band are provided. Spectrum sharing can be increased by focusing on three factors: (1) geography, (2) frequency, and (3) time.

The options are grouped into two broad areas: (1) commercial transmitter and (2) federal earth station receiver. Table 12 provides an overview of the mitigation options to increase spectrum sharing and the estimated dB improvement that it can provide. The dB improvements can then be translated to specifically to increased spectrum sharing (population availability) as described in Section 5.4. In general, it appears that the mitigation options are more favorable to urban commercial deployment, which means that sharing in this band might be more favorable in the urban areas. Transmitter mitigations would be considered on a case-by-case basis during coordination. It should be noted that mitigations are not needed outside of coordination zones (see Figure 16 and Figure 17).

Table 12: Mitigation Options, Spectrum Sharing Improvements

	Mitigation/Improvements	Estimated dB Improvement
Commercial Transmitter Mitigations		**38 – 127 dB**
Geography	Base Station Antenna Pointing Configuration (Downtilt/Azimuth)	10-30 dB
	Base Station Height (within Clutter)	19-27 dB
Frequency	Physical Resource Block (PRB) Blanking	3-60 dB
Time	Base Station Activity Factor and Network Loading	6-10 dB
Federal Earth Station Receiver Improvements		**36 – 50 dB**
Geography	Passive Side-Lobe Antenna	10-20 dB
	Site Improvements and RF Barriers	[6-10 dB]
Frequency	DCS Receiver	20 dB
Time	None Identified	---
Total Mitigations/Improvements		**74 – 133 dB**

5.2 Commercial Transmitter Mitigations

Commercial transmitter mitigations are emphasized to reduce the amount of power transmitted towards the federal receiver in the geography, frequency, and time domain. For example, base station antenna height (clutter), base station antenna pointing/beam forming, activity/loading factor, PRB blanking, can decrease the EIRP directed towards the federal incumbent from 38-127 dB. The list is not meant to be exhaustive. Other transmitter mitigations could be considered during coordination.

5.2.1 Base Station Antenna Pointing Configuration

Base station antenna pointing configuration, in the horizontal (azimuth) and vertical (downtilt), can help decrease the EIRP directed toward the federal earth station receiver. This could include antenna beam muting or null steering, if applicable.

The SPRES Report specifically looked at antenna downtilt:

> *"3.3.8 LTE cell tower antenna downtilt*
>
> *A potential RFI mitigation approach was examined involving simulations adjusting the LTE evolved NodeB (eNB) antenna downtilt in one degree increments from 2° to 6° below the horizon. An eNB can be adjusted electronically on most installations. Typically, dense urban areas have the highest site density and hence the highest signal coverage overlap. This results in the greatest downtilts for dense urban areas (as much as −8°). In rural areas, sites are farther apart and therefore require minimal downtilt (about −2° to point the main vertical lobe of antenna toward ground). In urban and suburban areas, −3° to −4° is common.*
>
> *SPRES Project 11 found that applying a mechanical downtilt in a large-cell downlink deployment effectively mitigates the exclusion zones required. This process included the application of 2°, 3°, 4°, 5°, and 6° downtilts."*[50]

For base stations that leverage antenna pointing configurations to mitigated interference, it is roughly estimated that there could be a 10-30 dB improvement. Transmitter mitigations would be considered on a case-by-case basis during coordination. It is estimated that the downtilt improvement will mostly be applied to urban base stations, which will improve spectrum sharing in urban areas.

5.2.2 Base Station Height within Clutter/Below Rooftop

The Report on the 38th meeting of Working Party 5D (WP 5D) provides insights into IMT deployment,[51] specifically "Chapter 4 - Annex 4.4 - Characteristics of terrestrial component of IMT for sharing and compatibility studies in preparation for WRC-23." For IMT deployment-related parameters for bands between 1 and 3 GHz, the report estimates that the percentage of base stations that we be deployment below the rooftop (or within clutter), see Table 13.

Table 13: Base Station Antenna Deployment Heights Below Rooftops

Below rooftop base station antenna deployment	Urban: 30% (1-2 GHz)	Suburban: 0%	Rural 0%

[50] SPRES Report at 92.

[51] The WP 5D report is available at https://www.itu.int/md/R19-WP5D-C-0716/en.

For base stations where the antenna is deployed below the rooftop, or within clutter, a 19-27 dB improvement is estimated. The clutter loss model is distance dependent between distances from 0.25 – 2.0km. (See P.2108 Clutter Loss, Section 3.4) It is estimated that this improvement will mostly be applied to urban base stations, which will improve spectrum sharing in urban areas.

5.2.3 Physical Resource Block (PRB) Blanking

PRB blanking/adjustment can increase spectrum sharing in the frequency domain.

The SPRES report looked at LTE resource block adjustment:

> *"3.3.9 LTE carrier modification*
>
> *SPRES evaluated the sharing benefits of reducing LTE signal overlap with GOES signals through the reservation (non-use) of the upper resource blocks (RB) in the LTE signal for LTE downlink and LTE uplink sharing. Each RB is 180 kHz wide, and SPRES considerd reserving up to 3 RBs. Creating frequency separation by reservation of the upper RBs may eliminate or reduce co-channel and possibly adjacent-channel interference, as the DCS receivers have limited rejection from signals below DCS frequencies."*
>
> *"3.3.9.2 Findings of the LTE resource block adjustment*
>
> *3.3.9.2.1 LTE downlink sharing*
>
> *As discussed in Section 3.3.2, the DCS IF receiver passband is about 2.5 MHz wide on the observed fielded receivers, and the amplifier chain provides 10–20 dB of excess gain. If these conditions are not remedied, removal of the upper resource block(s) provides only a 3 dB FDR improvement. This was true if the LTE signal was 40 W or 2000 W, or if the DCS receiver was in a non-linear condition. For a 10 MHz signal, expect a 9–15 dB improvement in FDR if the upper resource block is removed.*
>
> *3.3.9.2.2 LTE uplink sharing*
>
> *As observed in the results of the 10 MHz LTE downlink preliminary analysis described in Section 3.3.9.1, creating adequate frequency separation between the LTE carrier and the DCS channel can yield significant reduction of RFI to the DCS signal. The amount of frequency separation required to achieve the maximum benefit, perhaps 20 dB, is partly dependent upon receiver design parameters. Projects 6 and 7 identified excess amplifier gain and receiver IF bandwidth as contributors to intermodulation products that significantly increased the amount of frequency separation required. Optimizing GOES receiver performance in a shared environment should be considered first to minimize the amount of frequency separation through resource block non-use needed to achieve desired mitigation levels. This is recommended for further study."*

For base stations where the PRB is deployed, a 3-60 dB improvement is estimated.

Table 14 shows the number of 5G subcarriers that would have to be removed to achieve approximately 60dB of FDR for DCS.

For example, in the case of a 5 MHz and 15 kHz subcarrier spacing scenario, the upper guard-band is set such that the commercial carrier is able to adhere to the OOBE within 250 kHz. The goal of this exercise is to identify how many subcarriers (on the order of kHz) would have to be removed to achieve a similar frequency separation with the lower edge of DCS. This strategy can then be incorporated in combination with improved filtering at the federal receiver systems. In this approach, coordination is much simpler during the planning phase of the commercial carrier. The locations and pointing configurations of their antennas can be arbitrarily set based on their respective network requirements (only on-site scenarios at the federal receiver locations would have to be considered).

For example, in the 5 MHz bandwidth (BW) and 15 kHz SCS scenario the upper edge of the 5G occupied bandwidth is at 1679.75 MHz. For reference, the lower edge of DCS is at 1679.7 MHz. If the "new" upper edge of the 5G occupied bandwidth is set to 1679.45 MHz (250 kHz below 1679.7 MHz), then 20 subcarriers would have to be "blanked" to achieve the "new" upper edge of the occupied band. This results in a 5G network that is limited by 6.7% (or 93.3% of resources within the occupied band are available). The new network capacity was computed as shown below:

- Total subcarriers within occupied bandwidth between 1675-1680 MHz: 300 (12 subcarriers within each resource block, and there are 25 180 kHz resource blocks for a 5 MHz, 15 kHz SCS signal).
- Total blanked subcarriers: 20
- Number of available subcarriers following blanking: 280
- Percentage of resources available: (280/300)*100 = 93.33%

Table 14: FDR Values

Signal Type	Target Upper Bound of Occupied 5G Band (MHz)	Number of Removed Subcarriers	New 5G Network Capacity (in terms of frequency resources)
5 MHz BW 15 kHz SCS	1679.45	20	93.3%
5 MHz BW 30 kHz SCS	1679.18	10	92.4%
10 MHz BW 15 kHz SCS	1679.38	20	96.8%
10 MHz BW 30 kHz SCS	1679.02	10	96.5%
10 MHz BW 60 kHz SCS	1678.66	5	96.2%

5.2.4 Base Station Activity Factor and Network Loading

Considering the Frequency Division Duplex (FDD)/Time Division Duplex (TDD) activity factor and network loading into the coordination process can increase spectrum sharing.

The Report on the 38th meeting of Working Party 5D (WP 5D) provides insights into IMT deployment,[52] specifically "Chapter 4 - Annex 4.4 - Characteristics of terrestrial component of IMT for sharing and compatibility studies in preparation for WRC-23" and commentary on network loading factor.

> ***Network loading factor***
>
> *Network loading factors provided in this document reflect average IMT base station activity. In order to provide required and adequate quality of service, IMT networks are designed and dimensioned to avoid undue congestion, such that, overall cells in a network, most of the cells are not heavily loaded simultaneously and only a small percentage of cells are heavily loaded at any specific point in time. The average loading will therefore be significantly lower when averaged over a sufficient number of IMT transmitters.*
>
> *A network loading value of 20% would normally represent a typical/average value for the loading of base stations across a network (or part thereof), and should be used for sharing and compatibility studies that are considering a relatively wide area (e.g. a large city, province, country or satellite footprint). For studies involving only a small area where there are only a few IMT transmitters, a maximum network loading value of not more than 50% may be used.*
>
> *In a small area with a few IMT transmitters, if the loading is approaching 50%, then the IMT network performance will not be sufficient (e.g. dropped calls will occur, etc.) and more capacity will need to be installed. This can be solved by off-loading to other frequency bands, addition of additional frequency channels or installation of additional base stations. Mobile operators will try to avoid local situations where loading is greater than 20%. For larger areas a network loading factor of 20% should be used. This area will include a sufficient number of base stations to allow for averaging between highly loaded and lightly loaded base stations.*[53]

Taking into consideration a TDD activity factor and network loading could results in a 6-10dB improvement.

5.3 Federal Earth Station Receiver Improvements

Federal earth station receiver mitigations/improvements are emphasized to reduce the amount of received power from the commercial base stations. For example, side-lobe antenna improvements, site improvements, and receiver selectivity improvements, can increase sharing between 36 – 50 dB. The list is not meant to be exhaustive. Other earth station improvements could be considered in the future.

[52] The WP 5D report is available at https://www.itu.int/md/R19-WP5D-C-0716/en.

[53] *Id*. at 26.

5.3.1 Passive Side-Lobe Antenna Improvements

The SPRES report looked at earth station antenna improvements:

> *"3.3.3 Low-sidelobe ground-station antenna mitigation approach*
>
> *SPRES assessed passive and active measures for GOES antennas to achieve reductions in unwanted RF energy entering the antenna through the sidelobes. The passive measures consist of modifications to the ground-station antenna to reduce its sidelobe levels. Typical approaches include tapering the feed pattern that illuminates the reflector and the addition of shrouds. These methods are believed to provide 10–20 dB of sidelobe reduction. Design and implementation of shrouds would be subject to the unique requirements of each site.*
>
> *. . .*
>
> *In summary, if NOAA were to pursue a program to reduce antenna sidelobes and antenna susceptibility, only passive measures appear practical at this time, though active measures could be further studied. Passive measures can produce 10–20 dB of improvement, depending upon the antenna type, although additional development, testing, and demonstration would be needed to verify feasibility."*

5.3.2 Site Improvements and RF Barriers

The SPRES report looked at earth station site improvements and RF barriers:

> *"3.3.4 GOES site improvements and RF barriers*
>
> *SPRES evaluated the sharing benefits of shielding the GOES antennas from RFI by constructing or expanding existing block walls, chain-link fences, or metal-mesh fences used for antenna enclosure.*
>
> *To be effective, such infrastructure would need to extend to the height of the antenna without obstructing its view of the satellite. Effective shielding requires that the shield be taller than the feed height, which may be prohibitively high for GOES locations with large antennas. For some antenna locations with unusual limitations—such as placement immediately adjacent to a river, or on a rooftop—this technique would be infeasible."*

5.3.3 DCS Receiver Improvements

The SPRES report looked at DCS receiver improvements:

> *3.3.2.2 DCS DRGS receiver*
>
> *. . .*
>
> *"The DRGS internal and front-end (LNB) filtering and gain could be optimized for RFI mitigation. The effort starts with a defined RF (sharing) environment, followed by optimizing the antenna, RF frontend/LNB, and finally the receiver (IF) amplifier and filter stages.*

Narrower filters are achievable. Once the operating environments are understood and characterized, such improvements could yield benefits of at least 20 dB.

If combined with an LTE carrier modification that removes the LTE carrier from the 40 dB stop-bandwidth of the DCS filter, moving it from in-band to adjacent-band (see Section 3.3.9), additional mitigation would be achieved, resulting in potential reduction of exclusion zone distances. Further investigation is needed for both the single and combined approaches."

5.4 Mitigation/Improvement Results

Figure 18 shows the coordination zone size as function of dB mitigation/improvement for the Alternative Distribution Mechanism sharing scenario. If a commercial base station wants to operate closer to the federal earth station receiver, the amount of mitigation/improvement needed increases. Table 15 shows the population of the top 50 PEAs that overlap with the coordination zones. To allow more than 99% population availability for all but one of the top 50 PEAs (Baltimore, MD-Washington, DC), 40-50 dB of mitigation/improvements are needed. In some PEAs, only 10-20 dB of mitigation/improvements are needed to increase the population availability. Table 17, Table 18, Table 19, Table 20, and Table 21 show site specific results.

Table 16 shows the nationwide population availability as a function of dB mitigations/improvements.

Figure 18: Coordination Zones as a Function of dB Mitigation/Improvement
Scenario: Alternative Distribution Mechanism

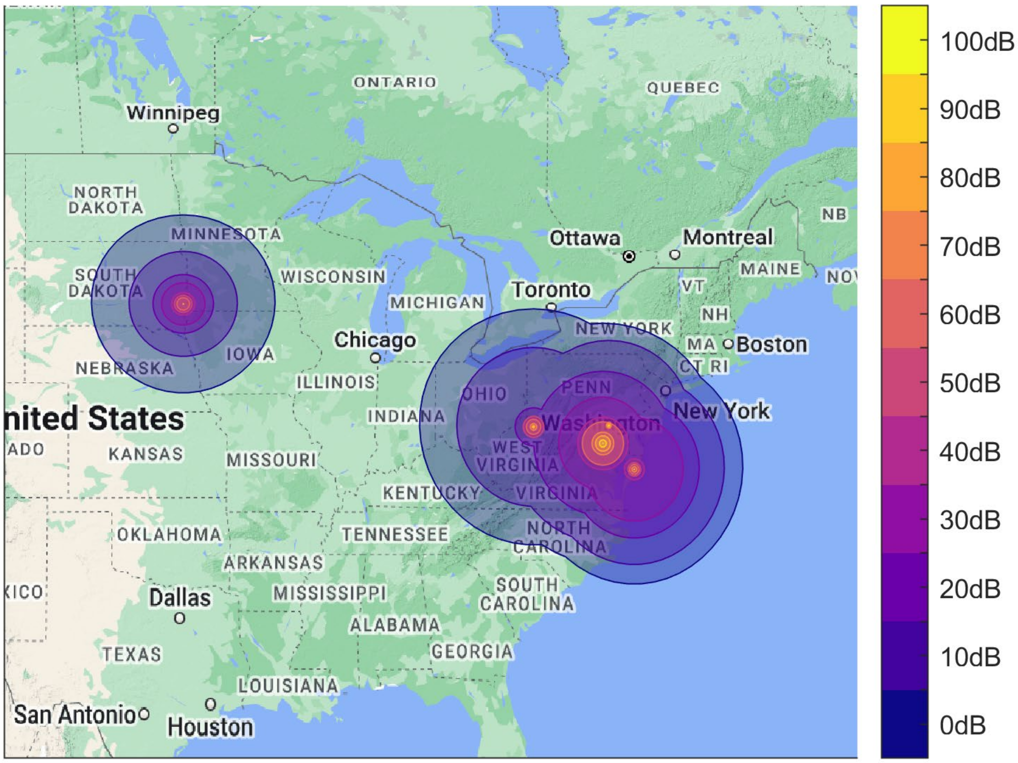


Table 15: Top 50 PEA Population Availability:
Scenario: Alternative Distribution Mechanism

PEA Name	PEA Number	Mitigations/Improvements (dB)										
		0	10	20	30	40	50	60	70	80	90	100
New York, NY	1	6%	18%	89%	100%	100%	100%	100%	100%	100%	100%	100%
Baltimore, MD-Washington, DC	5	0%	0%	0%	0%	1%	5%	5%	39%	60%	85%	100%
Philadelphia, PA	6	0%	0%	0%	64%	100%	100%	100%	100%	100%	100%	100%
Detroit, MI	12	15%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Cleveland, OH	14	0%	1%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Minneapolis-St. Paul, MN	17	3%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Pittsburgh, PA	23	0%	0%	90%	100%	100%	100%	100%	100%	100%	100%	100%
Cincinnati, OH	25	0%	96%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Indianapolis, IN	31	95%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Virginia Beach, VA	33	0%	0%	0%	1%	100%	100%	100%	100%	100%	100%	100%
Columbus, OH	37	0%	0%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Syracuse, NY	41	64%	94%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Charlotte, NC	43	89%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

Rochester, NY	44	58%	94%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Raleigh, NC	45	0%	12%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Harrisburg, PA	48	0%	0%	0%	6%	98%	100%	100%	100%	100%	100%	100%
Albany, NY	49	93%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

Table 16: Nationwide Population Availability:
Scenario: Alternative Distribution Mechanism

Mitigations/Improvements (dB)										
0	10	20	30	40	50	60	70	80	90	100
70.4%	79.4%	90.7%	94.2%	96.9%	97.1%	97.2%	98.3%	98.8%	99.5%	99.8%

Table 17: Wallops

Mitigation [dB]	Number of Base Stations Turned Off	Max Turn Off Distance [km]	Population
0	12,210	446	52,574,246
10	9,761	370	43,520,241
20	4,797	267	21,012,258
30	1,457	201	11,711,521
40	19	41	69,766
50	12	26	31,642
60	8	19	16,388
70	3	10	9,102
80	0	1	0

Table 18: Suitland

Mitigation [dB]	Number of Base Stations Turned Off	Max Turn Off Distance [km]	Population
0	12,951	468	63,108,618
10	10,339	385	51,968,055
20	5,726	281	27,190,706
30	3,048	180	14,725,534
40	1,885	102	8,581,282
50	1,458	84	7,960,338
60	1,110	84	7,960,338
70	898	44	4,696,725
80	608	30	3,093,025
90	246	14	1,142,934
100	1	1	4,240

Table 19: Sioux Falls

Mitigation [dB]	Number of Base Stations Turned Off	Max Turn Off Distance [km]	Population
0	1,106	346	7,953,873
10	233	204	1,188,140
20	84	114	522,752
30	45	82	354,821
40	25	44	228,112
50	14	33	194,058
60	7	24	81,849
70	0	1	0

Table 20: Fairmont

Mitigation [dB]	Number of Base Stations Turned Off	Max Turn Off Distance [km]	Population
0	6,618	459	57,065,730
10	1,136	309	24,168,592
20	63	74	585,321
30	27	41	269,147
40	16	41	269,147
50	12	41	269,147
60	11	29	156,296
70	8	13	55,292
80	2	5	8,000
90	0	1	0

Table 21: Hunt Valley

Mitigation [dB]	Number of Base Stations Turned Off	Max Turn Off Distance [km]	Population
0	9,271	388	53,462,856
10	3,822	331	48,239,337
20	582	121	11,932,635
30	116	35	1,971,629
40	29	15	382,125
50	17	13	224,571
60	12	13	224,571
70	9	10	96,975
80	6	5	38,590
90	0	1	0

Figure 19 shows the coordination zone size as function of dB mitigation/improvement for the Status Quo sharing scenario.

Table 22 shows the population of the top 25 PEAs that overlap with the coordination zones.

Table 23 shows the nationwide population availability as a function of dB mitigations/improvements.

Table 24 shows the coordination zones distances as a function of dB mitigations/improvements.

Figure 19: Coordination Zones as a Function of dB Mitigation/Improvement
Scenario: Status Quo

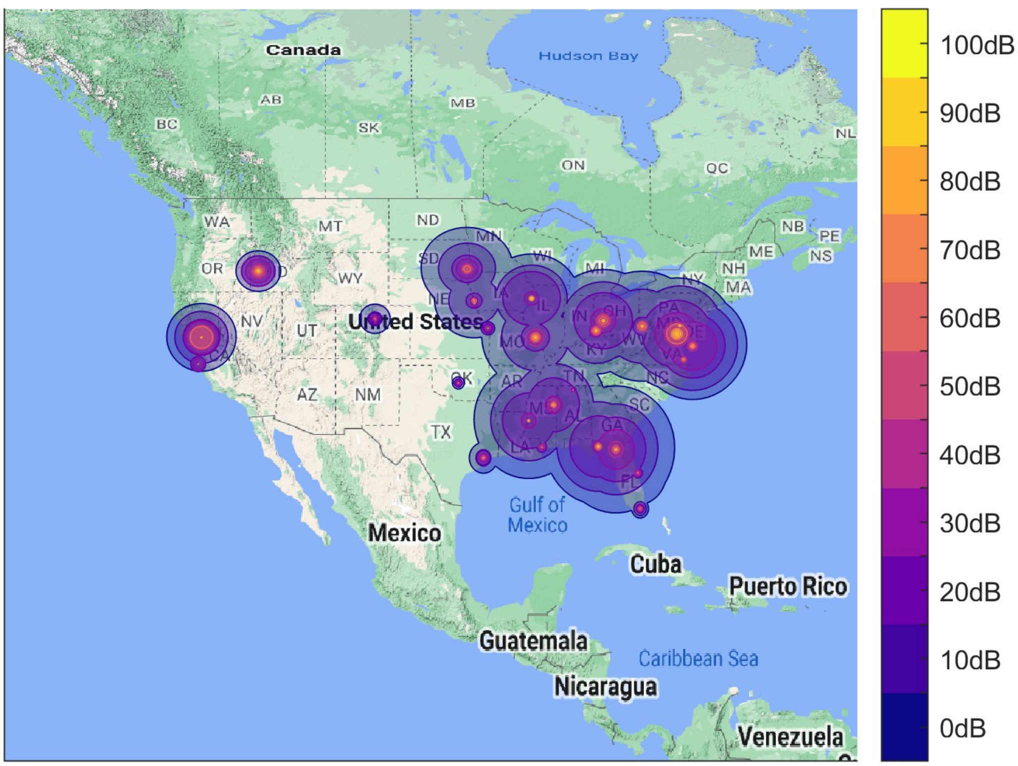


Table 22: Top 25 PEA Population Availability:
Scenario: Status Quo

PEA Name	PEA Number	Mitigations/Improvements (dB)										
		0	10	20	30	40	50	60	70	80	90	100
New York, NY	1	6%	18%	89%	100%	100%	100%	100%	100%	100%	100%	100%
Chicago, IL	3	0%	2%	65%	100%	100%	100%	100%	100%	100%	100%	100%
San Francisco, CA	4	0%	0%	6%	23%	69%	80%	81%	100%	100%	100%	100%
Baltimore, MD-Washington, DC	5	0%	0%	0%	0%	1%	5%	5%	39%	60%	85%	100%
Philadelphia, PA	6	0%	0%	0%	66%	100%	100%	100%	100%	100%	100%	100%
Miami, FL	9	1%	34%	52%	65%	76%	90%	100%	100%	100%	100%	100%
Houston, TX	10	0%	18%	32%	70%	86%	93%	98%	100%	100%	100%	100%
Atlanta, GA	11	0%	69%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Detroit, MI	12	0%	20%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Orlando, FL	13	0%	0%	8%	81%	97%	100%	100%	100%	100%	100%	100%
Cleveland, OH	14	0%	0%	79%	100%	100%	100%	100%	100%	100%	100%	100%
Minneapolis-St. Paul, MN	17	3%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Denver, CO	20	0%	13%	35%	72%	94%	97%	100%	100%	100%	100%	100%

Tampa, FL	21	0%	0%	8%	100%	100%	100%	100%	100%	100%	100%	100%
Sacramento, CA	22	0%	0%	0%	3%	10%	12%	12%	95%	99%	100%	100%
Pittsburgh, PA	23	0%	0%	90%	100%	100%	100%	100%	100%	100%	100%	100%
Saint Louis, MO	24	0%	0%	0%	6%	6%	20%	35%	61%	90%	99%	100%
Cincinnati, OH	25	0%	0%	0%	5%	14%	26%	47%	71%	91%	99%	100%

Table 23: Nationwide Population Availability:
Scenario: Status Quo

Mitigations/Improvements (dB)										
0	10	20	30	40	50	60	70	80	90	100
31.9%	45.3%	68.4%	84.6%	91.3%	93.0%	94.1%	97.4%	98.5%	99.4%	99.8%

Table 24: Coordination Zone Distance [km]

Location/System	Coordination Distance [km]										
	Mitigations/Improvements [dB]										
	0	10	20	30	40	50	60	70	80	90	100
Boise BOR DCS	121	121	91	55	39	18	16	10	5	1	1
Boise NIFC DCS	169	127	127	97	60	45	31	19	9	3	1
Boulder GRB	122	57	46	29	14	6	1	1	1	1	1
Cape Canaveral GRB	264	95	42	27	19	7	1	1	1	1	1
Cincinnati DCS	362	273	126	53	40	34	24	14	6	2	1
College Park GRB	48	37	31	19	13	6	1	1	1	1	1
Columbus Lake DCS	452	345	225	73	48	24	18	10	1	1	1
Fairmont DCS	459	309	74	41	41	41	29	13	5	1	1
Fairmont GRB	111	41	41	41	29	13	6	1	1	1	1
Houston GRB	128	68	59	37	23	14	6	1	1	1	1
Hunt Valley DCS	388	331	121	35	15	13	13	10	5	1	1
Huntsville GRB	48	23	23	14	2	1	1	1	1	1	1
Kansas City GRB	77	55	40	29	9	4	1	1	1	1	1
Lake City DCS	530	379	269	165	66	34	20	10	5	1	1
Miami GRB	79	58	37	27	19	11	1	1	1	1	1
Monterey GRB	63	63	63	47	7	4	1	1	1	1	1
Norfolk GRB	186	61	42	34	24	16	10	1	1	1	1
Norman GRB	51	34	32	18	7	4	1	1	1	1	1
Omaha AF GRB	64	27	27	27	6	1	1	1	1	1	1
Omaha ACE DCS	310	198	63	28	18	18	18	4	1	1	1
Rock Island DCS	371	278	225	56	20	20	20	15	8	4	1
Sacramento DCS	283	217	149	137	104	92	92	7	3	1	1
Sioux Falls DCS	346	215	114	82	44	33	24	1	1	1	1
St Louis DCS	438	276	114	70	70	42	30	20	8	2	1
Stennis GRB	150	65	44	25	19	7	1	1	1	1	1
Suitland DCS	468	385	281	178	102	84	84	44	30	14	1
Suitland GRB	111	97	84	50	33	17	3	1	1	1	1
Tallahassee DCS	482	374	256	52	31	28	20	11	8	3	1
Vicksburg DCS	482	335	232	63	10	10	10	10	3	1	1
Wallops DCS	446	370	267	201	41	26	19	10	1	1	1
Wallops GRB	281	211	43	28	19	10	1	1	1	1	1

6. MONITORING DISCUSSION

6.1 Overview

In this section, a discussion on monitoring is provided.

6.2 Monitoring Challenges

Several monitoring challenges exist from both a radio frequency monitoring and bit-level monitoring perspective. This section discusses those challenges.

6.2.1 Radio Frequency Monitoring Challenges

1. *Aggregate interference concerns.* It is likely that the system can detect interference purely based on energy detection, but it is more difficult to classify each individual offender because of aggregate interference, especially if there are sub-noise detection and classification requirements. Because there are a unique number of interferers that are geographically dispersed, it should be possible to extract who the exact offenders are even under aggregate interference conditions. The question is how reliably those conditions can be measured for different signal-to-noise ratio (SNR) values. In other words, what is the probability of detection vs SNR and the probability of classification vs SNR CDFs? The performance of the system should theoretically meet the percentage of time that ensures reliability for the NOAA receivers.
2. *Different system characteristics.* Since there are differences in antenna patterns and receivers, how could the monitoring system observe the signal environment observed by the DRGS?
3. *Different sensitivity levels.* A monitoring system cannot solely be used to establish the true sensitivity of the DRGS. Relating the signal environment observed by the monitoring system to the quality of the data received by the DRGS is required.
4. *Monitoring responsibility.* NOAA shouldn't need a sophisticated monitoring solution for this band for RFI. At maximum, a spectrum analyzer is required in combination with bit-level data monitoring. This exercise will allow NOAA to understand what their true RFI threshold is.
5. *Monitoring antenna location.* The monitoring antenna needs to be strategically placed such that it is exposed to the same RF environment as the ground station. This involves the monitoring antenna height to be level with the feed of the ground stations. Additionally, the antenna must not be shadowed by the dish itself or any other structures.

6.2.2 Bit-level data monitoring Challenges

1. *Cost and complexity.* Much more cost effective for NOAA to implement.
2. *Responsibility.* NOAA is responsible for identifying what their data quality is under normal operating conditions (outside of a spectrum sharing environment). This can be used as a baseline and compared to data quality observed within a spectrum sharing environment. This will provide insight to the effectiveness of coordination zones produced at a specific percentile (e.g., the 95th percentile).

3. *Existing capabilities.* The quality of DCS data is already compared between select sites. Risk mitigation and fail-safe solutions already exist. Fine tuning is required to move the best available data into different data distribution architectures.