

NIST Technical Note
NIST TN 2392

Citizens Broadband Radio Service (CBRS)
Sharing Ecosystem Assessment (SEA)
Modeling Methodology Report

*A guide to using and understanding modeling methodology
developed by the NASCTN CBRS SEA program.*

Thao T. Nguyen
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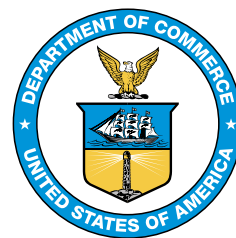
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National Advanced Spectrum and Communications Test Network (NASCTN)

Mission Statement: *The National Advanced Spectrum and Communications Test Network (NASCTN) provides, through its members, a network for robust test processes and validated measurement data necessary to develop, evaluate and deploy spectrum sharing technologies that can improve access to the spectrum by both federal agencies and non-federal spectrum users.*

NASCTN was founded in 2015 as a multi-agency chartered partnership and as of 2022, is a congressionally mandated function of the National Institute of Standards and Technology (NIST). NASCTN is coordinated with the National Telecommunications and Information Administration (NTIA) and other Federal agencies, as appropriate. NIST hosts the NASCTN capability at the Department of Commerce Boulder Laboratories in Boulder, CO.

The NASCTN program office facilitates and coordinates the use of intellectual capacity, modeling and simulation, and laboratory and test facilities to meet national spectrum interests and challenges.

NASCTN test projects follow a transparent framework including public dissemination of test plans, adjudicated comments to the test plans, formal reports containing test methods, data, and software to the maximum extent permissible.

The NASCTN provides an impartial, scientifically rigorous forum for addressing spectrum-sharing challenges in an effort to accelerate the deployment of wireless technologies among commercial and federal users and to measure the impacts of spectrum dependent systems deployments. NASCTN provides robust test processes, validated measurements data, and statistical analysis necessary to develop, evaluate, and deploy spectrum sharing technologies that can improve access to the spectrum by both federal agencies and non-federal spectrum users.



NASCTN CBRS SEA

This work is a result of the [NASCTN](#) Citizens Broadband Radio Service ([CBRS](#)) Sharing Ecosystem Assessment ([SEA](#)) program. The [NASCTN CBRS SEA](#) program was requested and sponsored by Defense Information Systems Agency ([DISA](#)) to measure emissions in the [CBRS](#) band. These emissions would be analyzed to ascertain the effectiveness of the sharing ecosystem between [CBRS](#) systems as managed by Spectrum Access Systems ([SASs](#)), and Department of Defense ([DoD](#)) systems as monitored by Environmental Sensing Capabilities ([ESCs](#)). The collected data will be used by [DoD](#) to provide insight into the sharing ecosystem's effectiveness and track changes in the spectrum environment over time. This document describes modeling methodology used to support the program. Test members are drawn from government, academia, and/or industry and are the foundation to [NASCTN](#)'s coordinated, national testing and evaluation capability to enable the improvement and expeditious addressing of national spectrum test interest and challenges. Test members' responsibilities include:

- Provide expertise and capabilities to cooperatively enable [NASCTN](#) studies;
- Work as a partnership to address the interests and equities of all spectrum stakeholders in a fair, equitable, and non-preferential manner; and
- Through sharing of technical resources, with consideration for cost, provide for, liaison, or coordinate access to testing and evaluation capabilities.

Test Members to the [CBRS SEA](#) Program are (in alphabetical order):

- MITRE Corporation
- National Aeronautics and Space Administration (NASA), Langley Research Center
- National Institute of Standards and Technology (NIST), Communications Technology Laboratory
- National Telecommunications and Information Administration (NTIA), Institute for Telecommunication Sciences (ITS)

Other collaborative partners that were critical to enabling the [CBRS SEA](#) program are:

- Department of Defense (DoD), Chief Information Officer (CIO)
- Hampton University, Norfolk VA
- Norfolk International Terminals, Port of Virginia
- Naval Surface Warfare Center, Dahlgren Division
- University of Colorado, Boulder CO
- United States Coast Guard, C5ISR Program, Rescue 21
- United States Marine Corps, IC4
- United States Navy, Naval Base Pt Loma
- United States Navy, Naval Air Station Oceana
- Virginia Department of Transportation

Abstract

The [NASCTN CBRS SEA](#) project uses measurements and modeling to provide data-driven insight into the [CBRS](#) sharing ecosystem and changes in the spectrum environment over time. This report describes modeling and simulation methods based on the Wireless Innovation Forum ([WinnForum](#)) Dynamic Protection Area ([DPA](#)) procedures for Citizens Broadband Radio Service 1.0 ([CBRS 1.0](#)) and Citizens Broadband Radio Service 2.0 ([CBRS 2.0](#)). The modeling uses Citizens Broadband Radio Service device ([CBSD](#)) deployment information from Full Activity Dump ([FAD](#)) data to calculate [CBSD](#) Move Lists and associated Keep Lists, estimate aggregate emissions at [DPA](#) protection points and [SEA](#) sensor locations, and inform sensor placement. Comparisons of modeled aggregate emissions with sensor measurements identified differences between modeled and measured power levels that vary by site and channel. Interpretation of these comparisons is subject to uncertainties in [FAD](#) data and actual [CBSD](#) operation, propagation and clutter modeling, duty cycle and network loading assumptions, antenna parameters, and the temporal and spectral characteristics of [CBSD](#) transmissions. The report also evaluates [CBRS 2.0 DPA](#) neighborhood distance calculations for selected [ESC-monitored DPAs \(E-DPAs\)](#) and demonstrates that the calculated distances can depend on protection point selection, [CBSD](#) deployment laydown, and the channel being evaluated.

Keywords

advanced communications; spectrum sharing; aggregate emissions; interference protection; citizens broadband radio service; CBSD; dynamic protection areas; environmental sensing capabilities; NASCTN

Acronyms

3GPP	Third Generation Partnership Project	GMM	Green Mountain Mesa
5G NR	Fifth Generation New Radio	HU	Hampton University
ADC	analog-to-digital converter	IAP	Iterative Allocation Process
AGL	above ground level	IJWG	Interagency Joint Working Group
AMA	Analytical Mechanics Associates	ITM	Irregular Terrain Model
AMSL	above mean sea level	ITS	Institute for Telecommunication Sciences
CBBT	Chesapeake Bay Bridge Tunnel	LaRC	Langley Research Center
CBRS	Citizens Broadband Radio Service	LOS	line-of-sight
CBRS 1.0	Citizens Broadband Radio Service 1.0	MITRE	The MITRE Corporation
CBRS 2.0	Citizens Broadband Radio Service 2.0	NASA	National Aeronautics and Space Administration
CBSD	Citizens Broadband Radio Service device	NASCTN	National Advanced Spectrum and Communications Test Network
CDF	cumulative distribution function	NIT	Norfolk International Terminal
CONUS	contiguous United States	NIST	National Institute of Standards and Technology
CPAS	Coordinated Periodic Activities among SASs	NLOS	non-line-of-sight
DISA	Defense Information Systems Agency	NTIA	National Telecommunications and Information Administration
DoD	Department of Defense	OSM	Office of Spectrum Management
DPA	Dynamic Protection Area	PAL	Priority Access License
E-DPA	ESC-monitored DPA	PDF	probability density function
EIRP	equivalent isotropically radiated power	PFP	periodic frame power
ESC	Environmental Sensing Capability	PPA	Priority Access License (PAL) Protection Area
E-UTRA	Evolved Universal Terrestrial Radio Access	PSD	power spectral density
FAD	Full Activity Dump	RF	radio frequency
FCC	Federal Communications Commission	RMS	root mean square
GAA	General Authorized Access	SAS	Spectrum Access System
GB-DPA	ground-based DPA	SEA	Sharing Ecosystem Assessment
		TDD	time division duplex
		USMC	United States Marine Corps
		UTC	Coordinated Universal Time
		WInnForum	Wireless Innovation Forum

Glossary

- CBRS:** A three-tiered shared spectrum ecosystem operating in the 3550 MHz to 3700 MHz band.
- CBSD:** Fixed stations or points of wireless access (e.g., base stations) managed and authorized by a [SAS](#).
- Clutter Loss:** A reduction in radio signal strength caused by obstacles like buildings or vegetation, modeled using the ITU-R P.2108 standard in [CBRS 2.0](#) calculations.
- CPAS:** A mandatory daily synchronization process executed by all [SAS](#) administrators between 07:00 UTC and 10:00 UTC to coordinate spectrum allocations.
- dBm:** Decibel-milliwatt is a unit of power level expressed in decibels (dB) with reference to one milliwatt (mW).
- DPA:** Predefined geographic boundaries where federal incumbent systems must be dynamically protected from commercial interference.
- ESC:** A specialized coastal network of sensors designed to detect federal incumbent radar activity and signal the [SAS](#) to protect those channels.
- E-DPA:** An [ESC](#)-monitored coastal or harbor [DPA](#).
- FAD:** Datasets generated by [SAS](#) administrators containing the formal registration and grant information of all active [CBSDs](#).
- GAA:** The third and lowest tier of [CBRS](#) spectrum access; General Authorized Access ([GAA](#)) users can use any open block but must yield to Tier 1 incumbents and Tier 2 [PALs](#).
- GB-DPA:** Terrestrial-based protection areas (such as inland military facilities like Camp Pendleton) that are treated as “always-on” and possess higher protection thresholds.
- Grant:** An authorization issued by a [SAS](#) to a [CBSD](#) to transmit using specified operating parameters, including an assigned frequency range and maximum equivalent isotropically radiated power ([EIRP](#)).
- IAP:** The core synchronous algorithm executed first during Coordinated Periodic Activities among [SASs](#) ([CPAS](#)) to calculate aggregate interference protection for non-federal higher-tier entities.
- ITM:** A point-to-point propagation model used to compute path loss over varied terrain contours.
- Keep List:** A compiled list of specific [CBSD](#) grants authorized by the [SAS](#) to continue transmitting on a protected channel when a [DPA](#) becomes active.
- Laydown:** A dataset representing the geographic distribution and associated characteristics of [CBSD](#) deployments used as input to modeling and simulation.
- Move List:** A list of [CBSD](#) grants that fall within an active [DPA](#) neighborhood and must be suspended or moved to an alternate channel within 300 seconds of radar detection.
- Neighborhood Distance:** The calculated geographic radius around a [DPA](#) protection point used to determine which [CBSDs](#) must be evaluated on the Move List.
- PAL:** The second tier of the [CBRS](#) framework, authorized via competitive bidding in 10 MHz blocks with spectrum priority over [GAA](#).

- PFP:** Measurement metrics extracted from sensor captures to isolate and analyze active wireless transmissions.
- PPA:** A bounded geographic area where a **PAL** licensee is legally protected from **GAA** interference.
- PSD:** A high-fidelity spectral measurement characterizing a signal's power distribution normalized per unit of frequency (dBm/Hz).
- SAS:** A highly automated, cloud-based coordinator that manages channel assignments, checks aggregate interference, and grants spectrum access for **PAL** and **GAA** users.

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Executive Summary

The purpose of the National Advanced Spectrum and Communications Test Network (NASCTN) Citizens Broadband Radio Service (CBRS) Sharing Ecosystem Assessment (SEA) project is to provide data-driven insight into the CBRS sharing ecosystem's effectiveness between commercial and Department of Defense (DoD) incumbent systems and to track changes in the spectrum environment over time. CBRS is a nationwide shared spectrum ecosystem in the 3550 MHz to 3700 MHz band. To support the SEA project, NASCTN developed modeling and simulation methods based on the Wireless Innovation Forum (WInnForum) CBRS Dynamic Protection Area (DPA) procedures. The modeling informed sensor site selection and supported comparison of modeled aggregate emissions with measurements collected at operationally relevant sites near Norfolk, VA and San Diego, CA.

The modeling implements the WInnForum DPA Move List procedures for Citizens Broadband Radio Service 1.0 (CBRS 1.0) and Citizens Broadband Radio Service 2.0 (CBRS 2.0) using Citizens Broadband Radio Service device (CBSD) deployment information from Full Activity Dump (FAD) data. The implementations are used to calculate CBSD Move Lists and associated Keep Lists and to estimate aggregate emissions at DPA protection points and NASCTN SEA sensor locations. Modeling was also used to estimate sensor radio frequency (RF) horizon coverage and expected CBSD emission levels to inform sensor placement.

Comparison of modeled aggregate emissions with sensor measurements identified differences between modeled and measured power levels that vary by site and channel. The analysis also illustrates differences between the CBRS 1.0 and CBRS 2.0 implementations. Interpretation of these comparisons is subject to uncertainties in FAD data and actual CBSD operation, propagation and clutter modeling, duty cycle and network loading assumptions, antenna parameters, and the temporal and spectral characteristics of CBSD transmissions. The comparisons presented in this report primarily use the July 1, 2025 FAD dataset and selected measurement intervals. Additional evaluation across other dates and operating conditions is needed to determine whether the observed relationships between modeled and measured results persist over time.

The report also evaluates the CBRS 2.0 DPA neighborhood distance calculation for selected Environmental Sensing Capability (ESC)-monitored DPAs (E-DPAs). The recalculation results demonstrate that the calculated neighborhood distances can depend on the number and spatial distribution of protection points, the CBSD deployment laydown, and the channel being evaluated. These results provide a basis for further evaluation of DPA neighborhood calculations using representative CBSD deployments and broader protection point configurations.

This modeling methodology report is not designed to be a comprehensive document about the NASCTN CBRS SEA project. Detailed information about the project's goals, sensor con-

struction, data manual, and ecosystem analysis can be found at <https://www.nist.gov/programs-projects/cbrs-sharing-ecosystem-assessment>.

This modeling report is targeted at commercial, military, and civilian stakeholders in CBRS who would benefit from modeling and analysis of a shared spectrum environment. To access the data and detailed analyses produced by this program, email nasctn@nist.gov. For more advanced analysis in the Python and MATLAB programming languages, users can access three repositories hosted on GitHub at:

- <https://github.com/usnistgov/nasctn-sea-modeling>
- <https://github.com/usnistgov/nasctn-sea-rf-mapping>
- <https://github.com/usnistgov/nasctn-sea-dpa-neighborhood>

1. Introduction

The Defense Information Systems Agency (DISA) proposed a measurement campaign to the National Advanced Spectrum and Communications Test Network (NASCTN) to measure emissions in the Citizens Broadband Radio Service (CBRS) band, i.e., the 3550 MHz to 3700 MHz band. This measurement campaign is designed to assess the effectiveness of the sharing ecosystem between Citizens Broadband Radio Service devices (CBSDs), as managed by Spectrum Access Systems (SASs), and Department of Defense (DoD) incumbent systems, whose operations are protected through the CBRS sharing framework. The collected data provide DISA with information to assess the sharing ecosystem and track changes in the spectrum environment over time.

1.1. CBRS Ecosystem

The Federal Communications Commission (FCC) established the CBRS in the 3550 MHz to 3700 MHz band using a three-tiered framework: Federal incumbent (Tier 1), Priority Access License (PAL) (Tier 2), and General Authorized Access (GAA) (Tier 3), as shown in Figure 1. Launched commercially in July 2020, this shared ecosystem relies on Environmental Sensing Capabilities (ESCs) to detect incumbent activity and SASs to automate spectrum coordination. To protect incumbents, SASs execute a Wireless Innovation Forum (WInnForum) Dynamic Protection Area (DPA) Move List Calculation, pre-calculated by all SASs at midnight Coordinated Universal Time (UTC). The calculation contains assumptions about propagation, CBSD location and height, antenna patterns, and other protection factors. The specific assumptions and methods used in this calculation can affect DPA protection results and CBSD operation. From July 2020 to June 2024, the calculations were implemented according to the specifications outlined in the WInnForum Release 1 Specification document [1], and this realization of the CBRS ecosystem is referred to as Citizens Broadband Radio Service 1.0 (CBRS 1.0). Beginning in June 2024, the calculations were revised based on the WInnForum Post Initial Certification Revisions Specification document, collectively referred to in this report as Citizens Broadband Radio Service 2.0 (CBRS 2.0) [2].

1.2. Test Request

The DoD 3.5 GHz Transition Plan focuses on ecosystem validation, environmental assessments, and continued engagement in refining the CBRS infrastructure. DISA identified one component for submission to NASCTN via a test request: to evaluate the effectiveness of the CBRS sharing ecosystem that manages coexistence between Federal incumbent systems and commercial users through an independent trusted agent.

The DISA test request sought to achieve four objectives regarding the assessment of the CBRS band:

1. Provide data to determine efficacy of permanent sharing between CBRS systems as managed by SAS systems and ESC systems

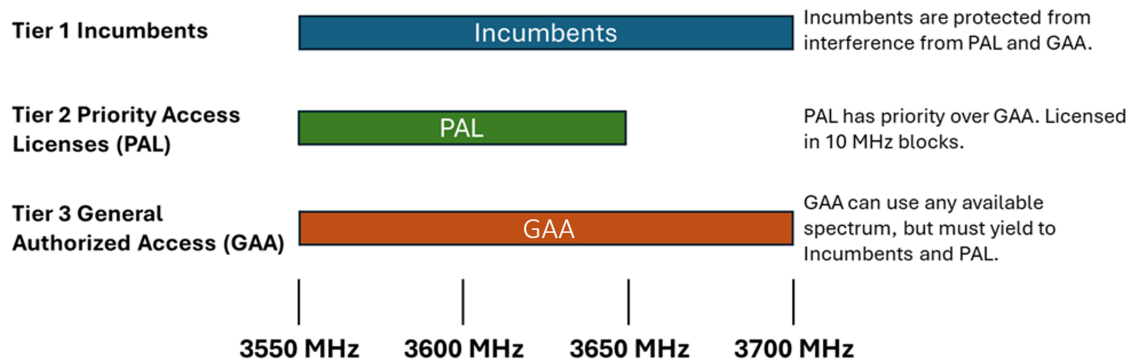


Fig. 1. FCC's three-tiered access for CBRS.

- Attempt to obtain corroborating data from [CBRS](#) community stakeholders
2. Collect power levels in the [CBRS](#) band through continuous automated observations
 3. Collect emissions in the [CBRS](#) band in the vicinity of San Diego, CA and Norfolk, VA
 4. Collect emissions in the [CBRS](#) band within at least one Always-On [DPA](#) (United States Marine Corps ([USMC](#)) Camp Pendleton)

The [DISA](#) test request was further divided into three major components:

- **Passive Observation Coastal [DPAs](#):** Characterize aggregate emissions within the [CBRS](#) band 3550 MHz to 3700 MHz in the vicinity of at least two Coastal [DPAs](#), with and without [DPA](#) activations. Assess ecosystem performance to respond in a timely manner, and measure the increase in background emissions due to wireless system deployments over time.
- **Passive Observation Always On [DPA](#):** Characterize aggregate emissions within the [CBRS](#) band 3550 MHz to 3700 MHz in at least one Always-On [DPA](#) or ground-based [DPA](#) ([GB-DPA](#)). Assess ecosystem performance to limit [CBRS](#) emissions in the Always-On [DPA](#).
- **Long Term Support:** Collection and analysis of Passive Observations over 4 years, and support transfer of data to a [DoD](#) data repository.

The [DISA](#) test request encompasses the full [CBRS](#) band, 3550 MHz to 3700 MHz. The [DPA](#) modeling analyses presented in this report focus on the lower 100 MHz, 3550 MHz to 3650 MHz, where [DPAs](#) are used to protect Federal incumbent operations. Accordingly, the [DPA](#) modeling generally evaluates ten 10 MHz channels spanning 3550 MHz to 3650 MHz.

These test request components form the basis for the objectives of the [NASCTN CBRS](#) Sharing Ecosystem Assessment ([SEA](#)), as described in the associated test plans for studying [CBRS](#) ecosystem dynamics, sensor development and deployment, and the data pipeline for

collecting and disseminating sensor observations [3, 4]. The following sections describe how modeling and simulation support these objectives and the assessment of the CBRS ecosystem.

1.3. Modeling Methodology

This document outlines the methodology used to inform sensor site selection and sensor data analysis before and during the execution phase of the test plan. The sensors are deployed on the East and West Coasts and in Boulder, CO. The East Coast sensors are in proximity to the coastal or ESC-monitored DPA (E-DPA) known as East 1, which covers the maritime region near Norfolk, Virginia, as well as the harbor E-DPA. The West Coast sensors are proximal to the E-DPA West 13 and West 14, which cover maritime regions near San Diego and Long Beach, California, as well as the harbor E-DPA for San Diego. One West Coast sensor is located inside GB-DPA Camp Pendleton, California. Figure 2 shows the locations of the deployed sensors. The sensor in Boulder, CO, provides a reference point in an area not covered by a DPA. Further information on the sensors and their installation parameters is provided in the NASCTN test plans and hardware development documentation [3–5].

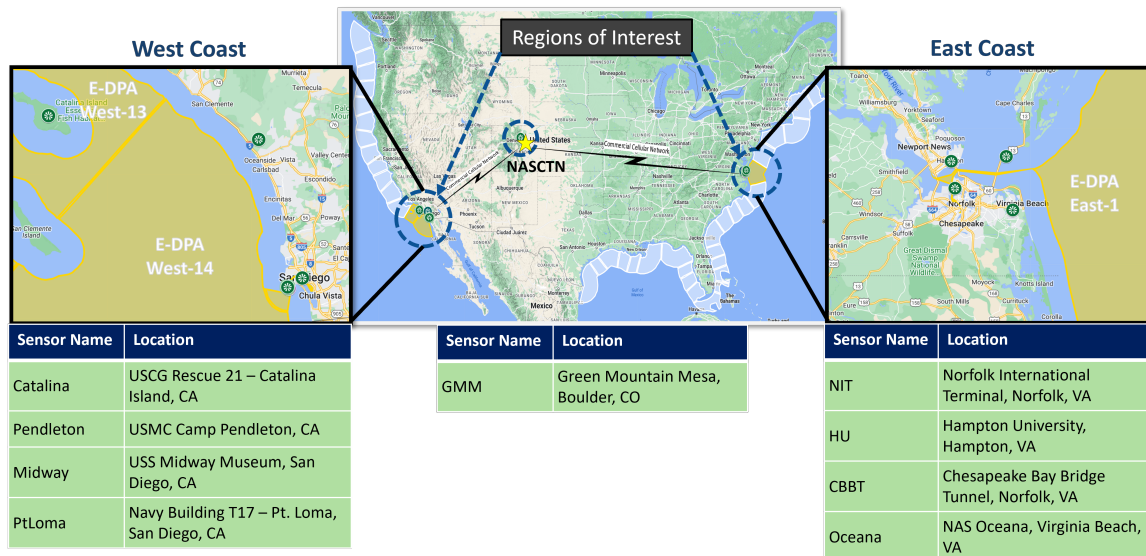


Fig. 2. Map of deployed NASCTN SEA sensors.

Figure 3 depicts the high-level modeling workflow. Through collaboration with National Telecommunications and Information Administration (NTIA), CBRS Interagency Joint Working Group (IJWG), and industry, several CBSD deployment laydowns were considered, including census population based, obfuscated, and Full Activity Dump (FAD) datasets. The census population based laydown represents a simulated deployment developed during the initial formulation of CBRS sharing rules, while the obfuscated laydown was developed

for use by Federal agencies while protecting industry data. The [FAD](#) data provide time specific information on registered [CBSDs](#) and grants and are used as the primary deployment input for the analyses presented in this report.

Both [CBRS 1.0](#) and [CBRS 2.0 DPA](#) Move List models based on the [WInnForum](#) reference implementations were used to calculate [CBSD](#) Move Lists and associated Keep Lists and estimate aggregate emissions at [DPA](#) protection points and [SEA](#) sensor locations. Section 2 describes the [CBSD](#) deployment data, [DPA](#) Move List calculations, and aggregate emission modeling. Section 3 describes how radio frequency ([RF](#)) horizon modeling and predicted [CBSD](#) emission levels were used to inform sensor location selection. Section 4 compares modeled aggregate emissions with sensor measurements and examines associated modeling assumptions and uncertainties. Finally, Section 5 evaluates the sensitivity of [CBRS 2.0 DPA](#) neighborhood distance calculations to protection point selection and [CBSD](#) deployment laydown.

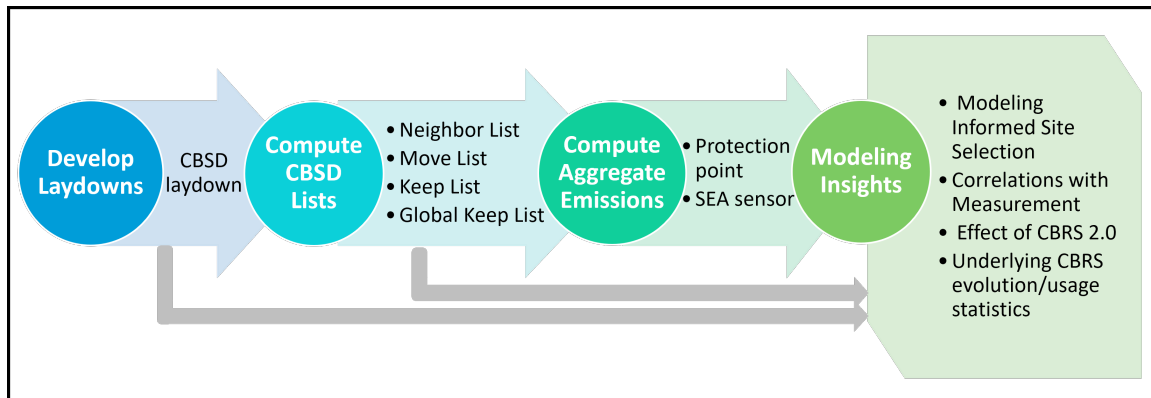


Fig. 3. Modeling workflow.

1.4. Program Publication

This document is not intended to be a comprehensive overview of the [NASCTN CBRS SEA](#) project. Several related documents are available in draft form [3, 4], have been published [5, 6], or are in preparation. Figure 4 shows the publication plan and responsible organizations as of the time of this publication. This document supplements the series of previous and pending publications.

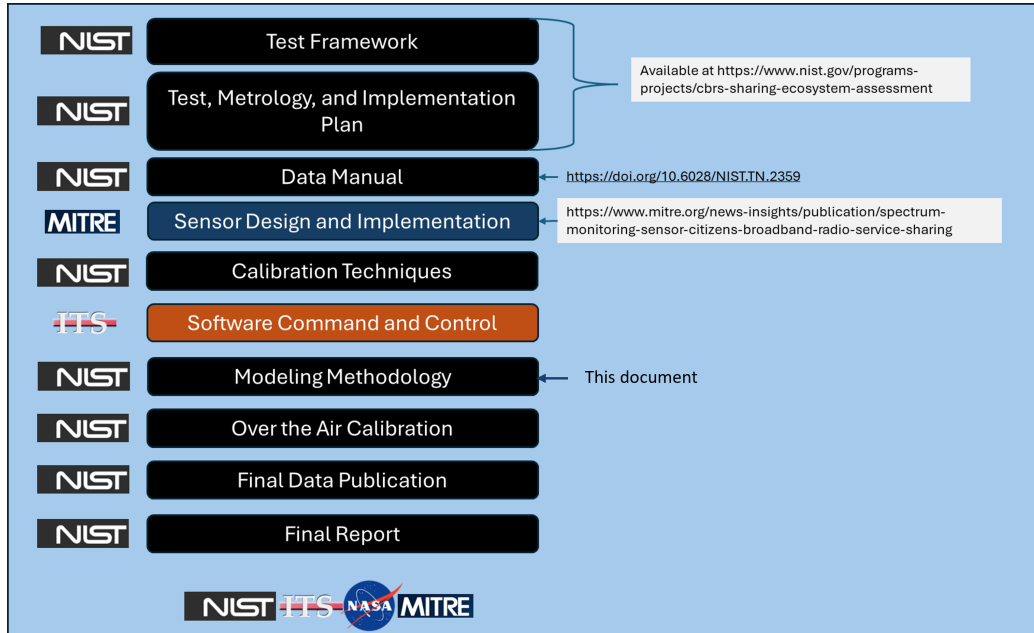


Fig. 4. NASCTN CBRS SEA publications.

2. Modeling Approach

This section details the foundational input data, algorithms, and software used for the modeling.

2.1. CBSD Deployment Laydown

The SAS Administrators provided the NTIA Office of Spectrum Management (OSM) and Institute for Telecommunication Sciences (ITS) FAD data on CBRS deployment on a quarterly basis [7]. In a joint collaboration to support the SEA project, NASCTN received two sets of FAD data generated on April 1, 2025 and July 1, 2025 from NTIA ITS. In this report, the July 1, 2025 FAD dataset is used to present the CBSD deployment laydown and modeling analyses. Analyses using the April 1, 2025 FAD dataset produced similar overall modeling results and, therefore, are not presented in this report.

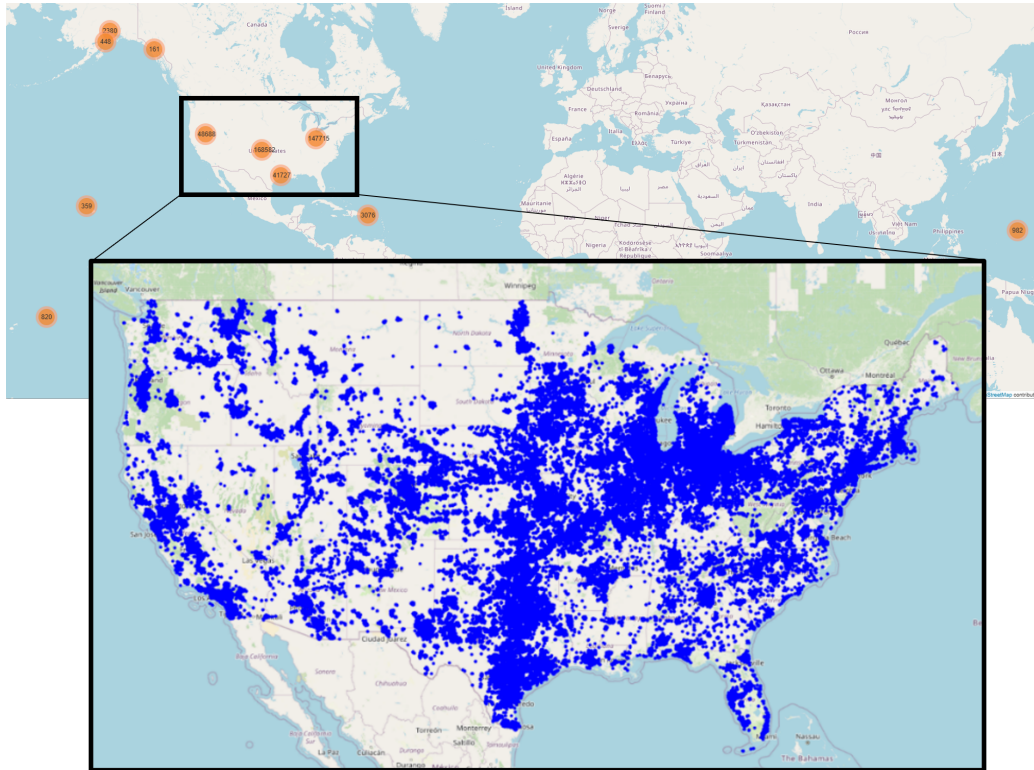


Fig. 5. CBSD laydown populated from July 1, 2025 FAD data.

Figure 5 depicts the CBSD deployment laydown populated from the FAD data. The total number of CBSDs with one or more unexpired grants is 414 938, where more than 400 000 CBSDs are deployed within the contiguous United States (CONUS). There are approximately 96 % outdoor Category B CBSDs and 4 % indoor Category A CBSDs. The CBSDs employ various radio access technologies, including Third Generation Partnership

Project (3GPP) Evolved Universal Terrestrial Radio Access (E-UTRA) and Fifth Generation New Radio (5G NR), as well as proprietary fixed wireless access protocols from vendors such as Tarana Wireless and Cambium Networks. According to the WInnForum standards [8], each CBSD can have multiple grants operating on different channels as either PAL or GAA. This dataset contains 1 236 605 active grants in total, with 19 % assigned to PAL and 81 % to GAA. The operational channel bandwidth for each grant can be from the set {5, 10, 20, 40} MHz. Additional information about FAD data and CBSD grants can be found in the WInnForum reports [8] and [9].

2.2. WInnForum Reference DPA Move List Algorithm

Regulatory rules [10] require that the SAS administrators manage their CBSD transmissions to protect the operations of existing incumbents in the band. To meet the requirement, the WInnForum CBRS standards specified the DPA protection procedure, also known as the DPA Move List Calculation, to be executed by all SASs during Coordinated Periodic Activities among SASs (CPAS) [11]. Given a set of CBSD transmissions that have or request grants overlapping with a protected frequency range, the Move List calculation identifies which transmissions must be suspended (and possibly relocated to a different channel) to avoid excessive interference in a protected federal incumbent area. Details of the calculation and its reference implementation can be found in [1, R2-SGN-24] and [12].

The primary output of the Move List algorithm is the Move List of CBSDs for each 10 MHz channel for each DPA. For the purpose of this modeling and simulation, a Neighbor List and a Keep List for the DPA are also considered. The Neighbor List is defined as the union of the Neighbor Lists of the protection points inside the DPA. The Keep List is defined as the complement of the Move List and contains grants that may remain active on the protected channel when the DPA is active.

In 2024, the CBRS IJWG proposed several changes that significantly impacted the DPA protection calculation and results. These algorithmic modifications form the basis for the transition from CBRS 1.0 to CBRS 2.0. Table 1 compares the methods and factors used in CBRS 1.0 to CBRS 2.0. These modifications include the Irregular Terrain Model (ITM) path loss and interference calculation, duty cycle and network loading factor, ITU-R P.2108 clutter loss [13, Section 3.2], and DPA neighborhoods. The 8 dB duty cycle and network loading adjustment corresponds to an assumed 80 % time division duplex (TDD) activity factor and 20 % network loading factor, resulting in an average power factor of $0.8 \times 0.2 = 0.16$, or approximately -8 dB [2].

Table 1. Implementation changes between CBRS 1.0 and CBRS 2.0 impacting DPA Move List and aggregate interference calculation.

Factor	CBRS 1.0	CBRS 2.0
Path loss and aggregate interference calculation	Use the 95 th -percentile aggregate interference from a 2000-iteration Monte Carlo with randomized ITM reliability values from 1 % to 99.9 %	Use a fixed 50 % ITM reliability (median)
Duty cycle and network loading factor	None	Apply an 8 dB duty cycle and network loading adjustment to all CBSDs
Clutter	None	Apply median clutter loss to all CBSDs with antenna height ≤ 6 m AGL
DPA neighborhoods	Use 4 neighborhood categories: - Category B CBSD - OOB Category B CBSD - Category A CBSD - OOB Category A CBSD	Use 8 neighborhood categories: - Category B CBSD (> 6 m AGL) - Category B CBSD (≤ 6 m AGL) - Outdoor Category A CBSD (> 6 m AGL) - Outdoor Category A CBSD (≤ 6 m AGL) - Indoor Category A CBSD (> 6 m AGL) - Indoor Category A CBSD (≤ 6 m AGL) - OOB Category A CBSD: 0 km - OOB Category B CBSD: 0 km

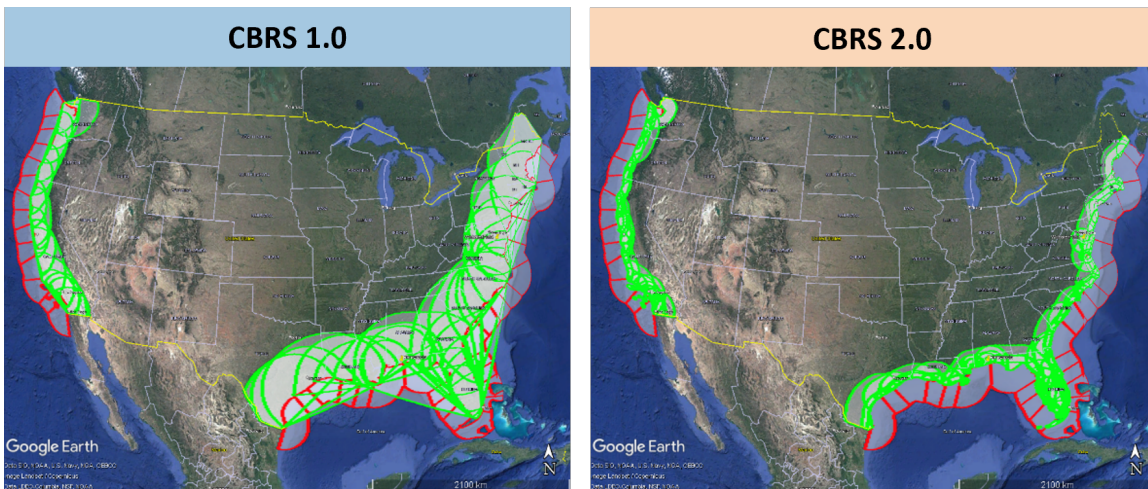


Fig. 6. Illustrations of E-DPA Category B neighborhood sizes used in CBRS 1.0 and CBRS 2.0 Move List calculation.

A major modification in **CBRS 2.0** is the reduction in **CBSD** neighborhood distances, especially for Category B **CBSD**s. Figure 6 illustrates the Category B **CBSD** neighborhoods (green polygons) associated with **DPAs** (red polygons) on the East and West Coasts. As shown in the figure, the neighborhoods are much smaller for **CBRS 2.0** than for **CBRS 1.0**, especially

on the East Coast. The larger **CBRS 1.0** neighborhood distances on the East Coast relative to the West Coast reflect differences in coastal geography and terrain-dependent propagation, including greater terrain blockage in mountainous areas along the West Coast. The reduced **CBRS 2.0** neighborhood distances result from revisions to the aggregate interference modeling framework intended to better represent **CBSD** operation and propagation while maintaining incumbent protection.

2.3. DPA List Sizes

To assess the impacts of **CBRS 2.0** on the aggregate emissions collected by **NASCTN CBRS SEA** sensors, **NASCTN** implemented both versions of the **DPA** Move List algorithm and ran simulations using the July 1, 2025 **FAD** data. Figure 7 compares the number of **CBSD** grants on the Move and Keep Lists for each 10 MHz channel using the **CBRS 1.0** and **CBRS 2.0** implementations for **E-DPAs** East 1, West 13, West 14, and **GB-DPA** Camp Pendleton.

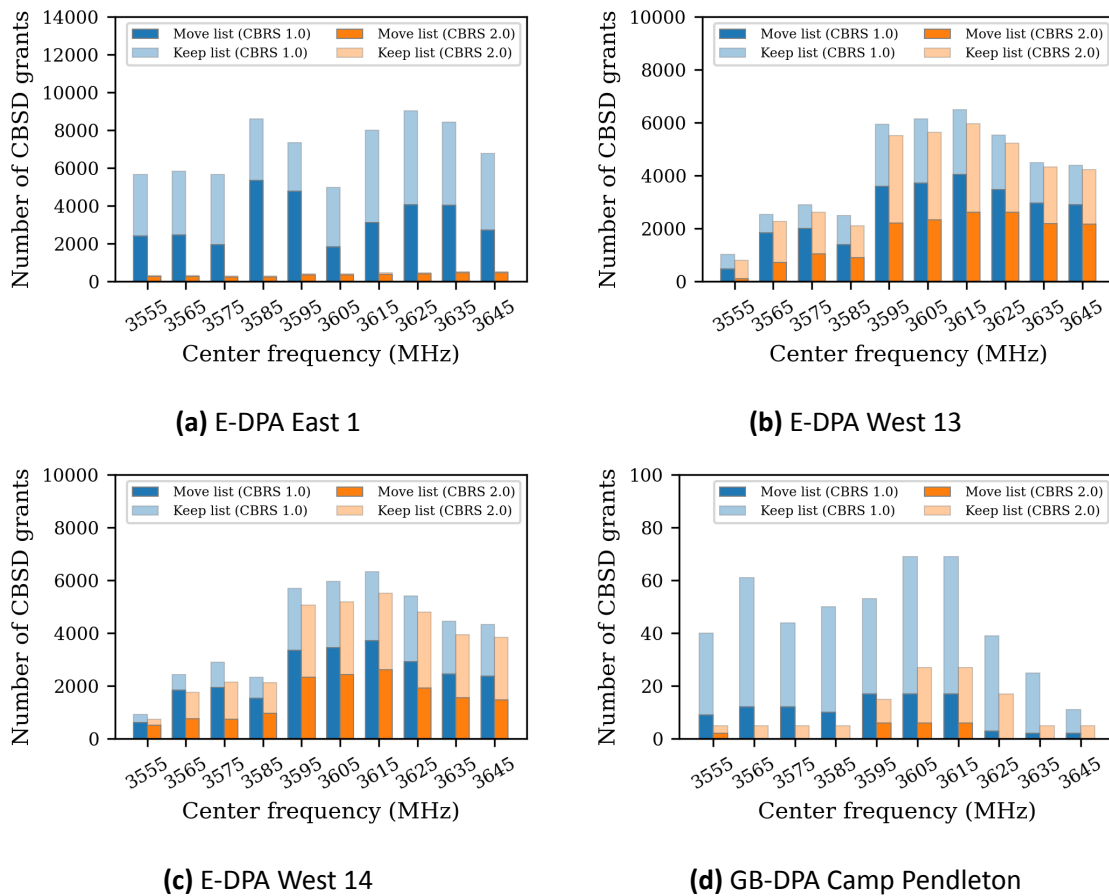


Fig. 7. Comparison of the number of CBSD grants on the Move List and Keep List of different DPAs for CBRS 1.0 and CBRS 2.0.

The smaller [DPA](#) neighborhood distances in [CBRS 2.0](#) result in smaller Neighbor Lists, i.e., the combined Move and Keep Lists, for the 10 MHz channels evaluated here. This effect is particularly apparent for [E-DPA](#) East 1 and [GB-DPA](#) Camp Pendleton. The Move List sizes are also affected by other changes implemented in [CBRS 2.0](#), including the 8 dB duty cycle and network loading adjustment, clutter loss, and the revised statistical treatment of [ITM](#) propagation.

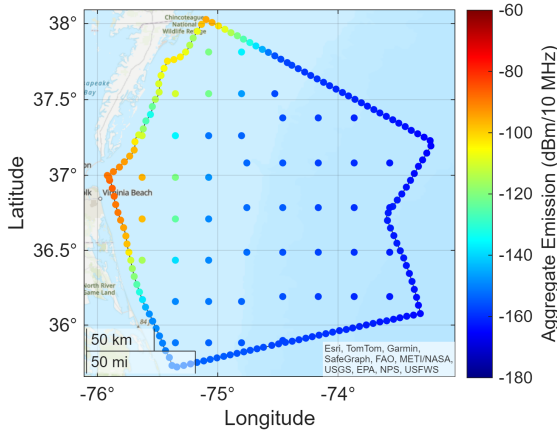
2.4. Aggregate Emission at Protection Points within a DPA

This section presents aggregate emission estimates at protection points within [DPAs](#) of interest. The calculation is based on the [WInnForum](#) aggregate interference check at a potential radar location [1, R2-SGN-12] and [12]. The statistical treatment of aggregate interference differs between the [CBRS 1.0](#) and [CBRS 2.0](#) implementations. For [CBRS 1.0](#), aggregate interference is evaluated using 2000 Monte Carlo iterations with varying [ITM](#) reliability, and the 95th-percentile aggregate interference is determined for each radar antenna pointing direction. For [CBRS 2.0](#), [ITM](#) propagation loss is evaluated at a fixed 50 % reliability (median). For both implementations, the reported aggregate interference value at each protection point is the maximum across 240 radar antenna pointing directions. In this report, the resulting aggregate interference estimates at [DPA](#) protection points are referred to as modeled aggregate emission.

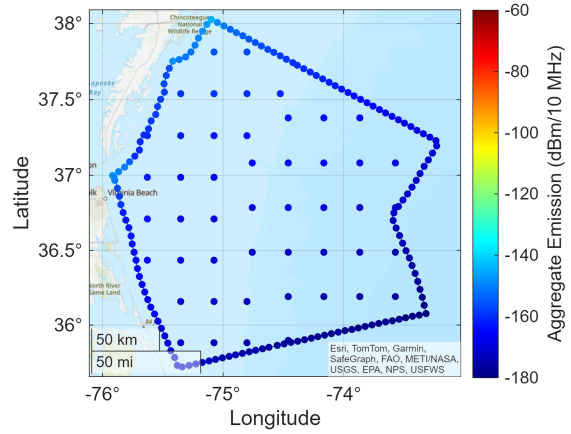
2.4.1. E-DPA

For [E-DPAs](#) East 1, West 13, and West 14, the aggregate emission at each protection point is estimated when the [E-DPA](#) is inactive and active. When the [E-DPA](#) is inactive, i.e., no incumbent presence is detected within the [E-DPA](#), the aggregate emission is calculated from the Neighbor List [CBSDs](#). When the [E-DPA](#) is active due to detection of incumbent presence, the aggregate emission is calculated from the Keep List [CBSDs](#). The reference radar directional antenna pattern in [1] is applied at each protection point, using a 3.0° beamwidth normalized to 0 dBi peak gain.

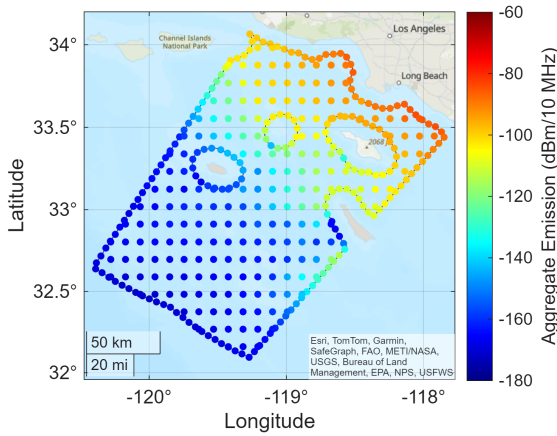
Figure 8 shows examples of aggregate emission heatmaps at protection points inside [E-DPAs](#) East 1, West 13, and West 14 for the 3570 MHz to 3580 MHz channel using the [CBRS 2.0](#) implementation and [CBSD](#) registrations from the July 1, 2025 [FAD](#) dataset. Figures 8a, 8c, 8e show heatmaps of inactive [DPAs](#), whereas Figures 8b, 8d, 8f show heatmaps of active [E-DPAs](#). When the [E-DPA](#) is inactive, the protection points closer to the shore receive stronger aggregate emission levels from the Neighbor List [CBSDs](#) than those protection points further offshore. This is mainly due to greater propagation losses at longer distances. When the [E-DPA](#) is activated, [CBSDs](#) on the Move List are suspended or re-assigned to another channel. The Move List calculation is designed to limit aggregate interference from the remaining Keep List grants at the protection points to the required protection level of -144 dBm/10 MHz [1, R2-IPM-04].



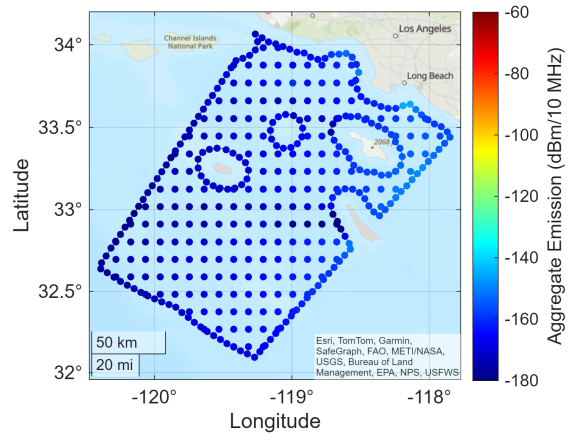
(a) E-DPA East 1 is inactive



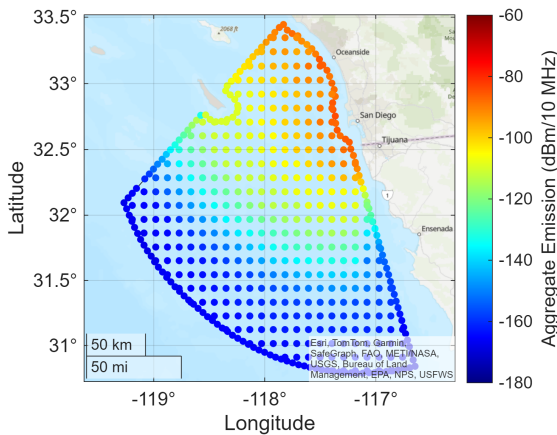
(b) E-DPA East 1 is active



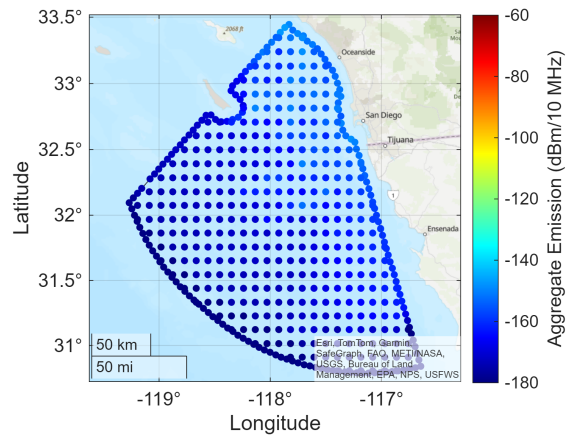
(c) E-DPA West 13 is inactive



(d) E-DPA West 13 is active



(e) E-DPA West 14 is inactive



(f) E-DPA West 14 is active

Fig. 8. Aggregate emission estimate at protection points inside E-DPAs East 1, West 13, and West 14 when the E-DPA is inactive and active for the 3570 MHz to 3580 MHz channel using the CBRS 2.0 implementation and the July 1, 2025 FAD dataset.

Figure 9 presents cumulative distribution functions (CDFs) of the modeled aggregate emission across the protection points within each E-DPA for the 3570 MHz to 3580 MHz channel. For each E-DPA, the left panel shows the inactive state, for which aggregate emission is calculated from grants on the Neighbor List, and the right panel shows the active state, for which aggregate emission is calculated from grants on the Keep List. The CBRS 1.0 and CBRS 2.0 implementations are shown for comparison. The dashed vertical line indicates the -144 dBm/10 MHz protection threshold. For the inactive DPA cases shown, the CBRS 2.0 distributions are shifted toward lower modeled aggregate emission levels relative to CBRS 1.0. The lower modeled aggregate emission levels result from the combined effects of changes implemented in CBRS 2.0, including the revised DPA neighborhood distances, the duty-cycle and network-loading adjustment, clutter loss, and the revised statistical treatment of ITM propagation. The contribution of each individual change is not isolated in this analysis. For the active E-DPA cases, the relative shift between the CBRS 1.0 and CBRS 2.0 distributions varies by DPA, reflecting differences in Keep List composition and in the propagation and aggregate interference calculations used by the two implementations.

To provide an overall comparison across the evaluated E-DPAs, Figure 10 pools the modeled aggregate emission values from all protection points, E-DPAs, and evaluated 10 MHz channels into empirical CDFs for the inactive and active states. These pooled distributions summarize the overall differences between the two implementations but do not preserve DPA-, channel-, or protection-point-specific behavior. When the E-DPAs are inactive, the CBRS 2.0 CDF is shifted to lower aggregate-emission levels relative to CBRS 1.0. This shift reflects the combined effects of the revised DPA neighborhood distances, duty-cycle and network-loading adjustment, clutter loss, and revised statistical treatment of ITM propagation; the contribution of each individual change is not isolated in this analysis. For the active DPA cases, the upper tails of both CBRS 1.0 and CBRS 2.0 distributions overlap more closely near the -144 dBm/10 MHz protection threshold, although differences remain at lower aggregate emission levels. These differences reflect the combined effects of changes to the Keep List composition and the propagation and interference calculation parameters used in the two implementations.

2.4.2. GB-DPA

Unlike E-DPAs, which can be activated or deactivated due to incumbent activities, a GB-DPA is always-on, with channel-specific static protection criteria to protect adjacent-band incumbent systems. This results in the suspension of all transmissions of Move List CBSDs until these CBSDs can be removed from the Move List during the next CPAS. Thus, the aggregate emissions at protection points inside the GB-DPA are computed only from the Keep List. In addition, unlike E-DPAs, which have a fixed protection threshold at -144 dBm/10 MHz, the protection threshold for GB-DPAs is much higher and varies across 10 MHz channels in 3550 MHz to 3650 MHz. Figure 11 shows a heatmap of aggregate emission estimates at protection points inside the always-on GB-DPA MCBPendleton-3 on 3570 MHz to

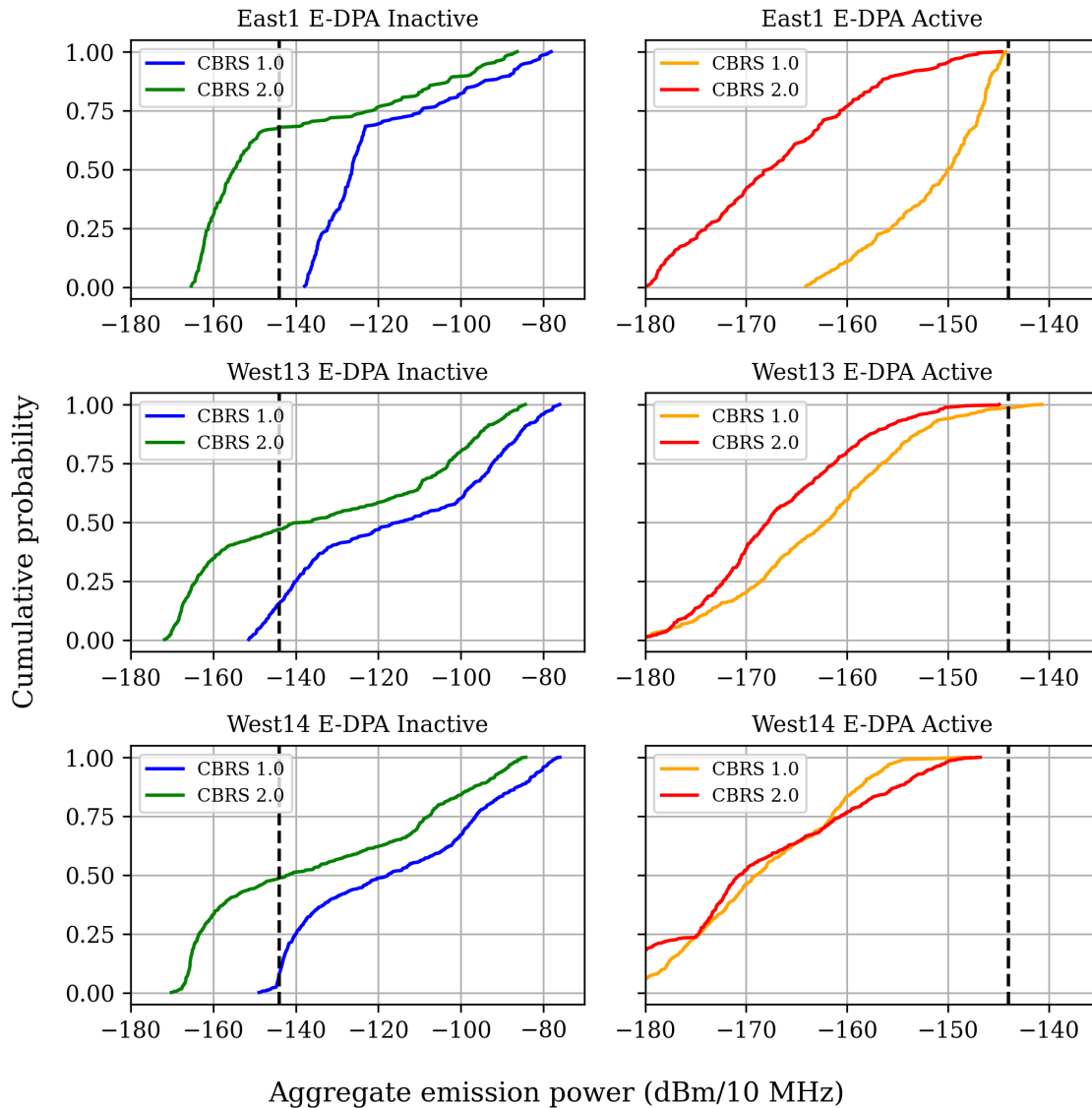


Fig. 9. Empirical CDFs of modeled aggregate emission across protection points within E-DPAs East 1, West 13, and West 14 for the 3570 MHz to 3580 MHz channel using the CBRS 1.0 and CBRS 2.0 implementations.

3580 MHz channel. The protection threshold on this channel is -76 dBm/10 MHz, which falls within the range of -79 dBm/10 MHz to -71 dBm/10 MHz for other channels in the 3550 MHz to 3650 MHz band. As shown in the figure, aggregate emissions are higher at protection points further south due to a nearby cluster of [CBSDs](#) operating on this channel, but all are below the required threshold of -76 dBm/10 MHz.

Figure [12](#) presents empirical [CDFs](#) of the modeled aggregate emission across protection points within [GB-DPA](#) MCBPendleton-3 for the 3570 MHz to 3580 MHz channel using the

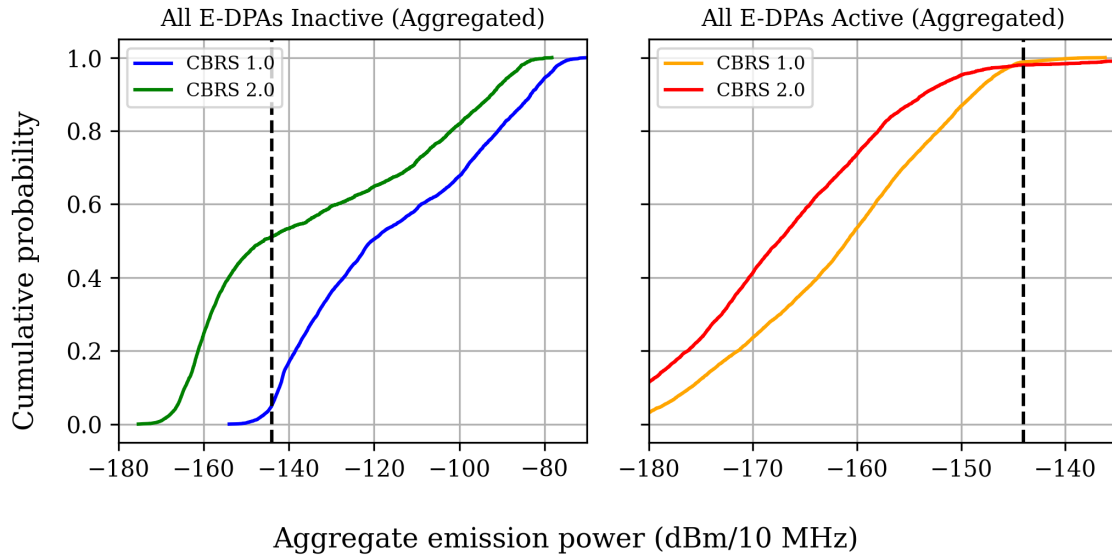


Fig. 10. Empirical CDFs of modeled aggregate emission pooled across protection points, E-DPAs, and 10 MHz channels using the CBRS 1.0 and CBRS 2.0 implementations.

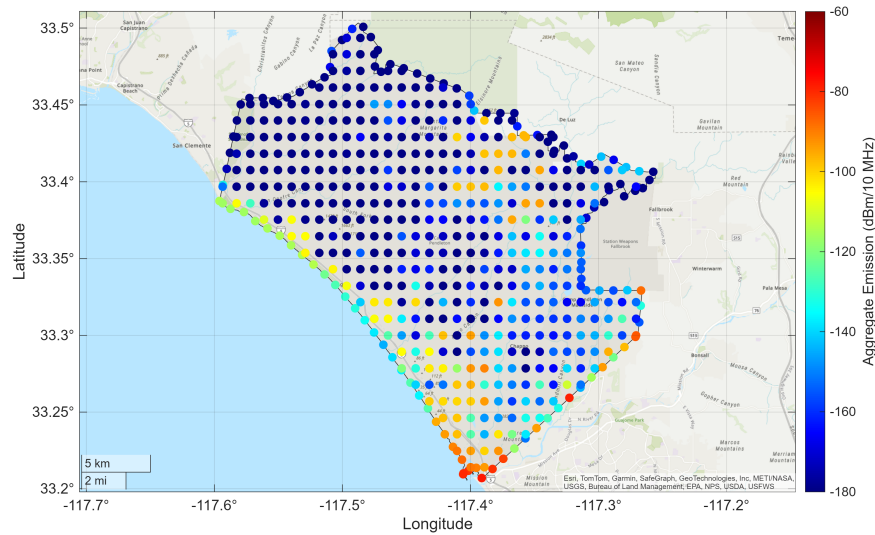


Fig. 11. Modeled aggregate emission at protection points within GB-DPA MCBPendleton-3 for the 3570 MHz to 3580 MHz channel using the CBRS 2.0 implementation.

CBRS 1.0 and CBRS 2.0 implementations. Because this GB-DPA is always on, aggregate emission is calculated from grants on the Keep List for both implementations. The CBRS 2.0 distribution is shifted toward lower aggregate-emission levels relative to CBRS 1.0 for this channel. The dashed vertical line indicates the -76 dBm/10 MHz protection threshold, and

the modeled aggregate emission remains below this threshold for all evaluated protection points under both implementations.

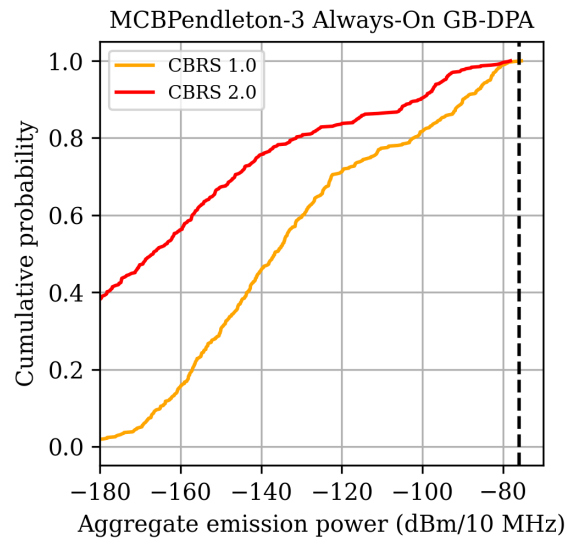


Fig. 12. Empirical CDFs of modeled aggregate emission across protection points within GB-DPA MCBPendleton-3 for the 3570 MHz to 3580 MHz channel using the CBRS 1.0 and CBRS 2.0 implementations.

3. Modeling Informed Sensor Location Selection

To assess the effectiveness of spectrum sharing in the [CBRS](#) ecosystem across geographic regions of interest, the [NASCTN SEA](#) project needed to identify potential sensor locations to survey the vicinity of San Diego, CA and Norfolk, VA. Modeling was used to identify potential sensor locations by estimating the SEA sensors' [RF](#) horizon coverage of [CBSDs](#) and predicting anticipated [CBSD](#) emission levels at these locations.

Once [RF](#) horizon mappings were modeled and anticipated [CBSD](#) emission levels were predicted, physical site surveys were conducted at identified candidate locations to determine whether a deployed sensor could achieve its desired functions:

- measure dynamics in emissions due to [DPA](#) activation,
- measure longitudinal changes in cellular emissions,
- observe aggregate and residual emissions during periods of [DPA](#) activation.

Besides technical challenges, there are obstacles and complexities in getting access and approval for sensor installations at civilian and military locations. The combination of constraints imposed by site survey results and logistical challenges was used to further reduce the set of potential locations and generate new locations, thereby developing an increasingly viable set of deployment sites. For each repetition of this process, the [RF](#) coverage of any new location was calculated. Thus, the site modeling and physical survey process was iterated to identify the practical sensor locations that meet the technical objectives within a given area.

3.1. Sensor RF Horizon Mapping

To aid in identifying potential sensor locations, a sensor [RF](#) horizon mapping tool was developed to estimate the geographic region over which a [CBSD](#) signal is expected to exceed the sensor sensitivity threshold. The tool is based on the [WinnForum](#) approach for computing an [ESC](#) sensor "whisper zone" [12, 14], with parameter adjustments appropriate for the [NASCTN](#) sensor design and deployment and the [CBRS 2.0](#) implementation. Although the tool can be applied to different [CBSD](#) categories and indoor and outdoor deployments, this section presents [RF](#) horizon mapping examples for outdoor Category B [CBSDs](#). Table 2 lists the parameters used by the tool, including [CBSD](#) installation parameters, sensor sensitivity and antenna pattern, propagation model, and other modeling factors.

To account for the directional response of the sensor antennas, modeled 2D radiation patterns for the commercial antennas are incorporated into the simulation. Figure 13 illustrates the modeled radiation patterns at 3600 MHz for an omnidirectional antenna and a 15° panel antenna in both vertical and horizontal polarizations. Figures 13a and 13b display the 0° elevation and full 2D patterns for the omnidirectional antenna. Figures 13c and 13d provide the corresponding views for the panel antenna in vertical polarization, and

Table 2. Parameter assumptions used by the RF horizon mapping tool to estimate SEA sensor coverage of Category B CBSDs.

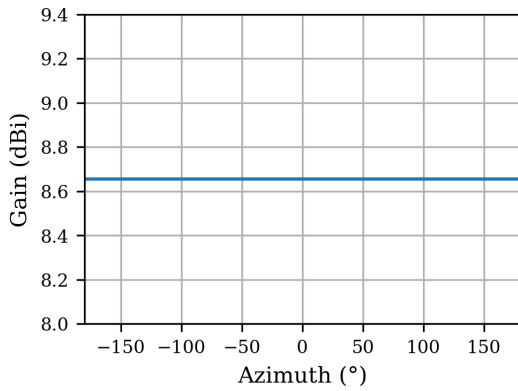
Parameter		Value
Category B CBSD	EIRP (dBm/MHz)	37
	Antenna height (m)	25
SEA Sensor	Sensitivity (dBm/MHz)	-108
	2D antenna pattern	Omnidirectional and panel
Path Loss	Propagation model	ITM (median)
	Center frequency (GHz)	3.625
	Duty cycle & network loading factor (dB)	8

Figures 13e and 13f show the panel antenna patterns in horizontal polarization. While an omnidirectional antenna maintains uniform gain over a full 360° azimuth, a panel antenna concentrates its power to provide higher gain over a narrower beamwidth.

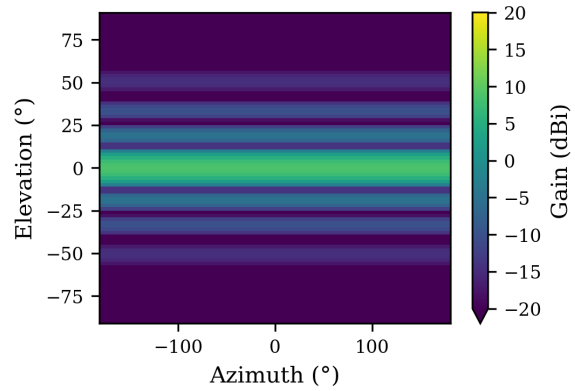
As sites were identified, the RF horizon mapping tool provides insight into what the sensors are expected to observe at each deployment location. Figure 14 shows examples of modeled RF horizon coverage of a Category B CBSD at different sensor locations using different antennas. Figures 14a and 14b show the mappings at a location on Island 4, Chesapeake Bay Bridge Tunnel (CBBT) in Virginia, using an omnidirectional antenna and a 15° panel antenna, respectively. Similarly, Figures 14c and 14d show the mappings at a location on Catalina Island using omnidirectional and panel antennas. The black circles show the areas around the sensor location with 10 km radius intervals. Under the assumptions in Table 2, Figures 14a and 14b indicate modeled coverage of a Category B CBSD extending to approximately 50 km from the CBBT sensor in some directions. For the omnidirectional antenna, the modeled coverage extends over most azimuths, whereas the panel antenna produces a narrower coverage region oriented toward the antenna pointing direction. Compared with the CBBT location, the Catalina sensor is at a much higher altitude, approximately 600 m, resulting in modeled coverage extending to approximately 140 km in some directions under the assumptions in Table 2. The modeled coverage also contains gaps where rugged terrain surrounding Catalina Island blocks the line-of-sight (LOS) path, and the remaining non-line-of-sight (NLOS) propagation paths do not provide sufficient link margin to meet the modeled detection threshold.

3.2. Sensor Placement

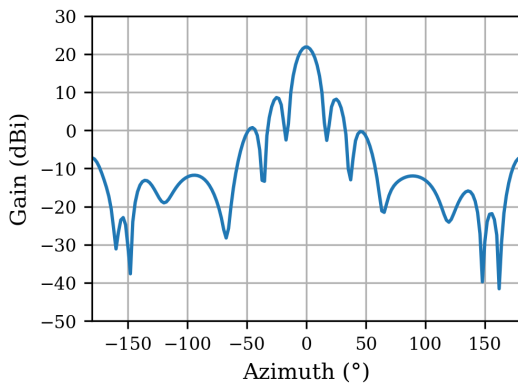
In discussions with the internal NASCTN team and stakeholders, an overall deployment strategy for sensors was developed for both the East and West Coasts. For sensors located within an area of dense CBSD deployment, variations in distance and propagation condi-



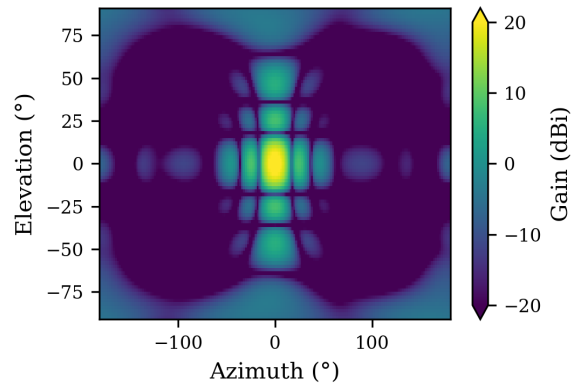
(a) Omnidirectional, 0° elevation pattern



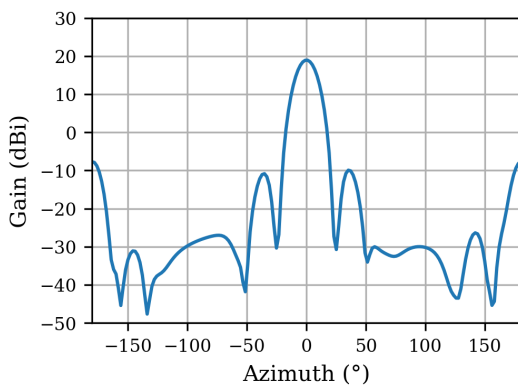
(b) Omnidirectional, 2D pattern



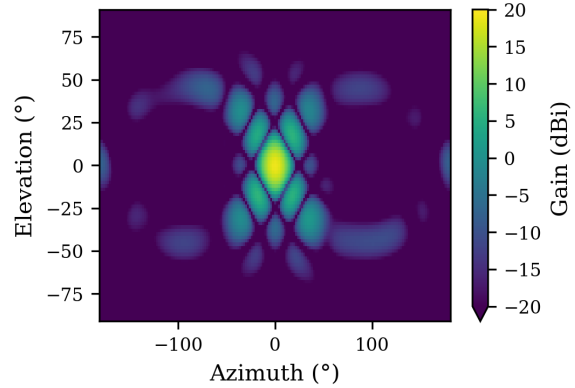
(c) Panel (vertical), 0° elevation pattern



(d) Panel (vertical), 2D pattern



(e) Panel (horizontal), 0° elevation pattern



(f) Panel (horizontal), 2D pattern

Fig. 13. 2D radiation patterns of omnidirectional and 15° panel antennas at 3600 MHz, with the panel antenna modeled in vertical and horizontal orientations.

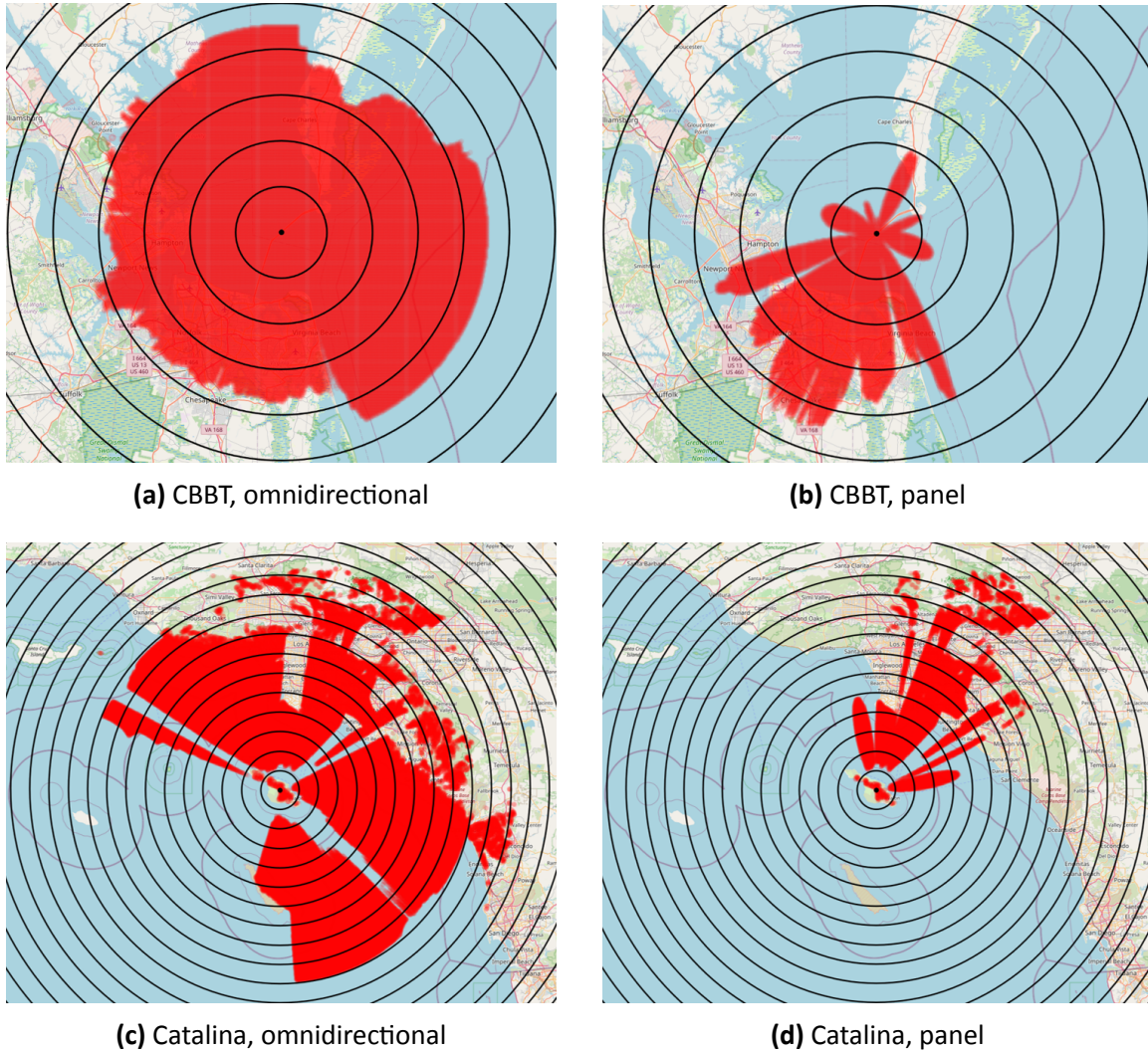


Fig. 14. RF horizon mapping of a Category B CBSD at Chesapeake Bay Bridge Tunnel (CBBT), Virginia, and Catalina Island, California. The radii of the concentric range circles increase in increments of 10 km.

tions can result in large differences in received power, such that measurements may be dominated by a small number of nearby **CBSDs**. For sensors located farther from the cluster, a given absolute difference in **CBSD**-to-sensor distance produces a smaller difference in free space path loss. As a result, the powers received from **CBSDs** within the cluster may be more comparable, allowing the sensor to provide a broader aggregate view of emissions from the cluster. Based on these considerations, sensors were considered both within and outside dense **CBSD** deployment areas.

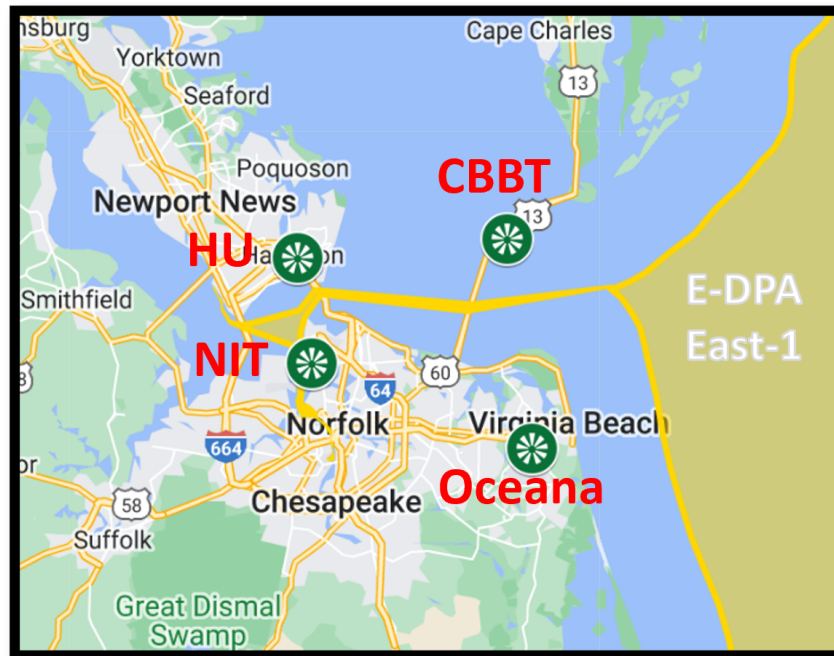
Using the **RF** horizon mapping tool, candidate sites were evaluated for their modeled coverage of **CBSD** emissions and their potential to observe aggregate emissions from multiple

CBSDs. As candidate locations were down-selected through modeling and physical site surveys, final sensor placements were determined based on deployment feasibility and the measurement objectives for each site. Table 3 provides installation parameters for the nine deployed sensors, with four sensors in the Norfolk, VA region, four sensors in the San Diego, CA region, and one sensor in Boulder, CO. Three sensors at **CBBT**, Catalina, and Point Loma have both omnidirectional and directional antennas installed. The sensor at Green Mountain Mesa (**GMM**) in Boulder, CO, serves as a non-**DPA** baseline sensor and a local development sensor to test software updates before deployment to remote sensors on the East and West Coasts. Figure 15a and Figure 15b display the deployed sensor locations on the maps.

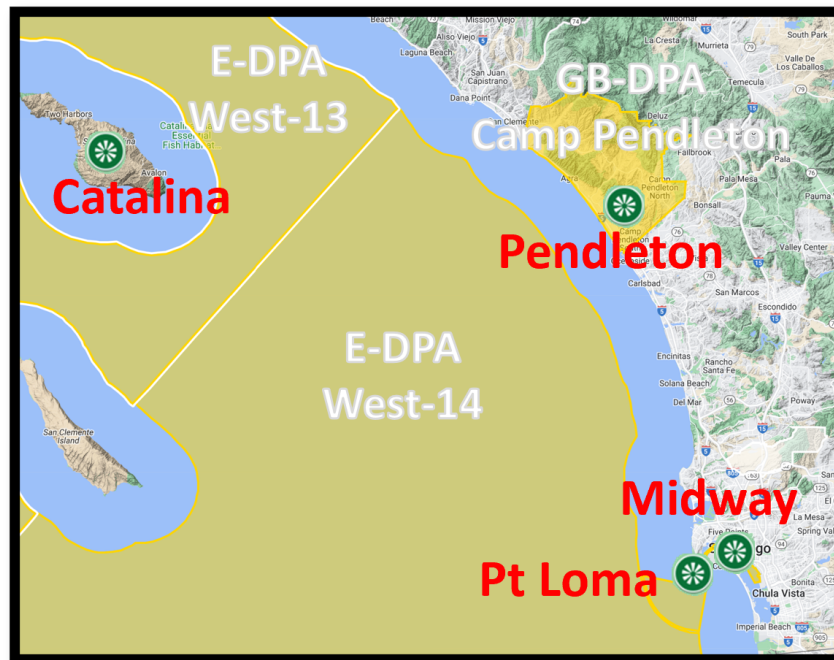
Table 3. SEA sensor installation parameters.

Sensor Short Name	Sensor Long Name	Location	Latitude	Longitude	Height (m)	Height Type	Antenna Type	Antenna Azimuth
NIT	Norfolk International Terminal	Norfolk, VA	36.91552	-76.32245	48.5	AMSL	Omni	
HU	Hampton University Tower	Hampton, VA	37.02578	-76.34120	70.4	AMSL	Omni	
CBBT-Omni	Island 4, Chesapeake Bay Bridge Tunnel	Chesapeake Bay, VA	37.04608	-76.06300	40.4	AMSL	Omni	
CBBT-Directional	Island 4, Chesapeake Bay Bridge Tunnel	Chesapeake Bay, VA	37.04608	-76.06300	39.5	AMSL	15° Panel Ver. Pol.	205°
Oceana	Naval Air Station Oceana	Virginia Beach, VA	36.82512	-76.02953	8.5	AGL	Omni	
Catalina-Omni	US Coast Guard Tower Site (Mt Orizaba)	Catalina, CA	33.37956	-118.41641	4.7	AGL	Omni	
Catalina-Directional	US Coast Guard Tower Site (Mt Orizaba)	Catalina, CA	33.37956	-118.41641	4.4	AGL	15° Panel Ver. Pol.	33.5°
Pendleton	USMC Camp Pendleton	USMC Camp Pendleton, CA	33.28231	-117.38838	6.4	AGL	Omni	
Midway	USS Midway Museum	San Diego, CA	32.71399	-117.17526	50.0	AGL	Omni	
PtLoma-Omni	Point Loma	San Diego, CA	32.67026	-117.24047	3.0	AGL	Omni	
PtLoma-Directional	Point Loma	San Diego, CA	32.67026	-117.24047	3.0	AGL	15° Panel Hor. Pol.	33°
GMM	Green Mountain Mesa	Boulder, CO	39.99180	-105.27452	1783.4	AMSL	90° Panel	12°

Taking the sensor deployments in the Norfolk, VA region, the two deployed sensors at Norfolk International Terminal (**NIT**) and Hampton University (**HU**) are both within areas of dense **CBSD** deployment. The sensor deployed at Naval Air Station Oceana is still within an area of **CBSD** deployment, but is farther from the highest concentration of **CBSDs**. These sensors are positioned to measure local **CBSD** emissions and changes associated with **DPA** activation and deactivation. The **CBBT** sensor, located outside the metropolitan area, provides a broader aggregate view of emissions from the Norfolk area with less influence from nearby **CBSDs**. Together, these sensor locations support measurements of **CBSD** emission changes in the Norfolk area associated with activation and deactivation of **E-DPA** East 1.



(a) East Coast



(b) West Coast

Fig. 15. Maps of deployed sensors near DPAs on the East and West Coasts.

On the West Coast, the Catalina sensor is located within the area enclosed by the inner boundary of E-DPA West 13, but outside the DPA itself and the metropolitan area, providing a broader view of aggregate emissions associated with DPA activation states. The Pendleton sensor is deployed within the always-on GB-DPA Camp Pendleton to measure residual emissions from CBSDs operating in the 3550 MHz to 3650 MHz band outside the GB-DPA. In the San Diego, CA region, the Midway and Point Loma sensors are located within areas of dense CBSD deployment and near E-DPA West 14 to measure local CBSD emission changes associated with DPA activation and deactivation.

Figure 16a and Figure 16b show the overlaid modeled RF horizon coverage for sensors deployed on the East and West Coasts, respectively. The black markers indicate sensor locations, and the shaded regions represent the modeled coverage of a Category B CBSD under the assumptions described in Section 3.1. On the East Coast, the relatively flat terrain results in more continuous modeled coverage, and the higher sensor density produces substantial overlap in coverage. On the West Coast, the rugged terrain creates gaps in the modeled coverage, while the more dispersed sensor deployment leads to less coverage overlap.

3.3. Emitter Coverage Check

Several analyses were performed to assess sensor coverage in the vicinity of a DPA for different measurement objectives, such as aggregate emission measurements and model comparisons. This section evaluates the coverage provided by the deployed NASCTN SEA sensors and can inform consideration of additional sensor deployments.

Figure 17 illustrates the distribution of CBSD grants on the Move List and Keep List for each 10 MHz channel in the 3550 MHz to 3650 MHz band for East 1, West 13, West 14, and Camp Pendleton. Grants are categorized according to whether their locations fall within the modeled RF horizon coverage of at least one SEA sensor. For East 1, most Move List grants fall within the modeled coverage of at least one sensor, whereas the Keep List grants are generally outside the modeled coverage. For West 13 and West 14, which have larger neighborhoods and more grants, smaller fractions of the grants fall within the modeled sensor coverage. For Camp Pendleton, transmissions associated with Move List grants are suspended, while a substantial fraction of the Keep List grants fall within the modeled coverage of the Pendleton sensor.

Table 4 summarizes the modeled RF horizon coverage of Move List and Keep List grants within the neighborhoods of East 1, West 13, West 14, and Camp Pendleton. For each DPA, the table lists the monitoring sensors, the total number of grants, and the percentage of grants whose locations fall within the modeled coverage of at least one sensor. Because these values vary by channel, they are presented as ranges representing the minimum and maximum values across the ten evaluated 10 MHz channels. None of the East 1 Keep List grants and only 0 % to 2 % of West 14 Keep List grants fall within the modeled sensor

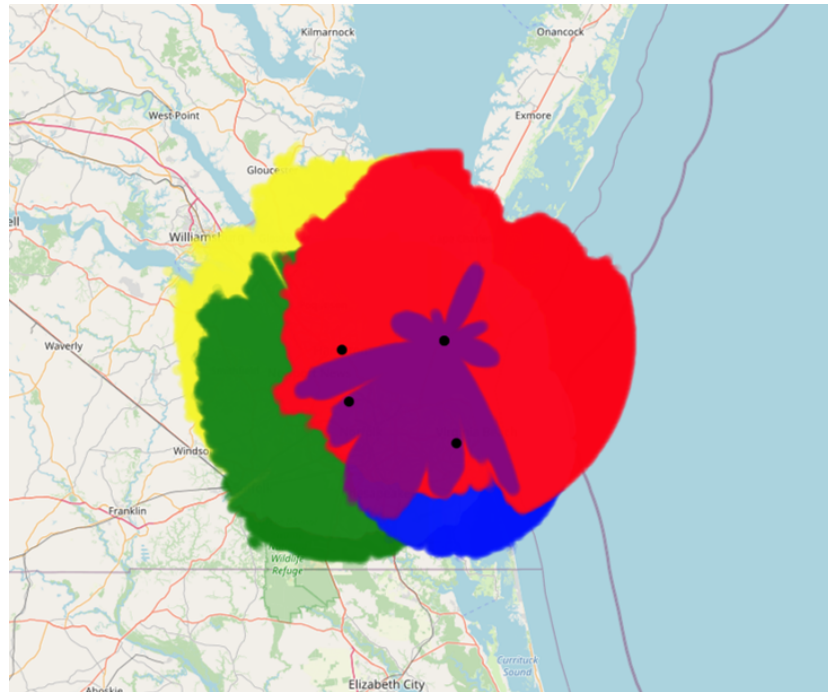
coverage. These grants are mostly associated with indoor CBSDs and/or low operating powers.

Table 4. Summary of modeled RF horizon coverage of CBSD grants by NASCTN SEA sensors.

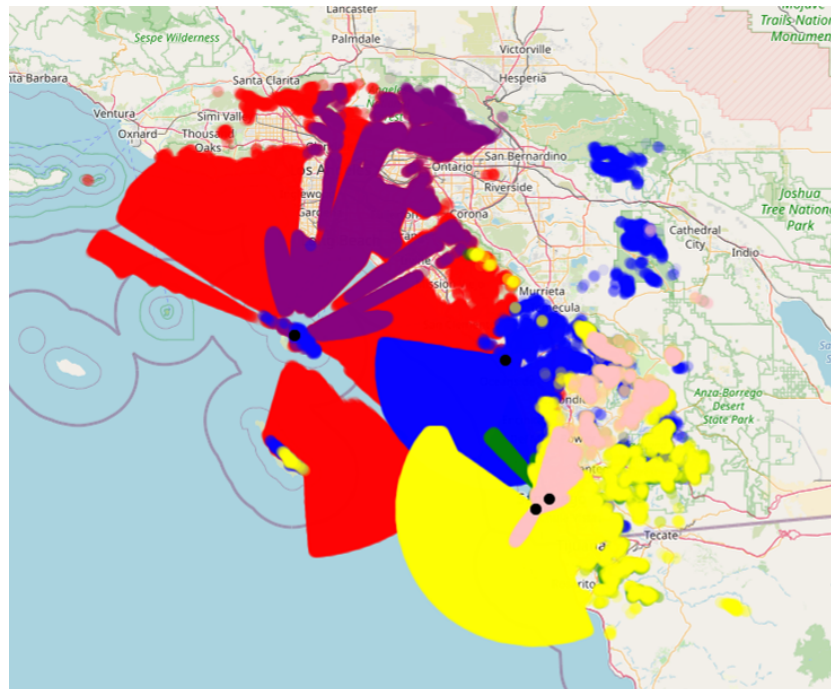
DPA	Monitoring sensor	Move List		Keep List	
		No. of CBSD grants	CBSD grants covered by at least 1 sensor	No. of CBSD grants	CBSD grants covered by at least 1 sensor
East 1	HU, NIT, Oceana, CBBT-Omni, CBBT-Directional	221 to 459	(57 to 75) %	46 to 72	0 %
West 13	Catalina-Omni, Catalina-Directional, Pendleton, Midway, PtLoma-Omni, PtLoma-Directional	112 to 2616	(5 to 19) %	678 to 3353	(3 to 32) %
West 14	Catalina-Omni, Catalina-Directional, Pendleton, Midway, PtLoma-Omni, PtLoma-Directional	506 to 2610	(17 to 46) %	233 to 2893	(0 to 2) %
Pendleton	Pendleton	0 to 6	50 %	3 to 21	(14 to 67) %

3.4. Dominant Emitters near Sensors

Figure 18 shows the modeled received power contribution from the dominant CBSD grant at each sensor location for each 10 MHz channel. Here, the dominant grant is the grant with the largest modeled received power contribution at the sensor. Because the link budget accounts for CBSD deployment and propagation parameters, the dominant grant is not necessarily associated with the geographically closest CBSD. Within each subplot, the circular markers indicate the modeled received power contribution (dBm/10 MHz) from the dominant grant, and the marker color represents the distance between the associated CBSD and the sensor. The annotations indicate the distance and the modeled received power. Consistent with the deployment patterns discussed in Section 3.2, the dominant CBSDs for HU, NIT, Oceana, Midway, Point Loma, and Pendleton are generally closer to the sensors than those for CBBT and Catalina.

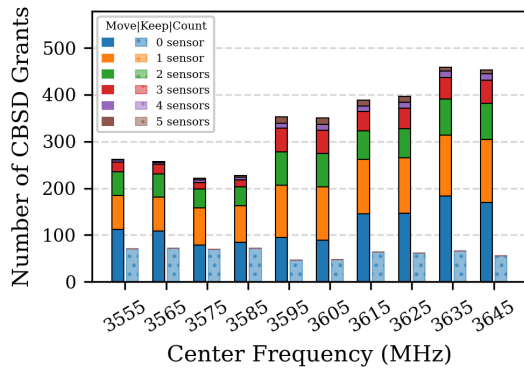


(a) East Coast

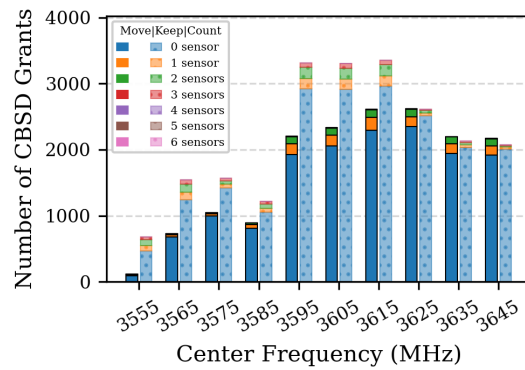


(b) West Coast

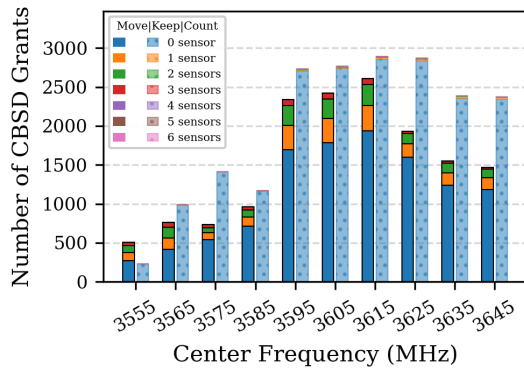
Fig. 16. Examples of RF horizon mapping of a Category B CBSD for sensors deployed on the East and West Coasts.



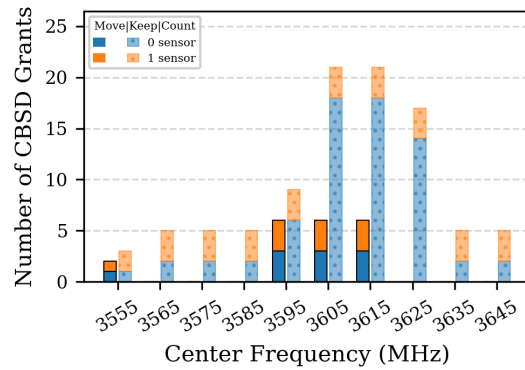
(a) E-DPA East 1



(b) E-DPA West 13



(c) E-DPA West 14



(d) GB-DPA Camp Pendleton

Fig. 17. Modeled SEA sensor coverage of CBSD grants on the CBRS 2.0 DPA Move and Keep Lists.

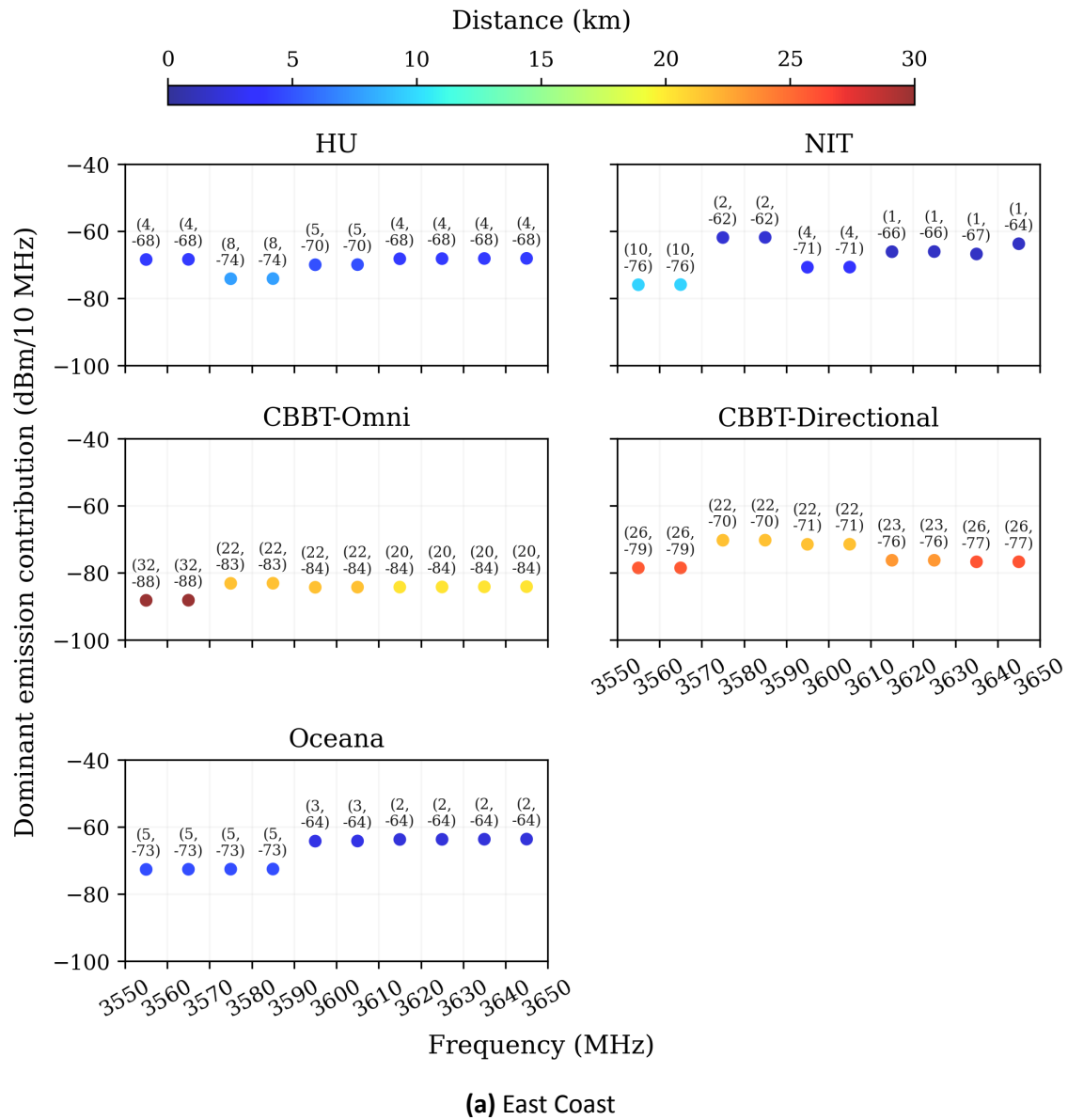


Fig. 18. Dominant emitters in the proximity of deployed sensors on the East and West Coasts. (Continued on next page)

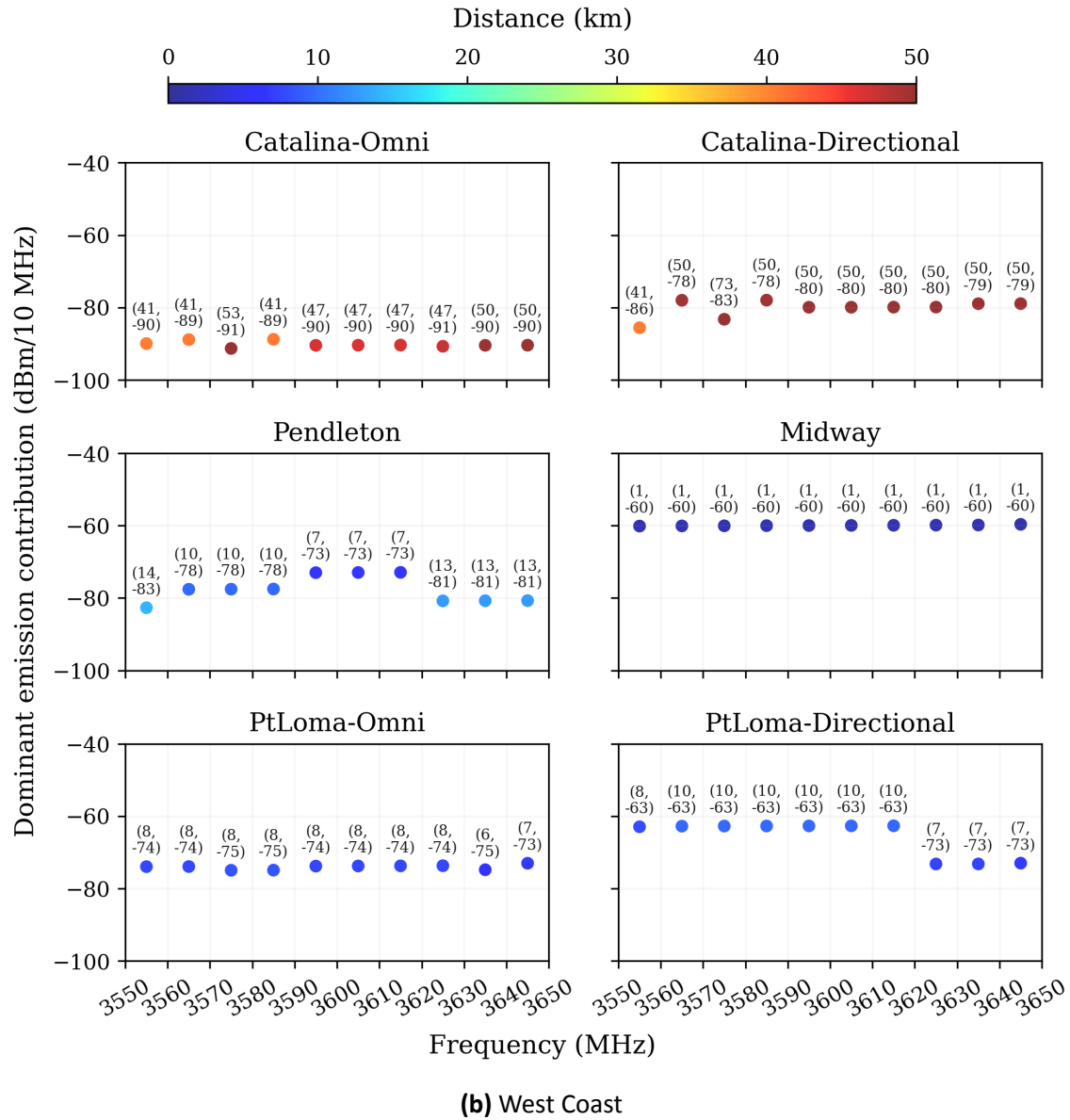


Fig. 18. Dominant emitters in the proximity of deployed sensors on the East and West Coasts. (Continued)

4. Modeled and Collected Sensor Data Comparison

The [NASCTN](#) modeling leverages industry-provided [FAD](#) data on [CBSD](#) deployment and the [WinnForum](#) reference [DPA](#) models to estimate aggregate emissions at [SEA](#) sensor locations when the [DPA](#) is either active or inactive. The modeling provides an estimate of the aggregate power received in each 10 MHz channel of the [CBRS](#) band at a specific sensor location. To examine the relationship between modeled and measured power levels, the estimated aggregate emissions are compared with measurements collected at several [NASCTN](#) sensor locations on the East and West Coasts. The comparisons provide insight into modeling assumptions and sources of uncertainty that may contribute to differences between modeled and measured results.

4.1. Modeled Sensor Data

Building on the aggregate emission calculation at [DPA](#) protection points described in Section 2.4, aggregate emissions are estimated at [SEA](#) sensor locations in the vicinity of San Diego, CA and Norfolk, VA. The modeled 2D antenna patterns of the deployed [SEA](#) sensors described in Section 3.1 are used in the sensor calculation instead of the reference radar antenna pattern used at [DPA](#) protection points [1, R2-IPM-04].

Given a [SEA](#) sensor location s and any 10 MHz channel ch in the 3550 MHz to 3650 MHz band, the aggregate emission model first identifies a set of N grants requesting or operating on any portion of channel ch . For this analysis, the set of candidate grants is limited to grants within the neighborhood of the [DPA](#) monitored by the sensor, for all [CBSD](#) categories. Using the [DPA](#) neighborhood to select candidate grants is a modeling assumption and may exclude detectable contributions from [CBSDs](#) outside the [DPA](#) neighborhood. The model then computes the received power contribution I_i (dBm) from each grant i , for $1 \leq i \leq N$, at sensor s .

The received power contribution from grant i is calculated using the link budget

$$I_i = \text{EIRP}_i - L_i + G_{s,i}, \quad (1)$$

where EIRP_i is derived from the maxEIRP value for grant i and the standard horizontal [CBSD](#) antenna pattern [1, R2-SGN-20], L_i is the path loss from grant i to sensor s , and $G_{s,i}$ is the sensor antenna gain in the direction of grant i .

To calculate the aggregate emission, the modeled received power contributions from the N grants are converted from dBm to linear power and summed:

$$I = \sum_{i=1}^N 10^{I_i/10}. \quad (2)$$

The aggregate received power is then converted to dBm as

$$I_{\text{dBm}} = 10 \log_{10}(I). \quad (3)$$

Using the July 1, 2025 FAD dataset, aggregate emissions are calculated at the SEA sensor locations listed in Table 3, on the East and West Coasts when the nearby DPA is inactive and active. To assess the impact of CBRS changes in the aggregate emission calculation, both CBRS 1.0 and CBRS 2.0 implementations are considered. The CBRS 1.0 and CBRS 2.0 implementations use the propagation and interference calculation parameters described in Section 2.2 and Table 1.

Figure 19 shows an example of modeled aggregate emission at the HU sensor in the proximity of E-DPA East 1. The figure shows the aggregate emission estimated for every 10 MHz channel in the 3550 MHz to 3650 MHz band. With the CBRS 1.0 implementation, the dark red and faded red triangle markers represent the aggregate emissions for the DPA in inactive and active states, respectively. For the CBRS 2.0 implementation, the dark blue and faded blue circle markers represent emissions for the inactive and active states, respectively. The vertical dashed line shows the projected noise floor of -98 dBm/10 MHz at the sensor. As shown in this figure, the aggregate emissions exceed the noise floor across all channels when the DPA is inactive, but drop to or below the noise floor when the DPA is active, for both CBRS 1.0 and CBRS 2.0 implementations.

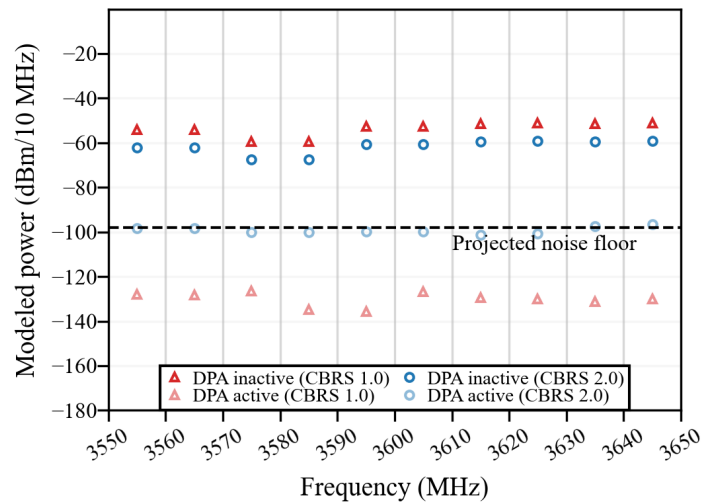


Fig. 19. Modeled aggregate emission at HU sensor in the proximity of E-DPA East 1.

Figure 20 shows the empirical probability density functions (PDFs) of the modeled channel power across ten channels and all sensors monitoring E-DPAs for inactive and active states using the CBRS 1.0 and CBRS 2.0 implementations. For the inactive DPA state, the CBRS 2.0 distribution is shifted toward lower modeled aggregate emission levels relative to CBRS 1.0. This shift reflects the combined effects of the CBRS 2.0 changes described in Section 2.2, including the 8 dB duty cycle and network loading adjustment, clutter loss, revised statistical treatment of ITM propagation, and changes in DPA neighborhood size. For the active DPA state, the CBRS 2.0 distribution has a larger mean and variance than the CBRS 1.0 distribution. This difference reflects changes in Keep List composition and in the propagation and aggregate interference calculations used by the two implementations.

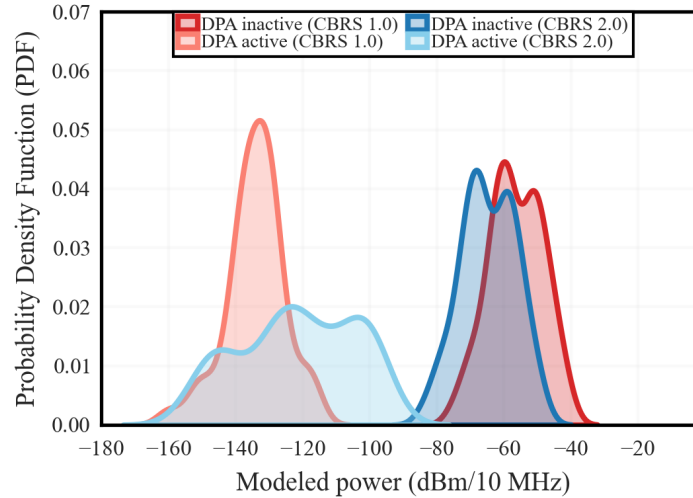


Fig. 20. Modeled aggregate emission distributions of all sensors monitoring E-DPAs.

4.2. Collected Sensor Data

To fulfill the main purpose of the [CBRS SEA](#) project of providing data-driven insight into the [CBRS](#) ecosystem [3, 4], [NASCTN](#) has been collecting sensor data over several years. The [CBRS SEA](#) Sensor Data Manual [6] provides an in-depth description of the installed sensor sites, the collected sensor data, the data repository and code, and the published data products. Among the different data products described in [6, Section 2.2], the Day Plot and the power spectral density ([PSD](#)) are used for comparison with the modeled data.

Figure 21 shows different representations of the measured data at the [HU](#) sensor on July 1, 2025. Figure 21a is the Day Plot, which shows transmissions detected throughout the day over the 3550 MHz to 3650 MHz frequency range. The left subplot shows an overload mask indicating whether the measured signal exceeds the analog-to-digital converter ([ADC](#)) maximum voltage during a 4-second capture. The two middle subplots are time-downsampled versions of the mean root mean square ([RMS](#)) and maximum peak periodic frame power ([PFP](#)) in a 10 MHz channel. The right subplot shows the maximum [PSD](#) trace, normalized to dBm/Hz. Figure 21b shows the mean [RMS](#) (green markers) and maximum peak [PFP](#) (yellow markers) extracted from the middle subplots in Figure 21a from 0:00 UTC to 7:00 UTC. This time window was selected based on the [SAS](#) administrators' recommendation to use measurements collected before [CPAS](#), the mandatory daily synchronization process among [SAS](#)s from 7:00 UTC to 10:00 UTC. This provides a more consistent temporal basis for comparison with the modeled data derived from [FAD](#) data generated at midnight. Figure 21c shows [PSD](#) traces at 7:00 UTC for several capture statistics, including the maximum, mean, median, and 99.99th percentile. The [PSD](#) traces characterize the spectral power of transmissions observed by the sensor at each time slice.

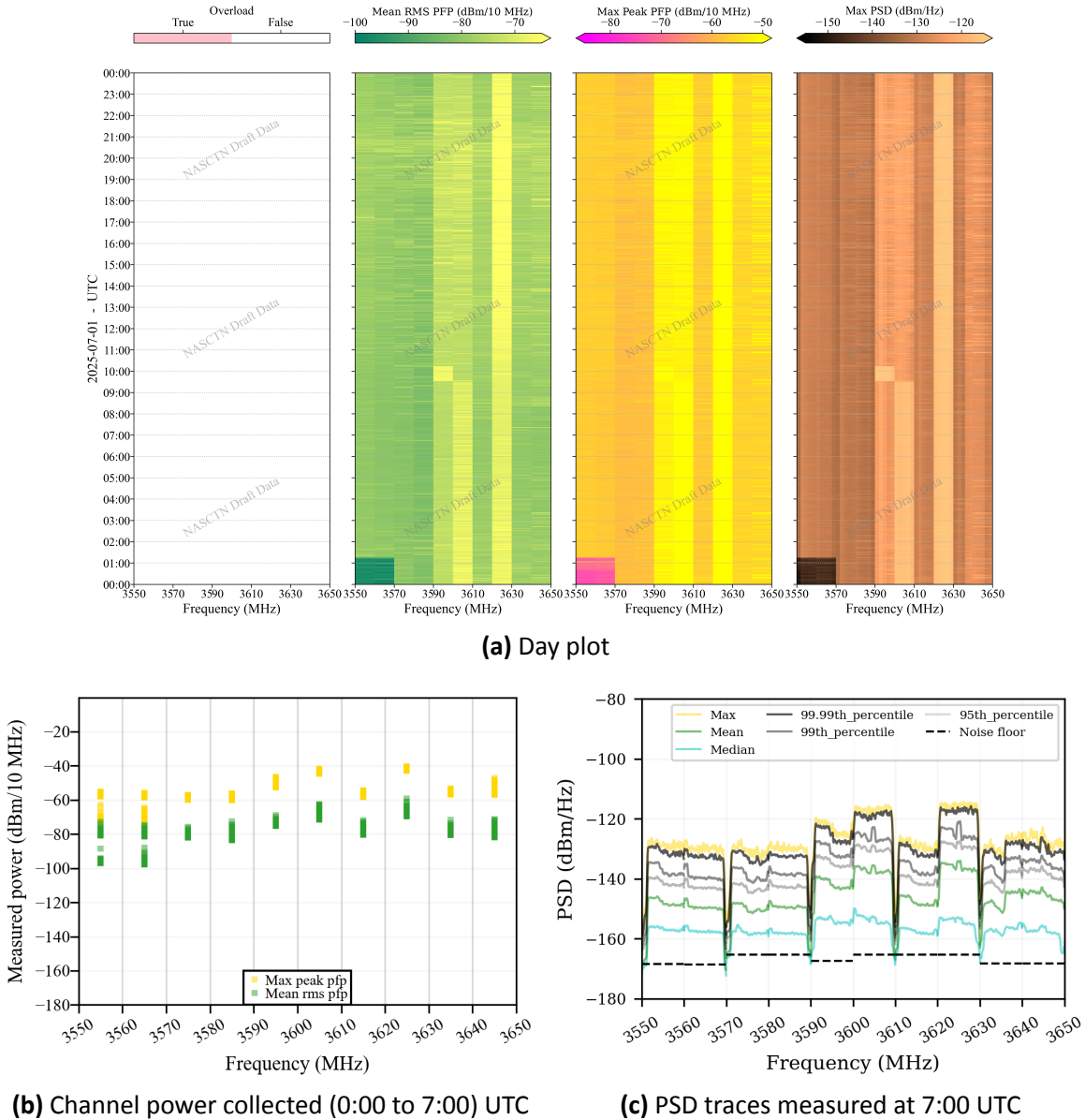


Fig. 21. Example of measured data at HU sensor on July 1, 2025.

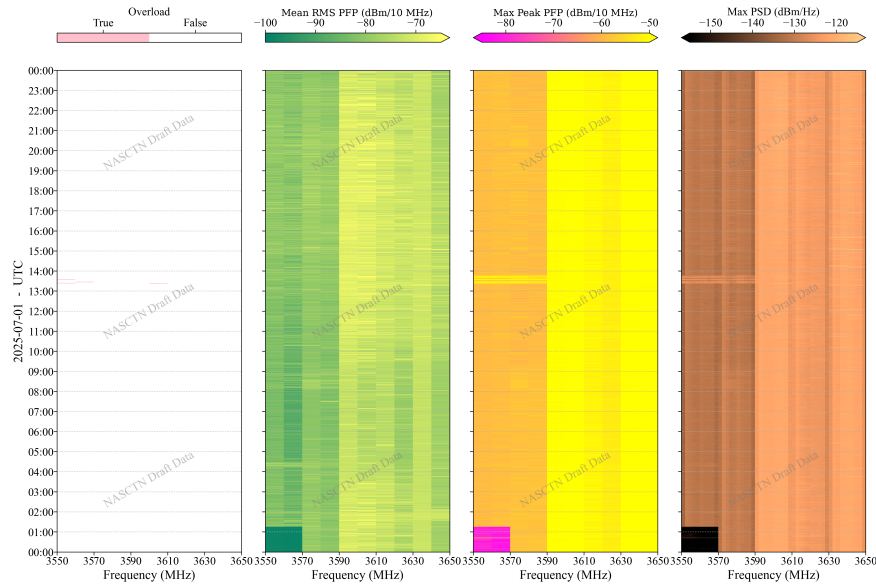
4.3. Sensor Data Comparison

This section compares modeled data with measurements collected at each deployed sensor site on July 1, 2025. The Day Plot provides an overview of the measured spectrum activity near each sensor on that day. Because the comparison focuses on **CBS** transmissions, measurement intervals are selected to minimize the influence of other detected signals where possible. Therefore, the measurement intervals used for channel power and the time instances used for **PSD** comparisons may vary among sensor locations. The mod-

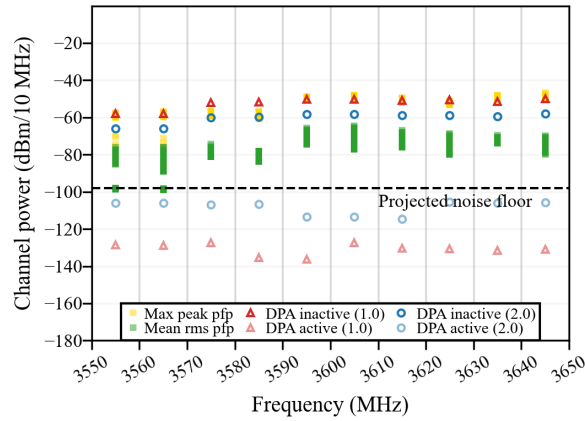
eled channel powers for inactive and active **DPA** states using the **CBRS 1.0** and **CBRS 2.0** implementations are overlaid with the measured mean **RMS PFP** and maximum peak **PFP**. To compare with the measured **PSD** traces, the modeled channel power is normalized from dBm/10 MHz to dBm/Hz and overlaid on the traces. The measured data are limited by the sensor noise floor; therefore, modeled values below the noise floor during **DPA** activation cannot be directly compared with the measurements.

4.3.1. Norfolk International Terminal (NIT), VA

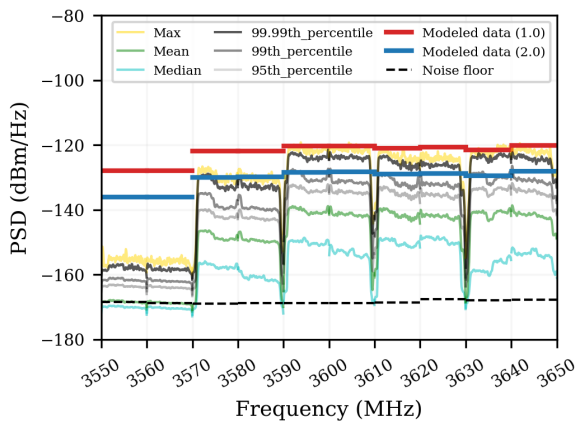
Figure 22 compares the modeled and measured data at the **NIT** sensor. The Day Plot in Figure 22a shows no apparent **CBSD** transmissions in the 3550 MHz to 3570 MHz band from 0:00 UTC to approximately 1:20 UTC, following a **DPA** activation observed on the previous day. Figure 22b shows the modeled channel powers overlaid with the measured mean **RMS PFP** and maximum peak **PFP** collected from 0:00 UTC to 7:00 UTC. For the inactive **DPA** state, the modeled **CBRS 1.0** powers are generally near the measured maximum peak **PFP** values, whereas the modeled **CBRS 2.0** powers generally fall between the measured mean **RMS** and maximum peak **PFP** values. The measured mean **RMS PFP** values near the projected noise floor in the 3550 MHz to 3570 MHz band are consistent with the absence of apparent **CBSD** transmissions during the early portion of the measurement interval. Figures 22c and 22d compare the normalized modeled powers for the inactive **DPA** state with measured **PSD** traces at 1:00 UTC and 7:00 UTC, respectively. Figure 22c shows no strong emissions in the 3550 MHz to 3570 MHz band at 1:00 UTC. At 7:00 UTC, Figure 22d shows strong channelized emissions with bandwidths of approximately 20 MHz across the 3550 MHz to 3650 MHz band. For most channels, the modeled **CBRS 1.0** levels are above the measured maximum **PSD** trace, whereas the modeled **CBRS 2.0** levels generally fall between the measured 99th and 99.99th percentile **PSD** traces.



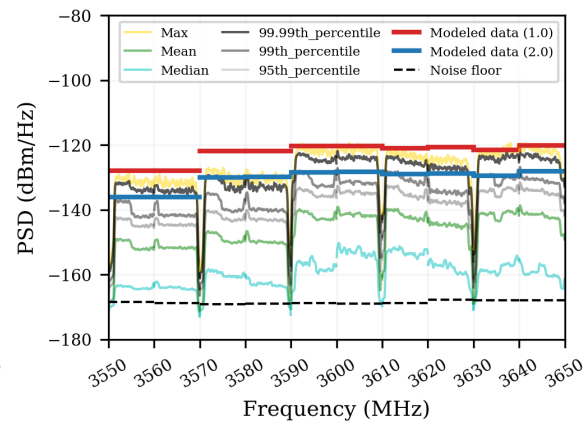
(a) Day plot



(b) Channel power collected (0:00 to 7:00) UTC



(c) PSD traces measured at 1:00 UTC



(d) PSD traces measured at 7:00 UTC

Fig. 22. Modeled versus measured data at NIT sensor.

4.3.2. Hampton University (HU), VA

Figure 23 compares the modeled and measured data at the HU sensor. Similar to the NIT measurements, Figure 23a shows no apparent CBSD transmissions in the 3550 MHz to 3570 MHz band around midnight. Figure 23b shows that the measured mean RMS PFP values in these channels are near both the projected noise floor and the modeled CBRS 2.0 values for the active DPA state. Figure 23c shows strong channelized emissions in the 3600 MHz to 3610 MHz and 3620 MHz to 3630 MHz channels. In these channels, the measured maximum and 99.99th percentile PSD traces exceed the modeled CBRS 1.0 levels. These differences may reflect uncertainties in the FAD data and modeling assumptions, including differences between registered and actual CBSD operating power and antenna parameters, as discussed in Section 4.4.1. For the other channels, the modeled CBRS 1.0 levels are generally near or above the measured maximum PSD trace, while the modeled CBRS 2.0 levels generally fall between the measured 95th and 99.99th percentile PSD traces.

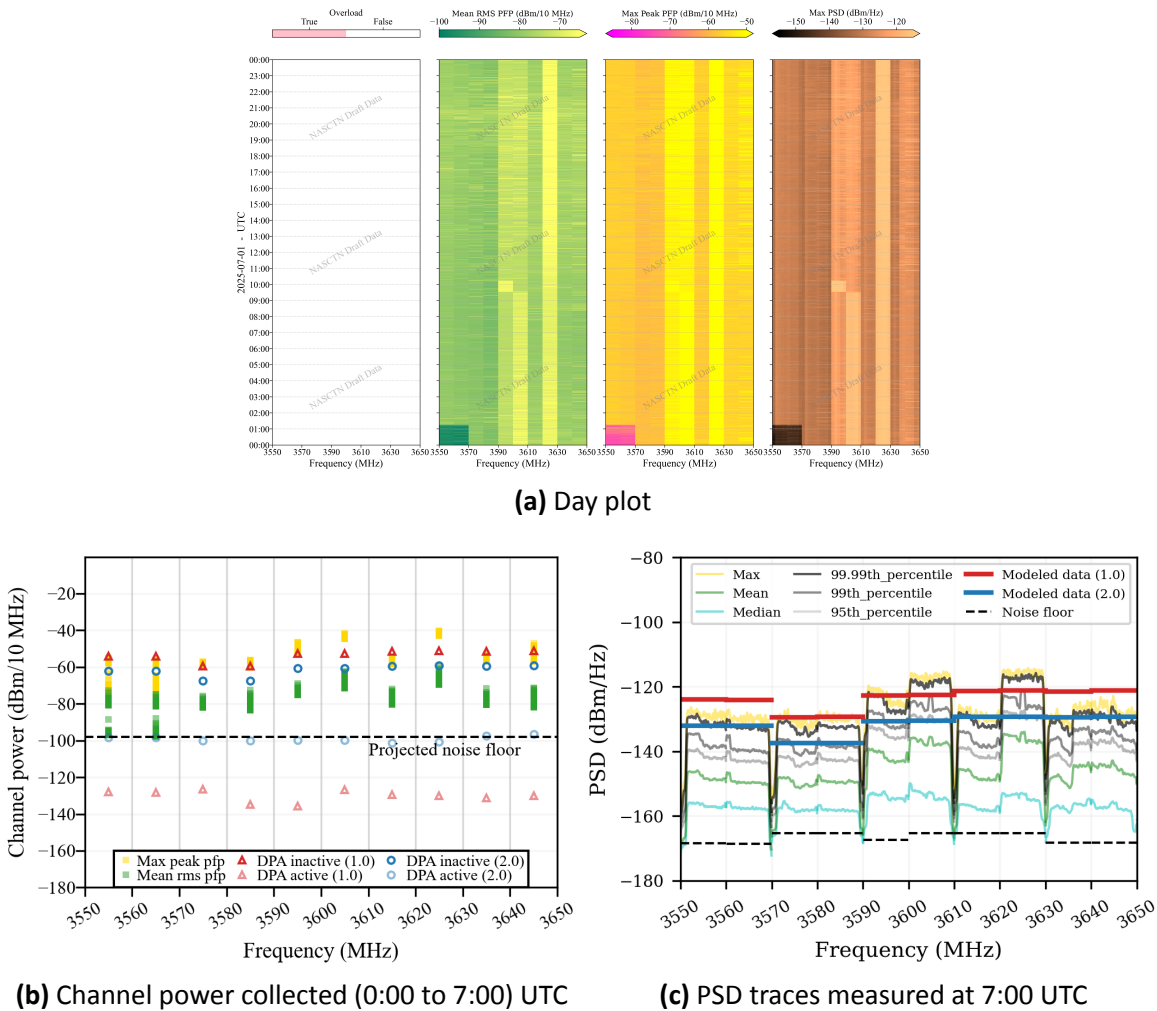


Fig. 23. Modeled versus measured data at HU sensor.

4.3.3. Oceana, VA

Compared with the [NIT](#) and [HU](#) sensors, the Oceana sensor generally measures lower received power levels, as shown in Figure 24a. The Oceana sensor also has a lower antenna height than the [NIT](#) and [HU](#) sensors, as listed in Table 3. Figures 24b and 24c show that the modeled [CBRS 1.0](#) and [CBRS 2.0](#) levels are generally higher than the measured levels, except in the lower 40 MHz where the modeled [CBRS 2.0](#) levels are closer to the measured maximum. One possible contributor to these differences is the use of [FAD](#) operationMaxEirp values in the modeled aggregate emission calculation, because actual [CBSD](#) operating powers may differ from the values reported in the [FAD](#). Other input data and modeling uncertainties discussed in Section 4.4.1 may also contribute to the observed differences.

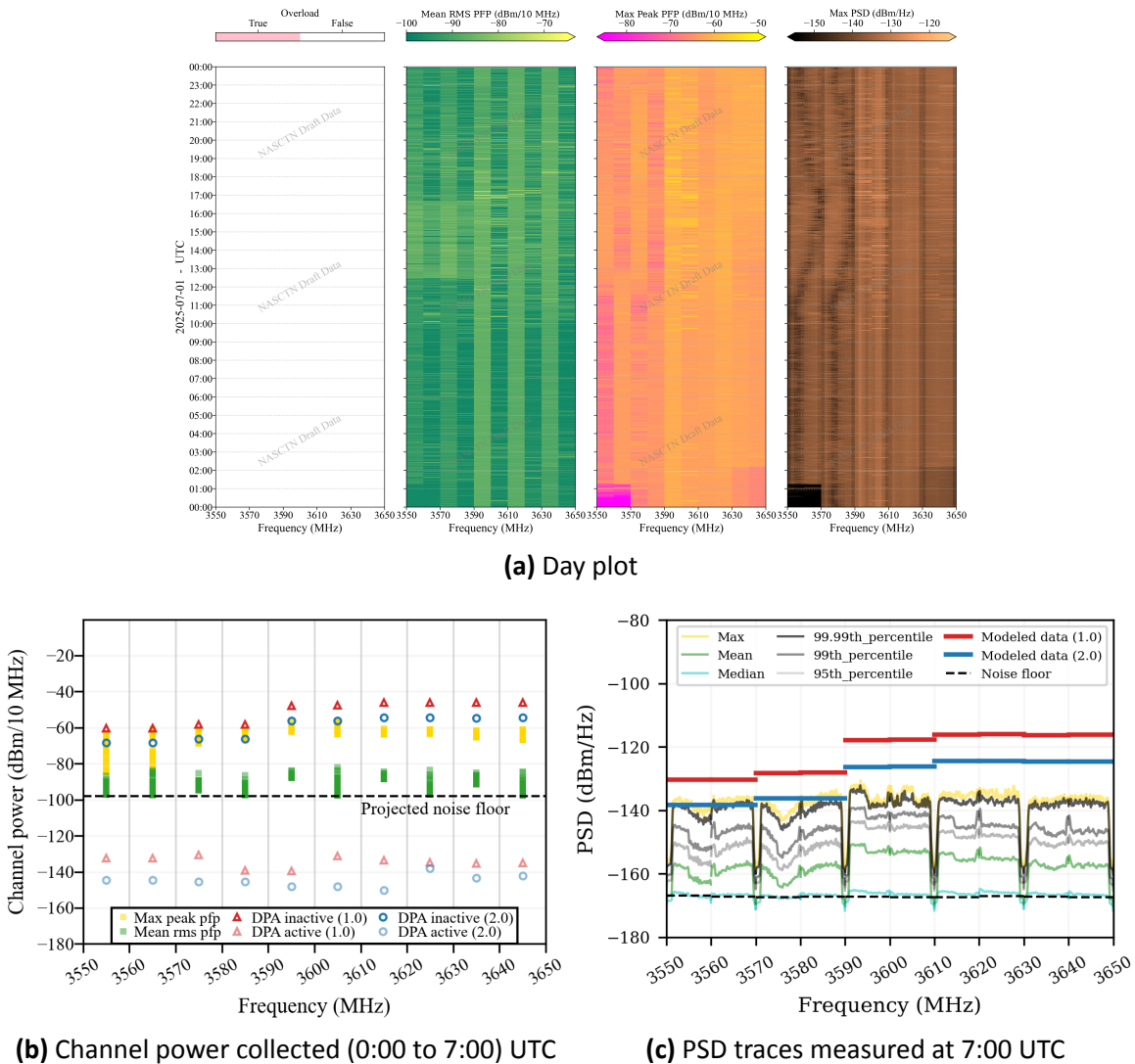


Fig. 24. Modeled versus measured data at Oceana sensor.

4.3.4. Chesapeake Bay Bridge Tunnel (CBBT), VA

While the [NIT](#), [HU](#), and Oceana sensors are deployed near metropolitan areas with dense [CBSD](#) deployments, the [CBBT](#) sensor is located on Island 4 of the Chesapeake Bay Bridge Tunnel, approximately 15 km from the Norfolk area. The measured [CBSD](#) emission levels at the [CBBT](#) sensor are generally lower than those observed at the other East Coast sensors.

Figure [25](#) compares the modeled and measured data at the [CBBT](#) sensor using an omnidirectional antenna. The Day Plot in Figure [25a](#) shows strong broadband emissions across much of the 3550 MHz to 3650 MHz band before approximately 4:00 UTC and after approximately 13:00 UTC. These emissions are also evident in the measured maximum peak [PFP](#) in Figure [25b](#) and the maximum [PSD](#) trace at 1:00 UTC in Figure [25d](#). Because the modeled data include only [CBSD](#) emissions, measurements from 4:00 UTC to 7:00 UTC, when these broadband emissions are less prominent, are used for the comparison in Figure [25c](#). The [PSD](#) traces at 7:00 UTC are shown in Figure [25e](#). The modeled [CBRS 1.0](#) levels are above the measured maximum levels across the evaluated channels, whereas the modeled [CBRS 2.0](#) levels are near the measured maximum in the lower 40 MHz and above the measured maximum in the upper 60 MHz.

With the directional antenna, the broadband emissions observed with the omnidirectional antenna are less prominent in the [CBBT](#) measurements. As shown in Figure [26](#), the modeled [CBRS 1.0](#) and [CBRS 2.0](#) levels are generally above the measured maximum levels across the evaluated channels.

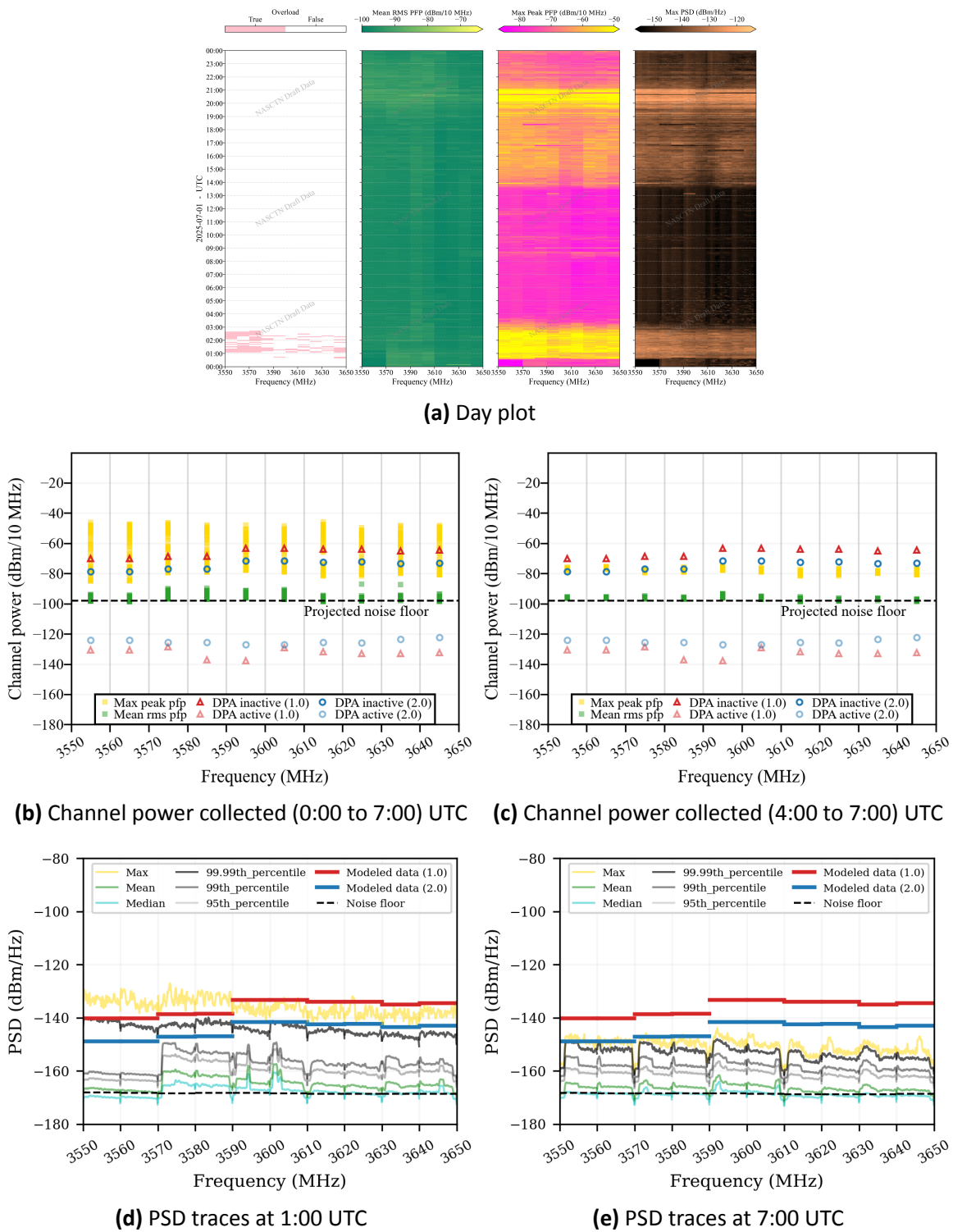


Fig. 25. Modeled versus measured data at CBBT sensor with an omnidirectional antenna.

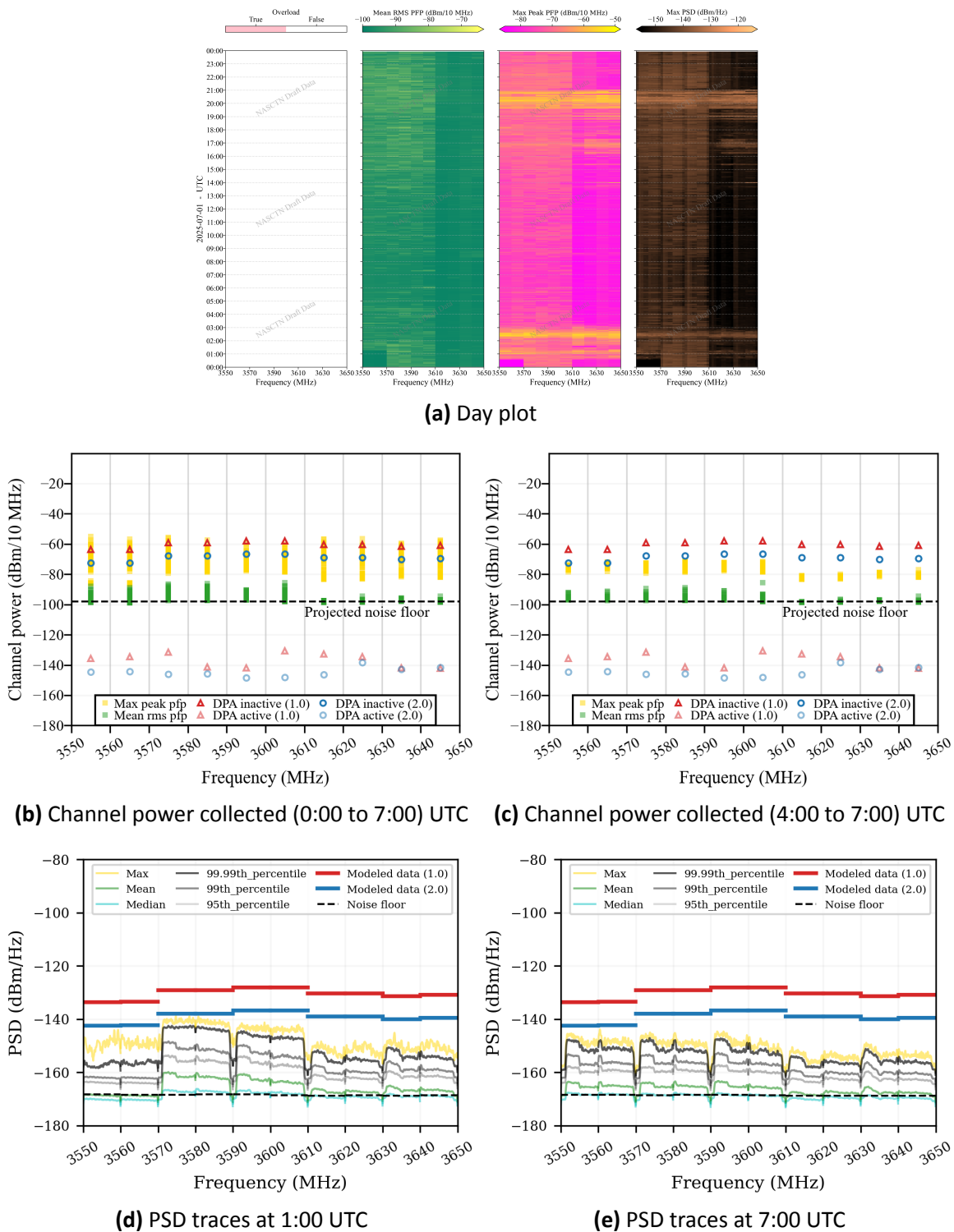


Fig. 26. Modeled versus measured data at CBBT sensor with a directional antenna.

4.3.5. Catalina, CA

On the West Coast, the Catalina sensor is deployed atop Mt. Orizaba, the highest point on Catalina Island, CA. Although the sensor is more than 40 km from metropolitan areas in Southern California, its high altitude provides extended propagation paths to [CBSD](#) deployments on the mainland. The Catalina sensor also measures other emissions within the [CBRS](#) band, particularly with the omnidirectional antenna.

Figure [27](#) compares the modeled and measured data at the Catalina sensor using an omnidirectional antenna. Strong broadband emissions are observed after approximately 5:00 UTC. Because the modeled data include only [CBSD](#) emissions, measured channel powers from 0:00 UTC to 5:00 UTC and [PSD](#) traces at 1:00 UTC are used for the comparison. As shown in Figure [27d](#), the modeled [CBRS 1.0](#) levels are generally near or above the measured maximum [PSD](#) trace, whereas the modeled [CBRS 2.0](#) levels generally fall between the measured 99th and 99.99th percentile [PSD](#) traces for most channels.

Figure [28](#) compares the modeled and measured data at the Catalina sensor using a directional antenna. The Day Plot shows predominantly channelized emissions with varying bandwidths. Figures [28b](#) and [28c](#) show that the modeled [CBRS 1.0](#) levels vary around the measured maximum levels in the lower 40 MHz and are generally near the measured maximum levels in the upper 60 MHz. The modeled [CBRS 2.0](#) levels generally follow a similar channel-dependent pattern relative to the measured 99th percentile [PSD](#) trace.

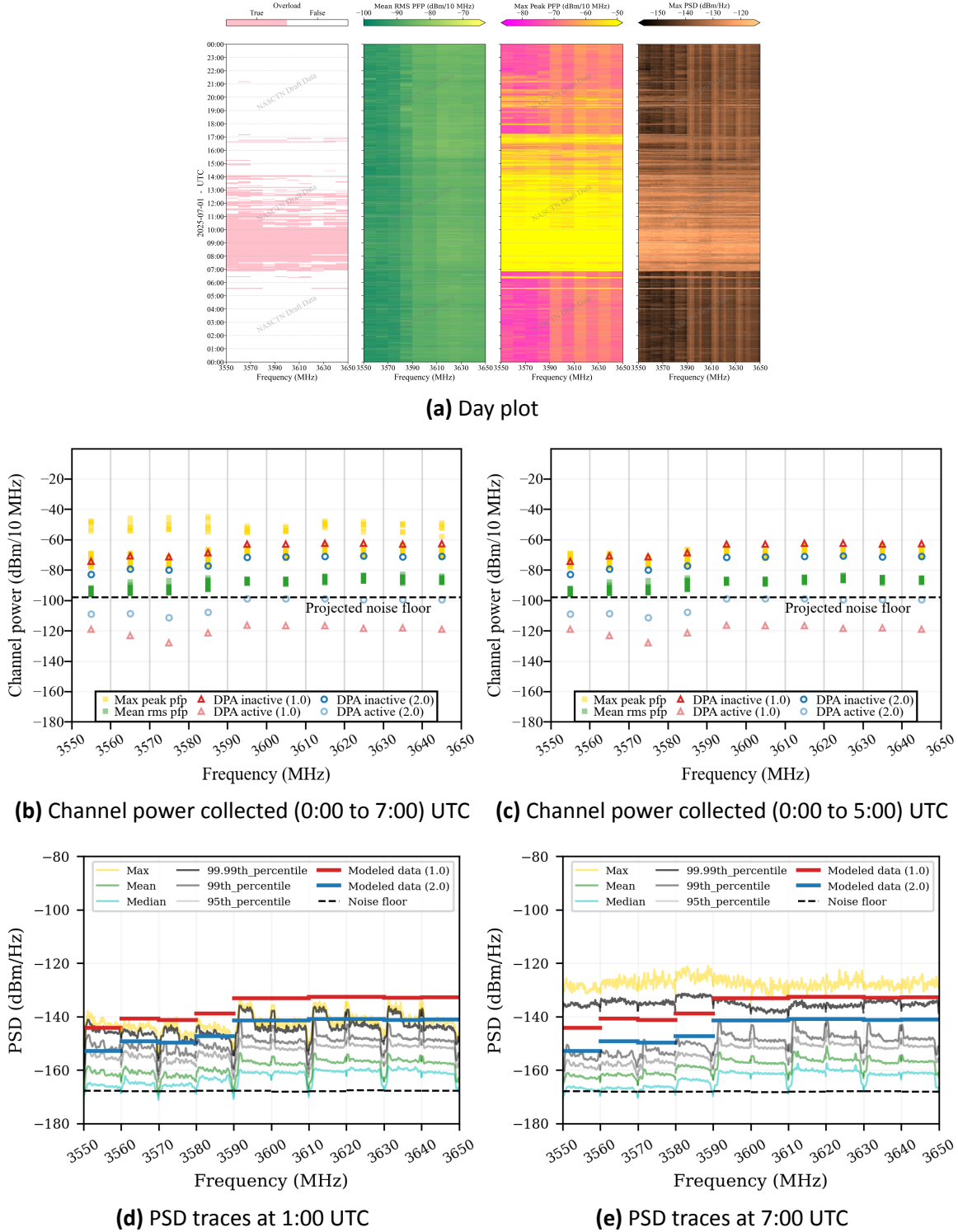


Fig. 27. Modeled versus measured data at Catalina sensor with an omnidirectional antenna.

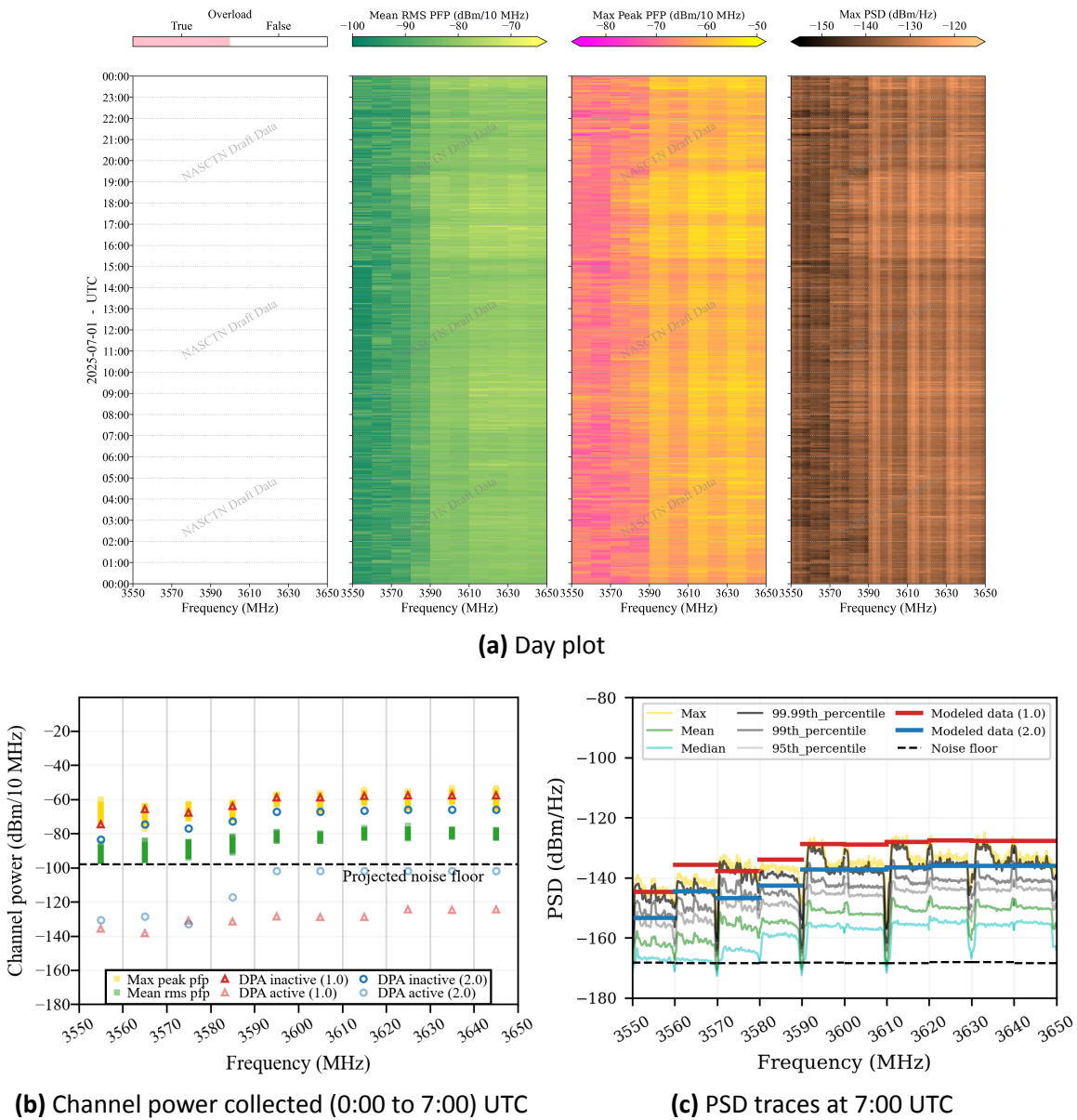


Fig. 28. Modeled versus measured data at Catalina sensor with a directional antenna.

4.3.6. Midway, CA

Figure 29 compares the modeled and measured data at the Midway sensor. The modeled CBRS 1.0 levels are above the measured maximum PSD trace across the evaluated channels, whereas the modeled CBRS 2.0 levels are generally near the measured 99.99th percentile PSD trace, except in the 3630 MHz to 3650 MHz band.

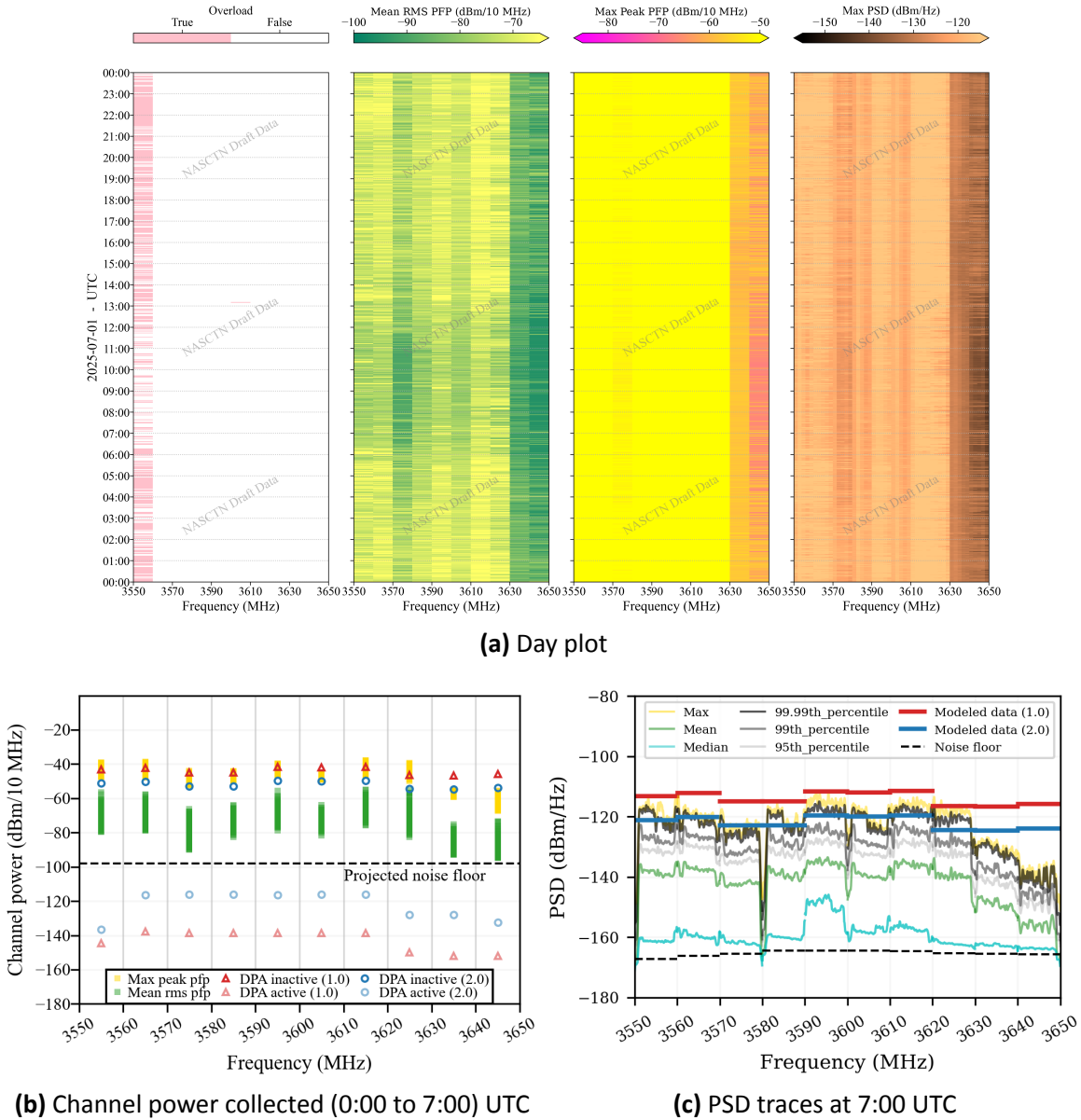


Fig. 29. Modeled versus measured data at Midway sensor.

4.3.7. Point Loma, CA

Since the Point Loma sensor was installed in mid-July 2025, no measured data from July 1, 2025 are available for comparison. Therefore, Figure 30 shows only the modeled channel powers for active and inactive DPA states using the CBRS 1.0 and CBRS 2.0 implementations.

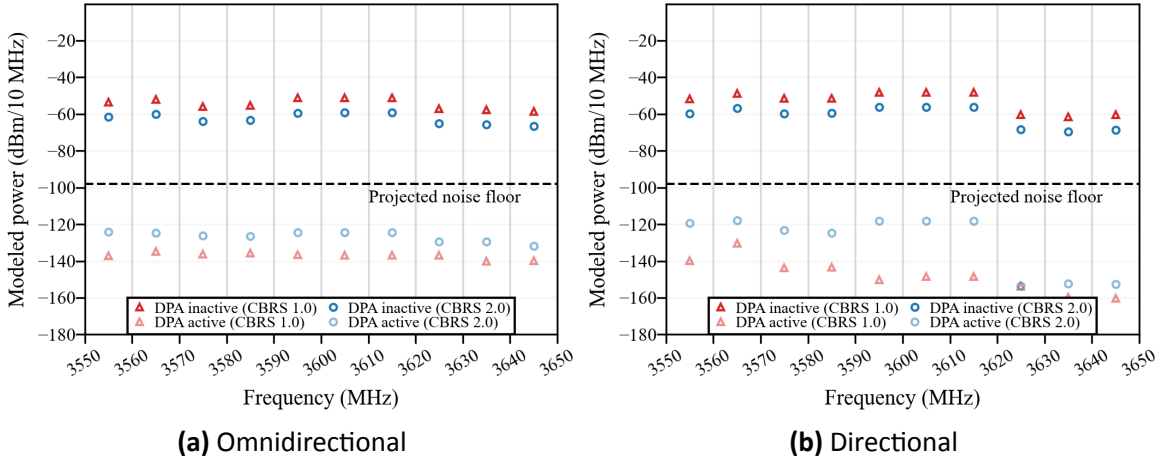


Fig. 30. Modeled channel power at Point Loma sensor.

4.3.8. Pendleton, CA

Unlike E-DPAs, GB-DPAs have channel-specific static protection criteria and are always on. The protection thresholds for GB-DPAs are higher than the -144 dBm/10 MHz threshold used for E-DPAs and vary by channel; the neighborhood distances also differ. Figure 31 compares the modeled and measured data at the Pendleton sensor deployed within GB-DPA Camp Pendleton. The modeled CBRS 1.0 and CBRS 2.0 levels remain above the sensor noise floor. For most channels, the modeled CBRS 1.0 levels are near or above the measured maximum PSD trace, whereas the modeled CBRS 2.0 levels generally fall between the measured 99th and 99.99th percentile PSD traces.

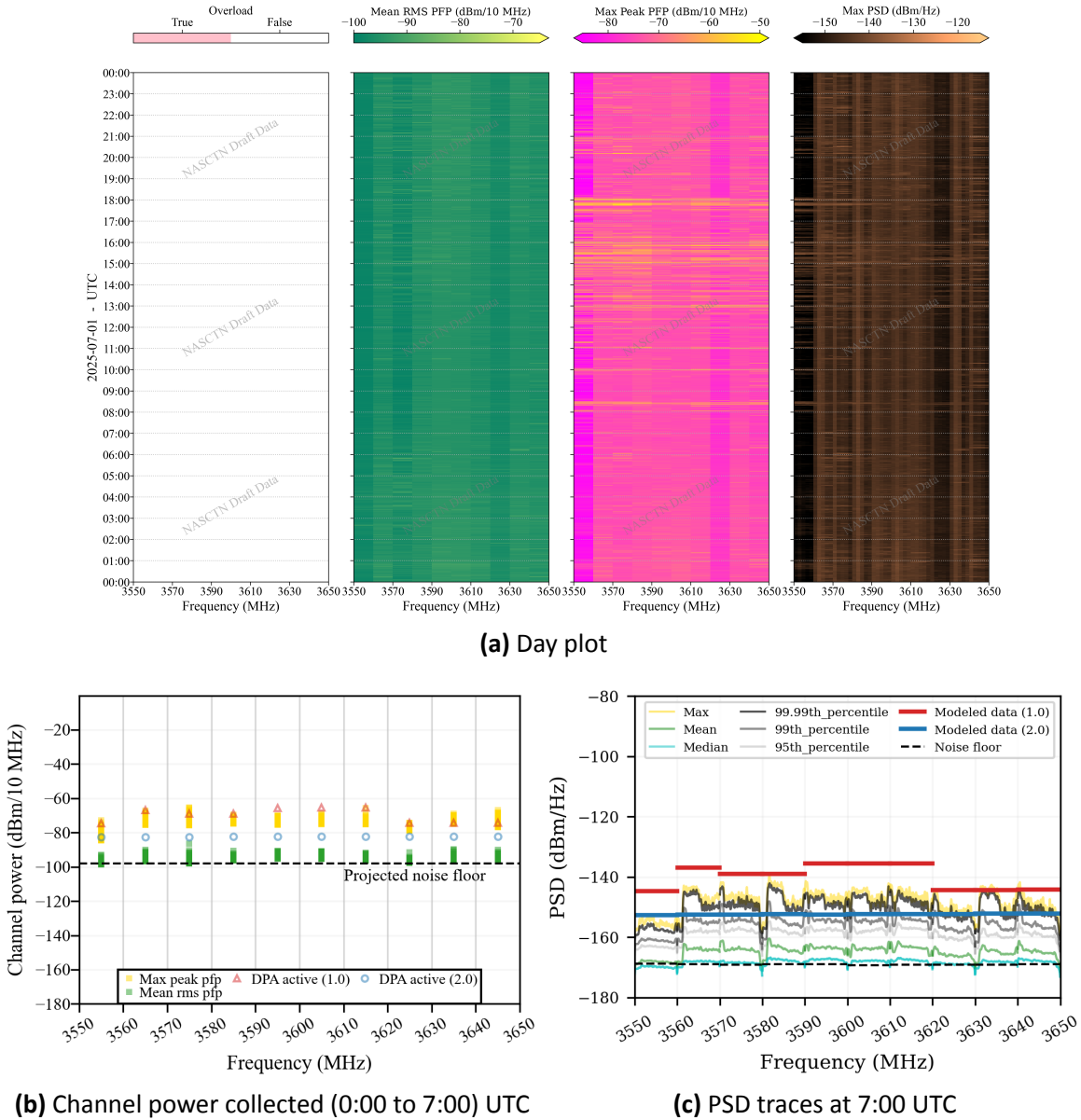


Fig. 31. Modeled versus measured data at Pendleton sensor.

4.4. Modeling Insights

4.4.1. Technical Uncertainties and Modeling Assumptions

The current modeling framework includes several assumptions and sources of uncertainty that may affect the modeling results:

1. CBSD Deployment and Operational Data

The CBSD deployment laydown used for modeling is based on limited FAD datasets.

- Temporal limitations: Although the [FAD](#) data have provided valuable information for modeling, they offer only a snapshot or a “static” view of the registered [CBSDs](#) and grants, which does not capture long-term deployment dynamics.
- Post-[CPAS](#) changes: Since the [FAD](#) data used in this analysis are generated before Iterative Allocation Process ([IAP](#)) and Move List calculations, they may not reflect subsequent grant termination, suspension, channel reassignment, or power reduction.
- Data limitations and artifacts: Potential uncertainties include antenna height references (above ground level ([AGL](#)) versus above mean sea level ([AMSL](#))), antenna beamwidth and gain parameters, and differences between [SAS](#)-assigned equivalent isotropically radiated power ([EIRP](#)) values reported in the [FAD](#) and actual [CBSD](#) operating power.

2. Propagation and Clutter Modeling

The use of [ITM](#) in point-to-point mode, with the reliability assumptions described in Section 2.2, combined with the ITU-R P.2108 clutter model, provides only an approximation of the physical environment. These models may not fully account for complex terrain, clutter, or building loss in indoor deployments.

3. Duty Cycle and Network Loading

Applying a constant 8 dB duty cycle and network loading adjustment to all [CBSDs](#) is a simplifying assumption that may not represent the temporal activity and network loading of individual [CBSD](#) deployments or radio technologies.

4. Algorithmic Implementations

The [NASCTN](#) modeling uses the [WInnForum](#) reference [DPA](#) Move List implementation. Differences between the reference implementation and operational [SAS](#) implementations, if present, could contribute to differences between modeled and operational results.

5. Aggregate Emission Uncertainties

Uncertainty in modeled aggregate emissions at the [NASCTN SEA](#) sensors may result from:

- Operational variables: Uncertainty regarding a [CBSD](#)’s post-[CPAS](#) transmit power, on/off state, and its precise antenna spatial orientation and gain.
- Physical modeling uncertainties: Uncertainties in the modeled [CBSD](#) antenna gain and path loss for specific links.
- Aggregate emission modeling: The modeled aggregate emission assumes that all [CBSD](#) grants included in the calculation contribute according to their modeled received power over the evaluated 10 MHz channel. Actual aggregate

emission depends on the temporal and spectral activity of individual [CBSD](#) transmissions, including differences in operating bandwidth, resource allocation, and network loading. In addition, sensor measurements may be dominated by a single or a few nearby [CBSDs](#).

4.4.2. Findings

This section summarizes the comparative analysis between modeled aggregate emissions and sensor-measured data derived from Section [4.3](#).

1. Comparative Analysis of Channel Power Distribution

Figure [32](#) illustrates the [PDFs](#) of channel power for both modeled and measured data across all sensor locations. The Point Loma results are not included because the sensor was deployed after July 1, 2025, and no measured data are available for comparison. The subplots contrast the measured Max Peak [PFP](#) (yellow) and Mean [RMS PFP](#) (green) against modeled [CBRS 1.0](#) (red) and [CBRS 2.0](#) (blue) results during inactive [DPA](#) states. Measured data were aggregated between 4:00 UTC and 5:00 UTC on July 1, 2025, to isolate [CBSD](#) transmissions; therefore, the distributions represent the conditions observed during this selected measurement interval.

Key observations include:

- Measured Max vs. Measured Mean: The max peak [PFP](#) distributions are generally shifted to higher power levels than the mean [RMS PFP](#) distributions, with an approximately 20 dB separation at several sensors. The degree of separation varies by sensor.
- Modeled [CBRS 1.0](#) vs. Modeled [CBRS 2.0](#): With the exception of the Pendleton sensor, the modeled [CBRS 2.0](#) distributions are generally shifted toward lower power levels relative to [CBRS 1.0](#). As discussed in Section [4.1](#), these differences reflect the combined effects of the [CBRS 2.0](#) modeling changes.
- Modeled [CBRS 1.0](#) vs. Measured Max: For most sensors, the mode of the modeled [CBRS 1.0](#) distribution is similar to or higher than the mode of the measured max peak [PFP](#) distribution. At the [HU](#) sensor, however, part of the measured max distribution extends above the modeled [CBRS 1.0](#) distribution.
- Modeled [CBRS 2.0](#) vs. Measured Max: The relationship between the modeled [CBRS 2.0](#) and measured max peak [PFP](#) distributions varies by sensor. At Oceana and [CBBT](#), the modeled distributions extend to higher power levels than the measured max distributions, whereas at several other sensor locations, the modeled distributions occur at lower power levels. These site-dependent differences are consistent with the modeling uncertainties described in Section [4.4.1](#).

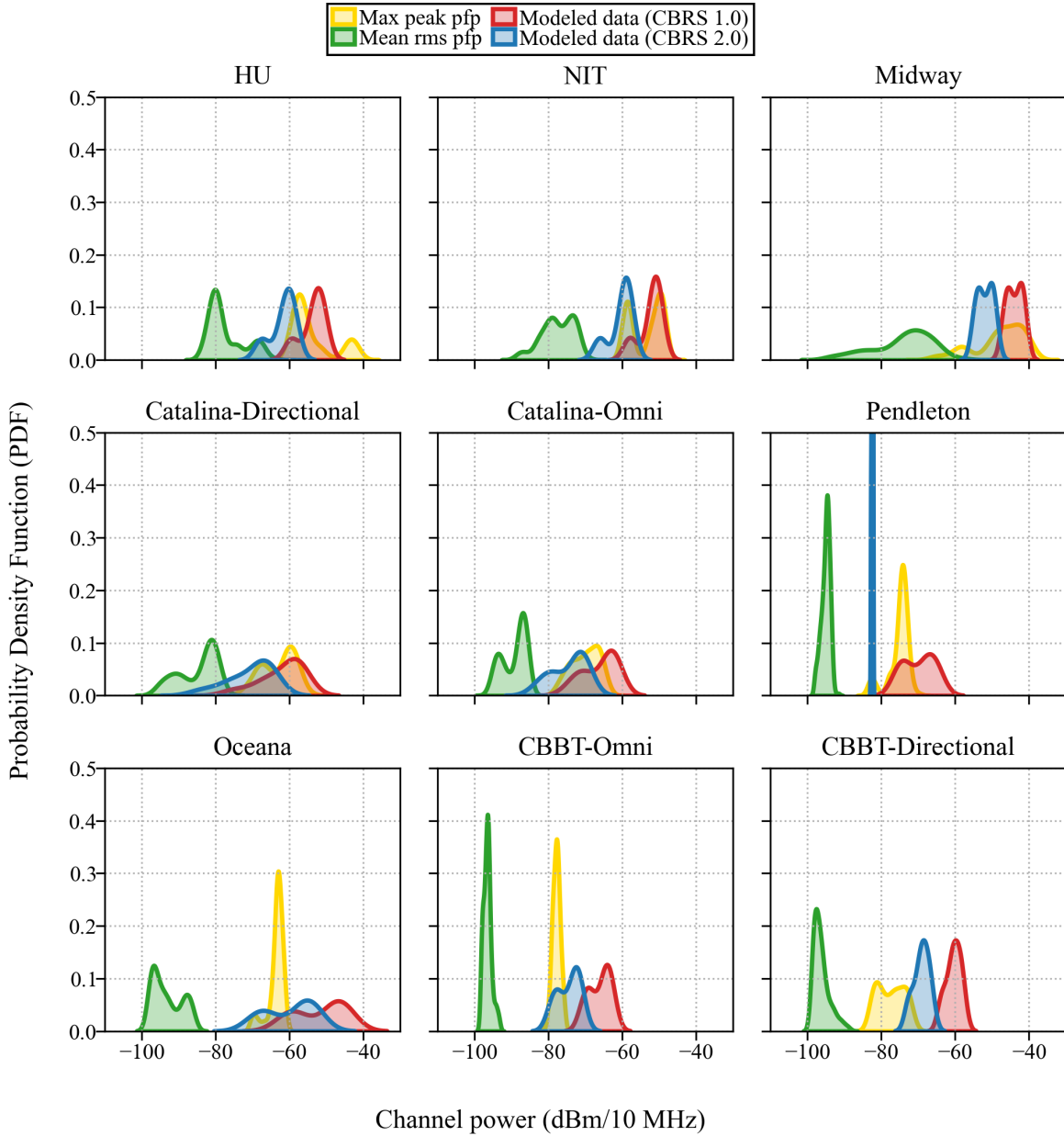


Fig. 32. Comparison of modeled and measured channel power PDFs.

2. Comparative Analysis of Power Spectral Density Traces

Figure 33 compares normalized modeled data with measured PSD traces captured at 5:00 UTC on July 1, 2025. The subplots show the modeled CBRS 1.0 (red) and CBRS 2.0 (blue) normalized channel powers alongside the measured PSD traces for Max Peak PFP (yellow), Mean RMS PFP (green), 99.99th percentile (black), and 99th percentile (gray).

Analysis of these traces reveals the following:

- Modeled [CBRS 1.0](#) vs. Measured Max: For most sensors and channels, the modeled [CBRS 1.0](#) levels are near or above the measured max [PSD](#) traces. Exceptions occur at the [HU](#) sensor in the 3600 MHz to 3610 MHz and 3620 MHz to 3630 MHz channels, where measured spectral peaks exceed the modeled values. Conversely, modeled [CBRS 1.0](#) levels exceed the measured peaks at several other sensor locations, e.g., Pendleton, Oceana, [CBBT-Omni](#), and [CBBT-Directional](#). These differences may reflect the input data and modeling uncertainties described in Section [4.4.1](#), including [CBSD](#) operating power, antenna parameters, and propagation modeling.
- Modeled [CBRS 2.0](#) vs. Statistical Measured Traces: Across most locations, the modeled [CBRS 2.0 PSD](#) levels are above the measured mean traces and generally fall between the measured 99th and 99.99th percentile traces. At Oceana, [CBBT-Omni](#), and [CBBT-Directional](#), however, the modeled levels approach or exceed the measured max traces. The variation among sensor locations illustrates the site dependence of the modeled-to-measured relationship.

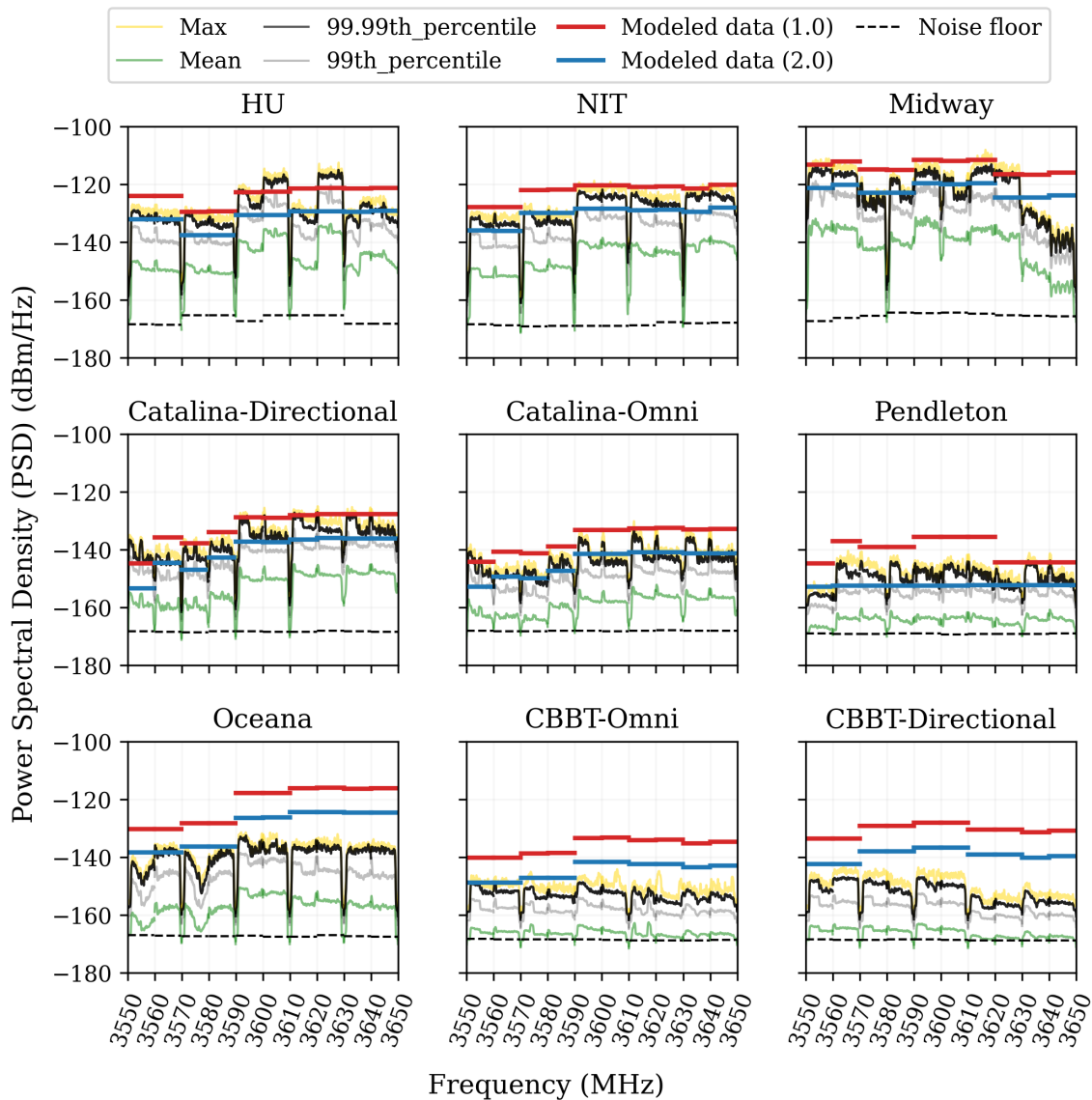


Fig. 33. Modeled versus sensor-measured PSD traces.

4.4.3. Recommendations

Based on the key observations detailed in the previous section, the following measures are recommended to refine the modeling and address identified sources of uncertainty:

- Conduct additional evaluations across a broader range of dates and longer measurement periods to assess the temporal variability and determine whether the observed modeled-to-measured relationships persist over time.

- Evaluate methods to verify [FAD](#) parameters and supplement [FAD](#) data with information on actual [CBSD](#) operation, including antenna installation parameters, operating [EIRP](#), transmission state, and operating channel.
- Perform additional studies to evaluate the modeling of [CBSD](#) antenna patterns and gains, propagation characteristics, and clutter loss. In addition, evaluate how representative the 80 % [TDD](#) activity and 20 % network loading assumptions underlying the 8 dB [CBRS 2.0](#) adjustment are of actual [CBSD](#) operation.
- Refine aggregate emission modeling to better account for spatial, temporal, and spectral characteristics across heterogeneous [CBSD](#) technologies and transmissions.

5. DPA Neighborhood Distance Recalculation

This section details the technical rationale for recalculating [DPA](#) neighborhood distances under the [CBRS 2.0](#) implementation and presents the resulting analytical findings.

5.1. Anomalous Aggregate Emission Estimates

The [NASCTN](#) modeling uses the [WInnForum CBRS 2.0 DPA](#) Move List implementation to estimate aggregate emissions at protection points within a [DPA](#) and at [NASCTN SEA](#) sensor locations. The simulation uses the July 1, 2025 [FAD](#) dataset and the [CBRS 2.0 DPA](#) neighborhood distances specified in the `e-dpas.kml` and `gb-dpas.kml` files [15].

As noted in Section 2.4, the pooled distributions in Figure 10 do not preserve [DPA](#)-, channel-, or protection-point-specific behavior. Examination of the individual protection-point results identified cases in which the modeled aggregate emission exceeds the protection threshold when an [E-DPA](#) is active. Figure 34 shows examples of modeled aggregate emission from Keep List grants at protection points within [E-DPAs](#) West 13 and West 14 for the 3610 MHz to 3620 MHz channel. At some protection points, the modeled aggregate emission exceeds the -144 dBm/10 MHz protection threshold by up to 19.4 dB for West 13 and 16.27 dB for West 14. These results motivated further investigation of the [CBRS 2.0 DPA](#) neighborhood distance calculation, including its sensitivity to protection point selection and [CBSD](#) deployment laydown.

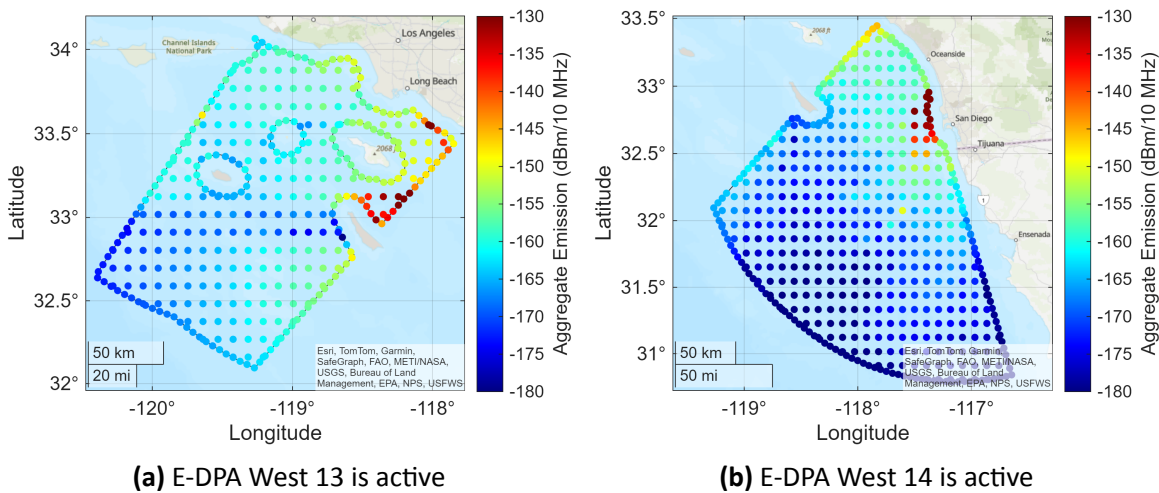


Fig. 34. Examples of aggregate emission estimates above the threshold at some protection points inside active E-DPAs on the 3610 MHz to 3620 MHz channel.

5.2. Recalculation Procedure

5.2.1. NTIA OSM Code and Assumptions

With the technical guidance of the [NTIA OSM](#), [NASCTN](#) utilized the [DPA](#) Neighborhood Calculation MATLAB code and associated datasets [16] to rerun the neighborhood distances for [E-DPAs](#) East 1, West 13, and West 14. To address data-sensitivity constraints on proprietary [FAD](#) records, [OSM](#) developed a simulated [CBSD](#) laydown based on census population data. The laydown, available as `cell_census_centroid.mat` in [16], serves as the primary input for the simulation. Figure 35 illustrates the [OSM CBSD](#) laydown, comprising 72 540 [CBSDs](#) across [CONUS](#) and Hawaii.

For the [OSM](#) simulated laydown, all [CBSDs](#) are modeled as operating cochannel within a single 10 MHz channel. The code allows various scenarios to be parameterized by adjusting [CBSD](#) configurations, including Category A/B, [EIRP](#) (dBm/10 MHz), and antenna height. This recalculation effort focuses primarily on Category B [CBSDs](#) with heights exceeding 6 m, as this scenario yields the largest neighborhood distances.

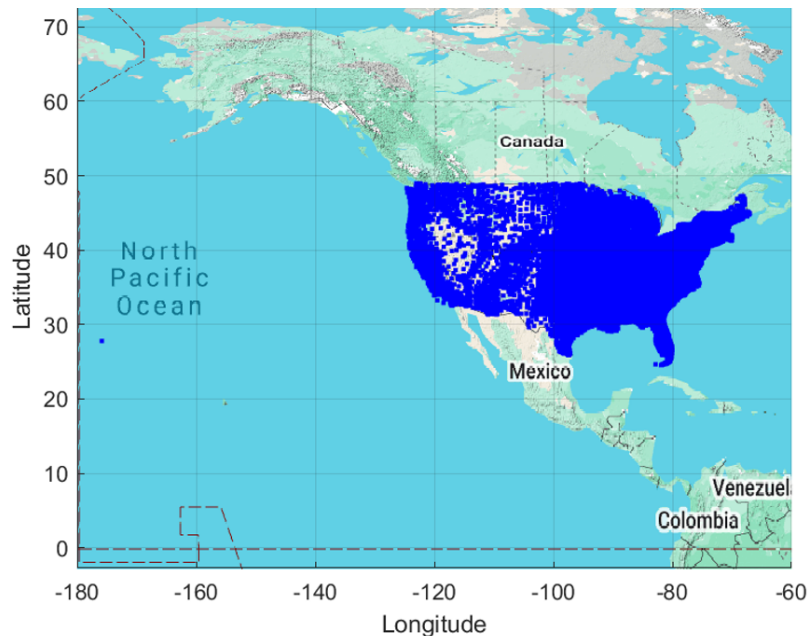


Fig. 35. Illustration of NTIA OSM simulated CBSD deployment laydown.

5.2.2. Impacts of Protection Point Selection

To optimize calculation runtime, the default configuration uses eight equidistant protection points along the inner boundary of the [DPA](#) base, which is a segment of the [DPA](#) closest to the shoreline. While protection points along the landward [DPA](#) boundary typically encounter the highest aggregate interference from inland [CBSDs](#), supplemental locations

within the **DPA** may experience comparable interference levels. To evaluate this hypothesis, the simulation was expanded to include 100 protection points: 50 distributed along the boundary and 50 situated randomly within the **DPA**. The **OSM CBSD** simulation laydowns (blue markers) in the vicinity of **DPA East 1**, contrasted with the 8-point and 100-point protection points (red markers), are illustrated in Figures 36a and 36b, respectively.

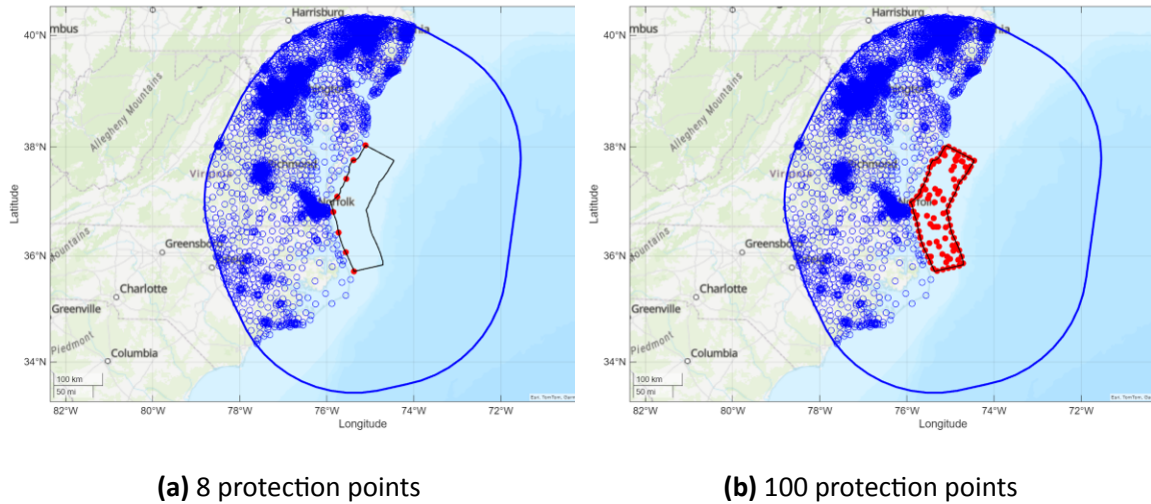


Fig. 36. OSM CBSD simulation laydown with different protection points inside DPA East 1.

Figure 37 summarizes the calculated neighborhood distances for Category B **CBSDs** with height above 6 m across **DPAs** East 1, West 13, and West 14. The results indicate that the 8-point configuration yields neighborhood distances identical to those specified in the `e-dpas.kml` file. Conversely, the 100-point configuration yields greater neighborhood distances for all three **E-DPAs**, demonstrating that the calculated neighborhood distances are sensitive to the number and spatial distribution of protection points used in the calculation.

5.2.3. Impacts of CBSD Deployment Laydowns

Beyond evaluating protection point configurations, it is necessary to assess the sensitivity of the results to variations in **CBSD** deployment laydowns. Consequently, the simulated **OSM CBSD** laydown was replaced by the July 1, 2025 **FAD** dataset detailed in Section 2.1. Neighborhood distance calculations using the 100-point protection configuration were subsequently performed across all ten 10 MHz channels.

Figure 38 summarizes the resulting neighborhood distances for Category B **CBSDs** with height above 6 m across **DPAs** East 1, West 13, and West 14. While the calculated distances for West 13 remain relatively stable across the ten evaluated channels, substantial variation is observed for East 1 and West 14, particularly between the lower and upper channels.

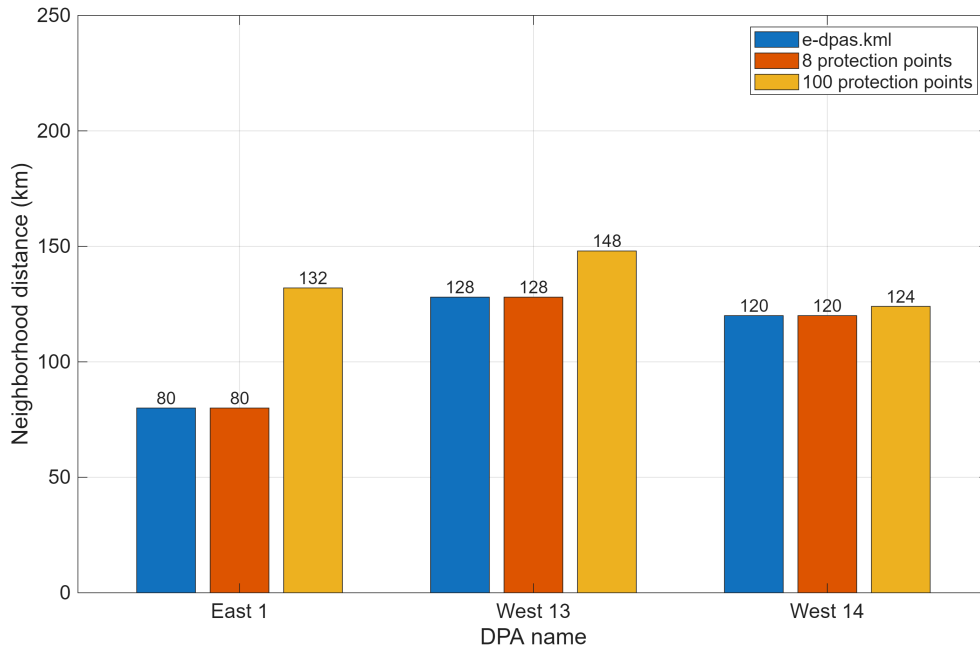


Fig. 37. Impact of protection point selection in neighborhood distances for Category B CBSDs above 6 m using OSM CBSD deployment laydown.

These results demonstrate that the calculated neighborhood distance can depend on both the CBSD deployment laydown and the channel being evaluated.

5.3. Remarks

Figure 39 compares the baseline e-dpas.kml neighborhood distances (blue) against two 100-point protection configurations: the OSM deployment (red) and the maximum distance across 10 channels from the July 1, 2025, FAD deployment (orange). For each of the three E-DPAs evaluated, at least one recalculated neighborhood distance exceeds the corresponding baseline value. The magnitude of the difference varies by DPA and deployment laydown. The results show that, for the E-DPAs and scenarios evaluated here, recalculated neighborhood distances can exceed the baseline CBRS 2.0 values specified in the e-dpas.kml file.

The DPA neighborhood distance calculations are sensitive to both protection point selection and the underlying CBSD deployment laydown. The results indicate that these factors should be considered when evaluating neighborhood distances and their applicability to evolving CBSD deployments. Additional evaluation using representative deployment laydowns and broader protection point configurations would help quantify the sensitivity of calculated neighborhood distances to these modeling inputs.

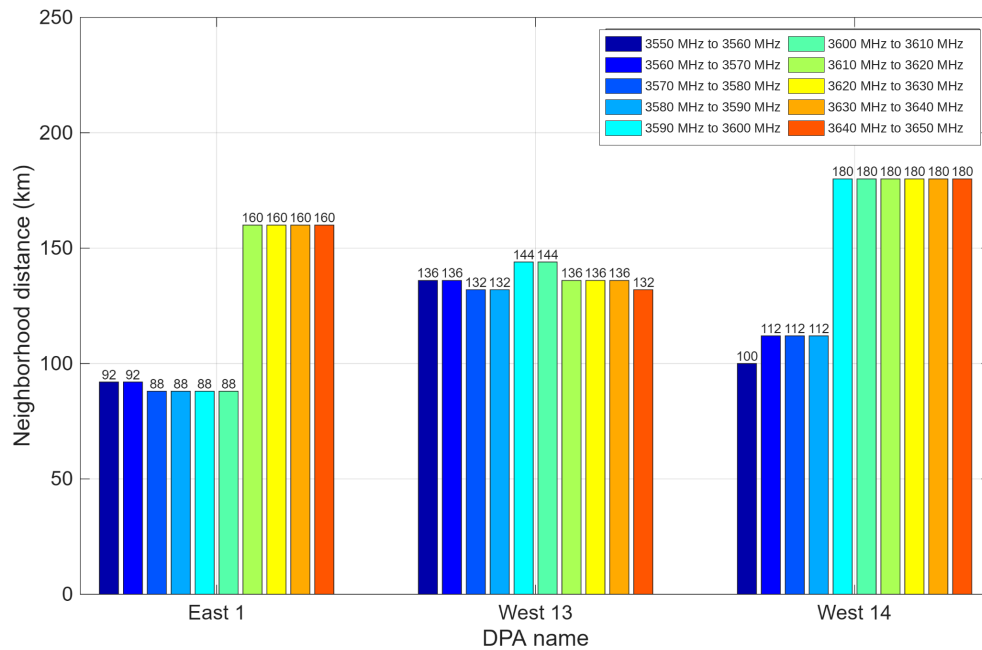


Fig. 38. Neighborhood distances for Category B CBSDs above 6 m using FAD July 1, 2025 deployment laydown for different channels.

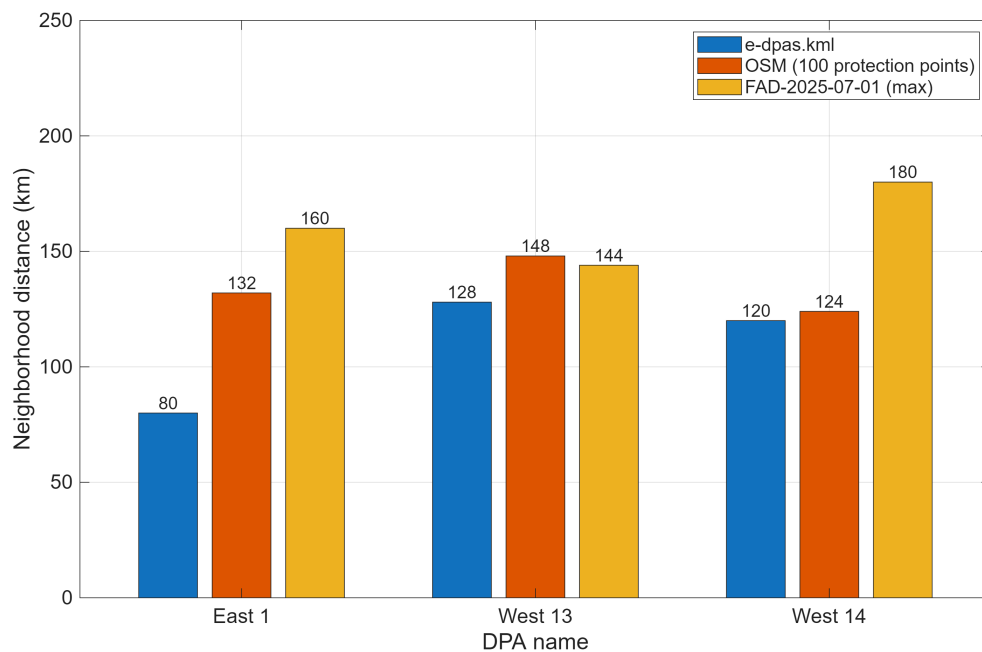


Fig. 39. Summary of baseline and recalculated neighborhood distances for Category B CBSDs above 6 m.

6. Conclusion

The [NASCTN CBRS SEA](#) project provides a data-driven framework for understanding the [CBRS](#) sharing ecosystem and monitoring changes in the spectrum environment over time. The project includes sensor deployments at selected sites on the East and West Coasts of the United States, sensor data collection and analysis, and modeling and simulation to support interpretation of the measurements.

This report describes the modeling methodology developed to support the [NASCTN CBRS SEA](#) project. The modeling implements the [WinnForum DPA](#) Move List procedures for [CBRS 1.0](#) and [CBRS 2.0](#) to calculate [CBSD](#) Move Lists and associated Keep Lists and estimate aggregate emissions at [DPA](#) protection points and [SEA](#) sensor locations. Modeling was also used to inform sensor placement by evaluating expected [CBSD](#) coverage and aggregate emission levels at candidate sensor locations.

Comparison of modeled aggregate emissions with measurements collected at the deployed sensors identified differences between modeled and measured power levels that vary by site and channel. The results also illustrate differences between the [CBRS 1.0](#) and [CBRS 2.0](#) implementations. Interpretation of these comparisons is subject to uncertainties in [FAD](#) data, [CBSD](#) operating parameters, propagation and clutter modeling, duty cycle and network loading assumptions, and the temporal and spectral characteristics of actual [CBSD](#) transmissions. Additional measurements across a broader range of dates and operating conditions are needed to determine whether the observed relationships between modeled and measured results persist over time.

Finally, recalculation of [CBRS 2.0 DPA](#) neighborhood distances for the [E-DPAs](#) evaluated in this report demonstrates that the calculated distances can depend on the number and spatial distribution of protection points, the [CBSD](#) deployment laydown, and the channel being evaluated. These results provide a basis for further evaluation of [DPA](#) neighborhood calculations using representative [CBSD](#) deployments and broader protection point configurations.

For further information on [NASCTN](#) please visit <https://www.nist.gov/ctl/nasctn> or contact the program at nasctn@nist.gov.

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