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DEPARTMENT OF DEFENSE

JOINT SPECTRUM CENTER

ANNAPOLIS, MARYLAND 21402-5064

NOAA GOES SENSOR DATA DOWNLINK COORDINATION ZONES FOR PROPOSED TRANSMITTERS IN THE 1670 to 1675-MHZ FREQUENCY BAND

Prepared for

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
National Environmental Satellite, Data, and Information Service
Office of Systems Development
Suitland, MD 20746-4304

JSC Project Engineer

Ted Grove

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CONSULTING REPORT

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This report was prepared by Alion Science and Technology under Contract DCA100-00-C-4012 in support of the DoD Joint Spectrum Center (JSC) in Annapolis, Maryland.

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14. ABSTRACT
An analysis was performed to determine the potential for radio frequency interference to the Geostationary Operational Environmental Satellite (GOES) sensor data downlink from fixed broadcast emitters in the 1670 to 1675-MHz frequency band proposed by Crown Castle USA, Inc. Coordination zones were developed for critical GOES sites at Wallops, VA, Fairbanks, AK, and Greenbelt, MD.

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FCDAS, GOES, RFI, WBU, WCDAS

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EXECUTIVE SUMMARY

The National Oceanic and Atmospheric Administration (NOAA) has been utilizing the nationally and internationally assigned frequency 1676 MHz to downlink Geostationary Operational Environmental Satellite (GOES) sensor data (SD) to several major sites, most critically at Wallops, VA, at the Goddard Space Flight Center (GSFC) in Greenbelt, MD, and at Fairbanks, AK. The Wallops Command and Data Acquisition Station (WCDAS) is the primary SD downlink site for the NOAA GOES system. The Wallops Back-Up (WBU), located at GSFC, and the Fairbanks Command and Data Acquisition Station (FCDAS) are used for test and training purposes, and to replace the WCDAS capability in times of emergency, such as a hurricane, which could preclude the usage of WCDAS capabilities. The WBU antenna accesses GOES-East, located at 75° W, and the FCDAS antenna accesses GOES-West, at 135° W.

The 1670 to 1675-MHz frequency band has been reallocated and auctioned. The winning bidder, Crown Castle USA, Inc., plans to use the reallocated spectrum in a single block, with fixed broadcast emitter sites, using 2 kW effective isotropic radiated power (EIRP) and a 5-MHz bandwidth. Crown Castle USA, Inc., has requested permission to radiate at 4 kW/MHz or 8 kW/MHz EIRP, depending on local population density.

Prospective RF emitters in the 1670 to 1675-MHz band are required to coordinate with NOAA. The critical nature of the SD downlink from GOES-East and GOES-West, makes this protection essential for the US national interest. Licensees are required to protect WCDAS and FCDAS at all times, and the WBU when it is active.

NOAA requested that the Joint Spectrum Center (JSC) develop geographic contours within which coordination is required to protect the NOAA sites from emitters proposed for the 1670 to 1675-MHz frequency band.

The contours were used to develop coordination zones to protect the GOES sensor data downlinks.

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GLOSSARY

bps	Bits Per Second
EIRP	Effective Isotropic Radiated Power
FCDAS	Fairbanks Command and Data Acquisition Station
FDR	Frequency-Dependent Rejection
GOES	Geostationary Operational Environmental Satellite
GSFC	Goddard Space Flight Center
JSC	Joint Spectrum Center
NOAA	National Oceanic and Atmospheric Administration
RFI	Radio Frequency Interference
SD	Sensor Data
VIEW	Visual Interactive Electromagnetic Compatibility (EMC) Workstation
WBU	Wallops Back-Up
WCDAS	Wallops Command and Data Acquisition Station

SECTION 1 – INTRODUCTION

1.1 BACKGROUND

The National Oceanic and Atmospheric Administration (NOAA) has been utilizing the nationally and internationally assigned frequency 1676 MHz to downlink Geostationary Operational Environmental Satellite (GOES) sensor data (SD) to several major sites, most critically at Wallops, VA, at the Goddard Space Flight Center (GSFC) in Greenbelt, MD, and at Fairbanks, AK. The Wallops Command and Data Acquisition Station (WCDAS) is the primary SD downlink site for the NOAA GOES system. The Wallops Back-Up (WBU), located at GSFC, and the Fairbanks Command and Data Acquisition Station (FCDAS) are used for test and training purposes, and to replace the WCDAS capability in times of emergency, such as a hurricane, which could preclude the usage of WCDAS capabilities. The WBU antenna accesses GOES-East, located at 75° W, and the FCDAS antenna accesses GOES-West, at 135° W.

The 1670 to 1675-MHz frequency band has been reallocated and auctioned. The winning bidder, Crown Castle USA, Inc., plans to use the reallocated spectrum in a single block, with fixed broadcast emitter sites, using 2 kW effective isotropic radiated power (EIRP) and a 5-MHz bandwidth. Crown Castle USA, Inc., has requested permission to radiate at 4 kW/MHz or 8 kW/MHz EIRP, depending on local population density.

Prospective users of the 1670 to 1675-MHz band are required to coordinate with NOAA. The critical nature of the SD downlink from GOES-East and GOES-West, makes this protection essential for the US national interest. Licensees are required to protect WCDAS and FCDAS at all times, and the WBU when it is active.

NOAA requested that the Joint Spectrum Center (JSC) develop geographic contours within which coordination is required to protect the NOAA sites from emitters proposed for the 1670 to 1675-MHz frequency band. The contours will be used to identify those cases for which more detailed calculations are required to support coordination based on the specific locations of proposed emitters.

1.2 OBJECTIVE

The objective of this study was to define the geographic regions within which coordination is needed for Crown Castle USA, Inc., emitters prior to licensing approval of the 1670 to 1675-MHz band.

1.3 APPROACH

The first step in this study was to obtain system RF characteristics for the emitters proposed by Crown Castle USA, Inc. These emitters are essentially a fix-tuned broadcast system using 5 MHz of bandwidth adjacent to the GOES SD downlink. The technical data for the GOES SD receiver was obtained from National Telecommunications and Information Administration (NTIA) frequency assignment requests. The maximum interference level allowable to the GOES SD downlink was established. Frequency-Dependent Rejection (FDR) was calculated using the Crown Castle USA, Inc., emissions spectrum and the SD downlink selectivity. Since these systems operate at fixed center frequencies separated by 3.5 MHz, FDR was a constant. Coordination zones were established to avoid exceeding the GOES SD interference threshold, based on the proposed Crown Castle USA, Inc., effective isotropically radiated power, terrain-dependent propagation loss, GOES receive antenna gain, and FDR.

SECTION 2 – SYSTEM DESCRIPTION

2.1 NOAA SYSTEMS

The WCDAS earth station antenna points toward GOES-East and GOES-West. The FCDAS earth station antenna points toward the GOES-West satellite, and the antenna at the WBU points toward the East satellite. The GOES SD downlink is centered at 1676 MHz and has a -3 dB bandwidth of 2.6 MHz. Table 2-1 presents NOAA earth station characteristics and locations. [2-1, 2-2] The antennas analyzed at WCDAS and WBU are identical with 16.4-meter diameters. The antenna at FCDAS has a 21-meter diameter.

Table 2-1. NOAA Earth Station System Characteristics

Parameter	Value		
Location	WCDAS	WBU	FCDAS
Antenna height, m AGL	10	10	15
Emissions Spectrum	Level, dB	Bandwidth, MHz	
	-3	2.6	
	-20	8.2	
	-60	20.7	
G/T, dB/K	26	26	31
Latitude, dms	37 56 44 N	39 00 02 N	64 58 23 N
Longitude, dms	075 28 40 W	076 50 29 W	147 30 04 W
Azimuth, deg	179 GOES-East 250 GOES-West	177 GOES-East	166 GOES-West
Elevation, deg	46 GOES-East 15 GOES-West	45 GOES-East	16 GOES-West

AGL – Above Ground Level
dms – degrees minutes seconds
G/T – Gain-to-System Noise Temperature
N – North
W – West

The earth station antenna pattern for the identical antennas at WCDAS and WBU was calculated by the antenna manufacturer. The JSC developed the corresponding envelope for the antenna gains at WCDAS and WBU. Measurements show that the antenna at FCDAS conforms to a 35-25 log (angle) antenna pattern envelope, with a minimum gain of -10 dBi. The antenna patterns for WCDAS, WBU, and FCDAS used in this analysis are shown in Figure 2-1.

[2-1] *NOAA/NESDIS Antennas and RF Systems Capabilities Handbook*, NOAA/OSD3-2001-0043 ROUDO, Silver Spring, MD: NOAA, 10 August 2001.
[2-2] Richard Barth, Department of Commerce, memorandum to Spectrum Planning Subcommittee, Subject: *Spectrum Support for GOES Central*, US Department of Commerce, Office of Radio Frequency Management, 3 March 1997.

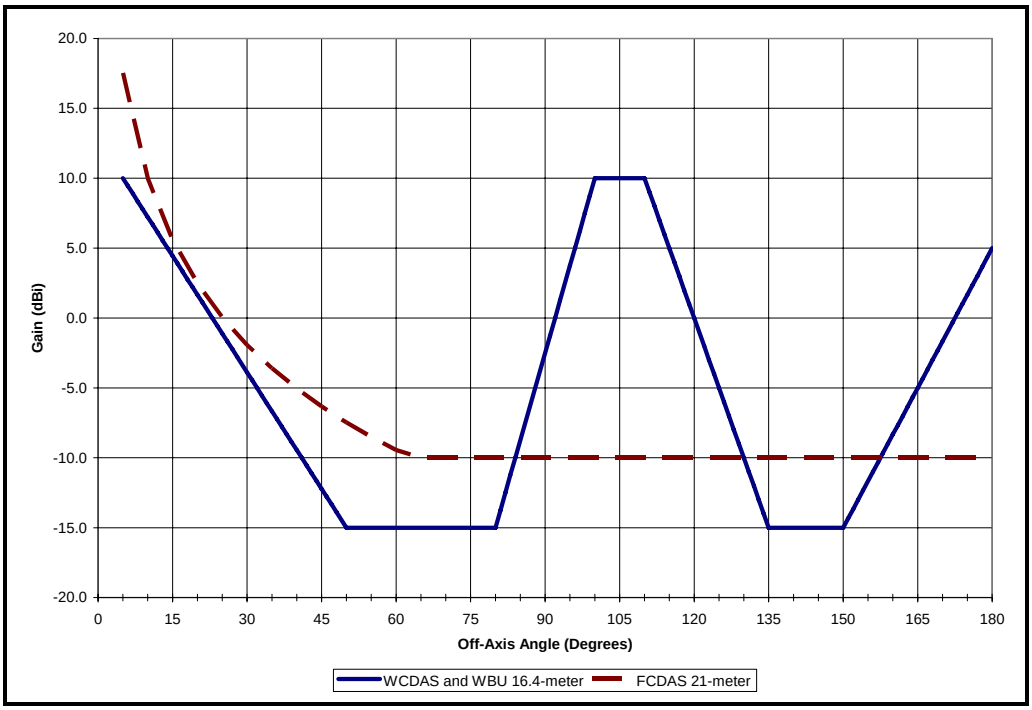

Figure 2-1. Antenna Sidelobe Envelope Patterns

2.2 CROWN CASTLE USA, INC., SYSTEM

Crown Castle USA, Inc., has proposed the use of fixed-broadcast emitters in the 1670 to 1675-MHz frequency band. The broadcast emitters will send data to mobile receivers. Transmit antennas will be elevated and will utilize the entire 5 MHz of reallocated spectrum. The system characteristics, shown in Table 2-2, were derived from references supplied by Crown Castle USA, Inc. [2-3, 2-4]

Table 2-2. Proposed Crown Castle USA, Inc., System Characteristics

Parameter	Value	
EIRP, kW	2 (in 5 MHz)	
EIRP Requested, kW/MHz	4 or 8	
Emissions Spectrum	Level, dB	Frequency, kHz
	0	200
	-3	4500
	-35	5000
	-68	7000
	-76	>10000
Antenna Height, m above ground level	25-80	
Center Frequency	1672.5 MHz fixed	

[2-3] *Axcerra-LL50ATC FCC Type Acceptance Report, Operational Description and Test Report,* Lawrence, PA: Axcerra LLC, June 2005

[2-4] *Innovator LX Series 1.67 GHZ 200W DVB-H Transmitter Instruction Manual (Preliminary*), Lawrence, PA: Axcerra LLSC, June 2005.

SECTION 3 – ANALYSIS

In this section, criteria to protect GOES SD downlinks are developed. FDR is calculated for radio frequency interference (RFI) from the Crown Castle USA, Inc., system to the SD downlinks. Contours outside of which RFI is not predicted were developed. Within the contours, coordination is required with NOAA to ensure that the downlinks are not degraded.

3.1 PROTECTION CRITERIA

The interference threshold derived in Table 3-1 is for the current GOES I-M (8-12) spacecraft and the next generation GOES N-Q (13 and above) satellite designs. The thresholds in Table 3-1 agree closely with thresholds developed separately for the International Telecommunication Union. [3-1] The protection criterion used in this study was -116.8 dBm.

Table 3-1. Link Budget for GOES SD Downlinks

Item	Value		Notes
Satellite Type	GOES I-M	GOES N-Q	
Satellite Power, dBm	33.0	37.3	
Line losses, dB	2.9	2.9	
Spectrum Truncation Loss, dB	0.5	0.5	
Satellite Antenna Gain, dBi	16.5	14.5	
Satellite EIRP, dBm	46.1	48.4	
Path Loss, dB (edge of earth)	189.4	189.4	
Polarization Loss, dB	0.2	0.2	
Gain-to-Noise Power Ratio, dB/K	26.0	26.0	T=174 K and gain = 48.4 dBi
Pointing Losses, dB	0.5	0.5	
Boltzmann's Constant, dBm/kHz	-198.6	-198.6	
Carrier-to-Noise Power Ratio, dB-Hz	80.6	82.9	
Data Modulation Loss, dB	2.0	2.0	
Data Rate, Mbps	2.6	2.6	bps = bits per second
Data Rate, dB-Hz	64.1	64.1	10 log (2.6×10^6)
Bit Energy-to-Noise Power Ratio, dB	14.5	16.8	
Required Bit Energy-to-Noise Power Ratio, dB	13.0	15.5	Bit Error Rate (BER) I-M = 10^{-6}, BER N-Q=10^{-8}
Margin, dB	1.5	1.3	
Total Power RFI Threshold, dBm	-116.1	-116.8	Uses up link margins

[3-1] *Sharing Criteria for Data Dissemination and Direct Data Readout Systems in the Earth Exploration-Satellite and Meteorological-Satellite Services Using Satellites in Geostationary Orbit,* Recommendation ITU-R SA.1161-1, Geneva: ITU, 1999.

3.1.1 Frequency-Dependent Rejection

The Crown Castle USA, Inc., transmitter center frequency is fixed at 1672.5 MHz. FDR was calculated using software developed by the JSC. [3-2] The model employs transmitter emission spectrum and receiver selectivity data to determine signal rejection due to off-tuning and spectrum mismatch. Figure 3-1 shows the emission spectrum of the Crown Castle USA, Inc., system and the selectivity of the NOAA systems. The off-tuning from the SD signal center frequency is 3.5 MHz. The calculated FDR at the 3.5 MHz off-tuning between the systems s 13.3 dB.

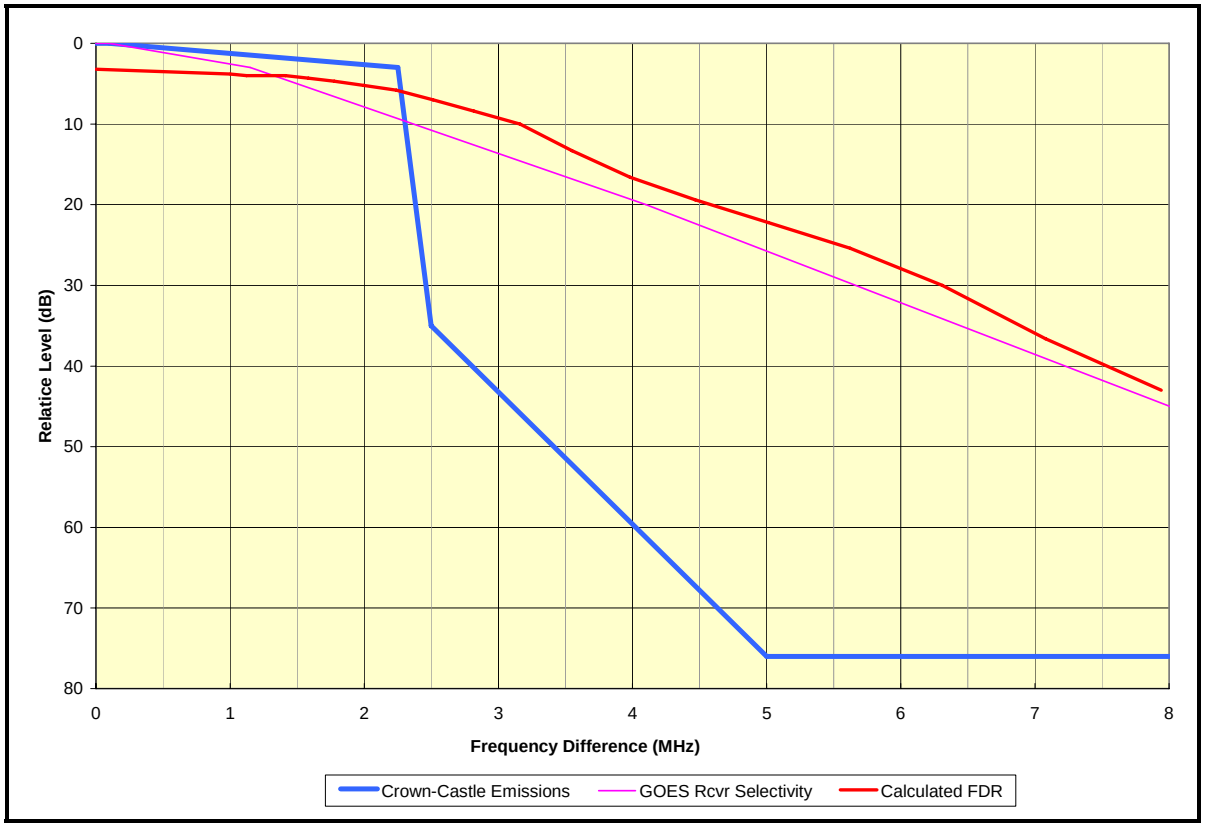

Figure 3-1. Spectra and Selectivity

3.2 COORDINATION ZONES

The JSC Visual Interactive Electromagnetic Compatibility (EMC) Workstation (VIEW) program was used to determine coordination zones. VIEW uses terrain-dependent path loss and calculates the received signal level between locations, including: antenna patterns, height, and pointing angle;

[3-2] Kenneth Clubb, et al, *EMC Programs for IBM-Compatible Personal Computer; User Manual*, UM-91-045, Annapolis, MD: IITRI (now Alion Science and Technology), August 1991.

frequency; transmitter power; and other parameters. The maximum allowable interference was calculated using Equation 3-1.

$$I_{max} = I_{th} - FDR \quad (3\text{-}1)$$

where I_{max} = maximum radio frequency interference, in dBm
I_{th} = radio frequency interference threshold, in dBm
FDR = frequency-dependent rejection, in dBm

VIEW was used to produce a set of contours, outside of which interference levels from the Crown Castle USA, Inc., system would not exceed the SD RFI threshold. For locations inside of the contours additional analysis is required to determine if the level of interference from a proposed Crown Castle USA, Inc., transmitter would be above the SD RFI threshold required to protect the NOAA sites. The calculated coordination contours are presented in Figures 3-2, 3-3, and 3-4. The regions shaded in red are coordination zones for a 2 kW/5 MHz transmitting antenna located 80 meters above ground level. The regions shaded yellow correspond to 4 kW/MHz zones, and the regions shaded green correspond to 8 kW/MHz. The contours are specific to each site and incorporate digitized terrain data, technical characteristics of the receive system, and antenna pointing based on the appropriate GOES satellite. The coordination zones for WCDAS are composites protecting both the GOES-East and the GOES-West downlinks. Although these regions are large and may appear daunting, antennas placed at the peripheries of the designated regions will be within line-of-sight of most areas, thus permitting Crown Castle USA, Inc., operations, except for a region around the NOAA antennas.

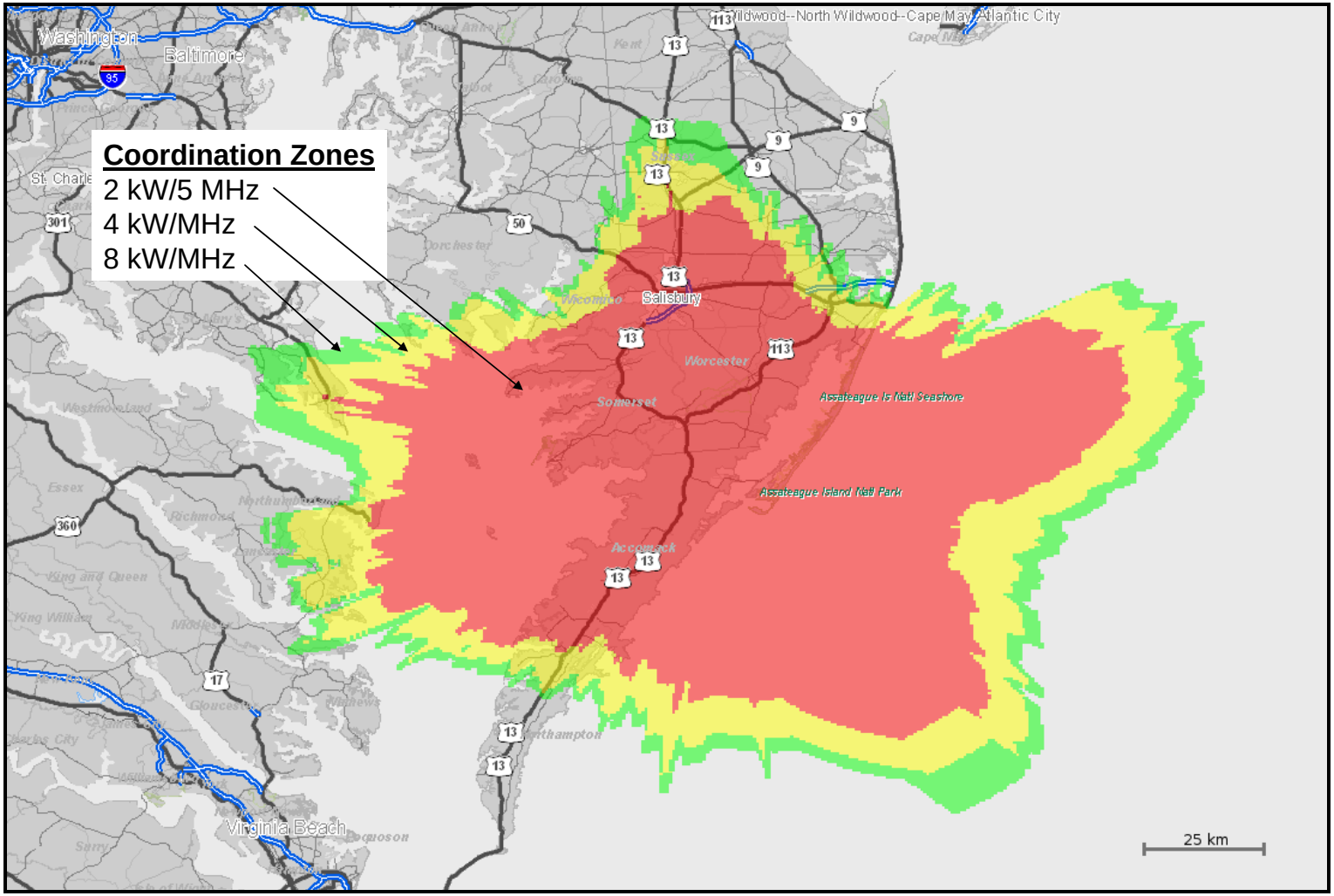

Figure 3-2. Coordination Zones to Protect NOAA Downlinks at the WCDAS

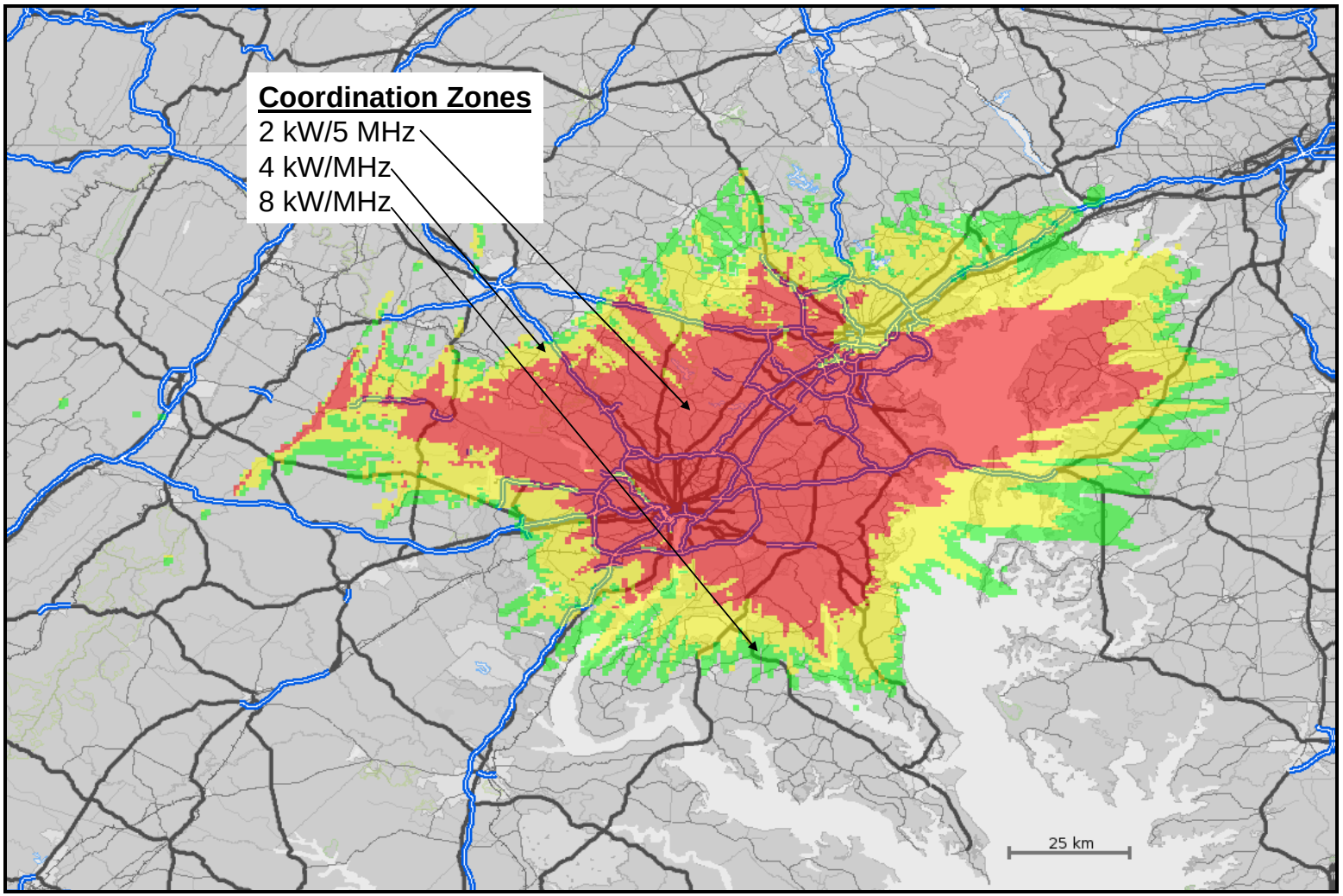

Figure 3-3. Coordination Zones to Protect NOAA Downlinks at the WBU

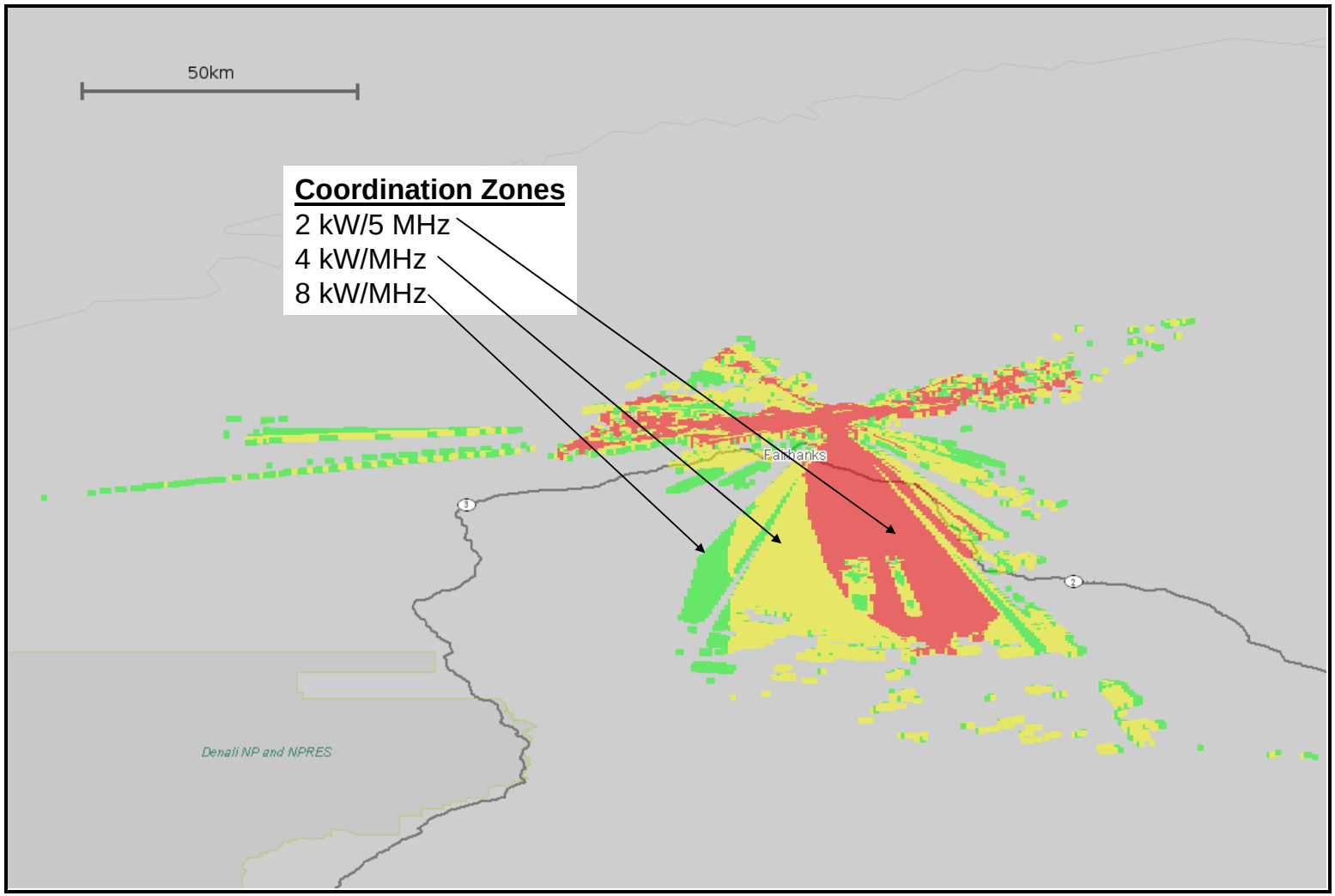

Figure 3-4. Coordination Zones to Protect NOAA Downlinks at the FCDAS

SECTION 4 – CONCLUSIONS AND RECOMMENDATIONS

The operation of a system that radiates 2 kW or more using one 5-MHz channel in the frequency range from 1670 to 1675 MHz may cause harmful RFI to the NOAA SD downlinks at the WCDAS, WBU, and FCDAS, if the transmitters are within the contours developed in Figures 3-2, 3-3, and 3-4. The contours are based on the maximum antenna height proposed and on 15-second resolution terrain data. If specific locations within the contours are proposed, they should be analyzed based on higher resolution terrain data, actual proposed transmitter power, and antenna heights.

Emitters with antenna heights at or below 80 meters outside the applicable power contours do not require further analysis because they are not predicted to cause RFI.

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in the 1670-1675-MHz Frequency Band
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