Dodge County, Wisconsin

Needs Assessment Deliverable

July 2025



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1 Executive Summary

TUSA Consulting Services II, LLC (TUSA), a radio consulting firm experienced in the field of public safety communications, was retained by Dodge County Wisconsin to provide professional consulting services associated with the modernization of the County's existing public safety radio network. TUSA was requested to perform a full need assessment study. As part of this study, TUSA conducted a series of interviews and surveys with the radio system stakeholders to gain an understanding of the operational and reliability shortfalls within the existing system(s). Additionally, TUSA was asked to identify the technical and cost challenges with modern public-safety systems, and site visits to study the overall sustainability of the current systems.

Dodge County has a total area of 907 square miles (2,350 km2), of which 876 square miles (2,270 km2) is land and 31 square miles (80 km2) (3.5%) is water. The county seat is the city of Juneau, Wisconsin, and as of the 2020 census the population was 2,658. The population density was 1,611.9 inhabitants per square mile (622.4/km2).

The County utilizes a mixture of systems and repeaters for communications. The primary communications for the Sheriff, Fire, Fire Paging, EMS, and the Highway Department are VHF conventional channels in a simulcast configuration.

As part of Phase I of this project, TUSA's scope of work included interviewing and surveying key project stakeholders. These interviews were undertaken in June of 2025 and during the process, the following salient concerns were identified:

- Inadequate Portable Radio Coverage
- Noisy and degraded audio communications
- Interoperability with agencies inside and outside the county

During the interviews, users conveyed that the current system is very noisy and suffers from lack of coverage, usability, and interoperability. Many of the County users struggle with day-to-day operations on this system with the inability to talk to dispatch and other users in the field. Portable radio coverage problems offer significant struggles for the users and create safety concerns for first responders. There are many areas of the county, especially in the outlying areas, where radio coverage is inadequate. TUSA has reviewed these issues and developed this report to provide conceptual radio configuration solutions for the County's consideration.

These conceptual configurations consider future growth, emerging technologies, and are structured to support a radio system over a life cycle of 20 years. The solutions directly address

coverage, performance, reliability, interoperability/operability, procurement, and ongoing maintenance costs.

Included are budgetary estimates that leverage fresh information gleaned from recent conventional and P25 radio system procurements throughout the United States. This includes comprehensive budgetary spreadsheets that depict the costs of each conceptual configuration. Likewise, the report includes coverage map predictions for individual tower sites, thereby allowing the county to consider the relative effectiveness of each site and its contribution to overall coverage reliability. This allows the county to adapt the conceptual system configuration that best meets its envisioned needs and funding realities.

TUSA includes several recommendations throughout this report for immediate consideration prior to moving to a next generation radio system:

- Work to achieve industry standards and best practices for grounding the radio equipment at dispatch and the radio sites.
- Perform preventative maintenance on all existing equipment, including backbone infrastructure and user radio equipment. This should be accompanied by a detailed report from the contractor describing what work was performed, and documented results of the preventative maintenance.
- Review the Site Visit Summary and perform recommendations in Section 3 of this report.

This report explores four conceptual designs that are further defined in Section 13 Conceptual System Designs. These designs include,

- Solution 1: A P25 digital conventional VHF system replacing/refreshing any existing aging, end-of-life equipment.
- Solution 2: A 700/800 MHz P25 trunking system
- Solution 3: Partner with the WISCOM2 700/800 system and sharing resources such as tower sites and cores.
- Solution 4: Partner with the WiPSN 700/800 system and sharing resources such as tower sites and cores.

Budget details and summaries for the conceptual designs are presented in Section 14 of this report.

2 Existing Network Configuration

The Dodge County radio network consists of nine tower sites with seven conventional channel (six analog and one P25 digital) VHF repeater sites configured as a simulcast system. The repeater tower locations that make up the system are located at,

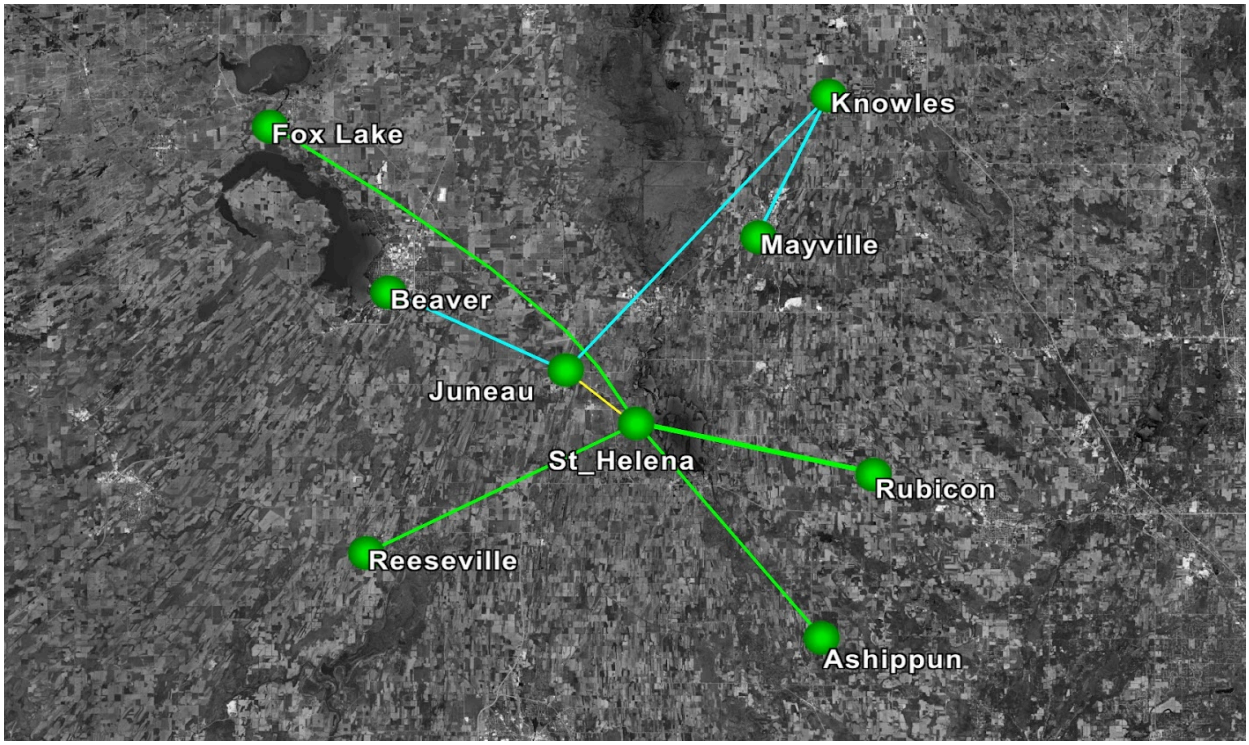
- Ashippun
- Beaver Dam Fire Department
- Fox Lake
- Juneau Highway Department
- Knowles
- Mayville
- Reeseville
- Rubicon
- St. Helena

Each of the seven VHF tower sites have repeaters for the channels shown in the following table.

Radio Channel	Transmit Simulcast	Voted Receive	Band/Type
Dodge Law 1	Yes	Yes	VHF Analog
EM5	Yes	Yes	VHF Analog
Fire	Yes	Yes	VHF Analog
Fire Paging	Yes	Yes	VHF Analog
Highway	Yes	Yes	VHF Analog
Sheriff	Yes	Yes	VHF Analog
Sheriff Encrypted	Yes	Yes	VHF P25 Digital

The seven simulcasted VHF radio channels used by the county

The core of the system, where the Motorola MCC 7500E dispatch consoles are interconnected, is at the Dodge County Sheriff's Office located at 124 West St, Juneau, WI. The Motorola core, along with the voting and Intraplex mux equipment is the heart of the nine site simulcast system. A fiber connection between the core at dispatch and the Juneau/Highway Department tower, provides a path to the microwave network which in turn provides connectivity to the simulcast tower sites. This interconnectivity is represented in the following diagram demonstrating a star type microwave configuration. The green and blue lines represent microwave paths and yellow lines represent fiber routes. There is a fiber connection between the dispatch server room and the courthouse that provides connectivity for the console located at the jail.



Current system Interconnection diagram.



Fiber connectivity between the Juneau tower, dispatch, and the jail.

2.1 FCC Licensing

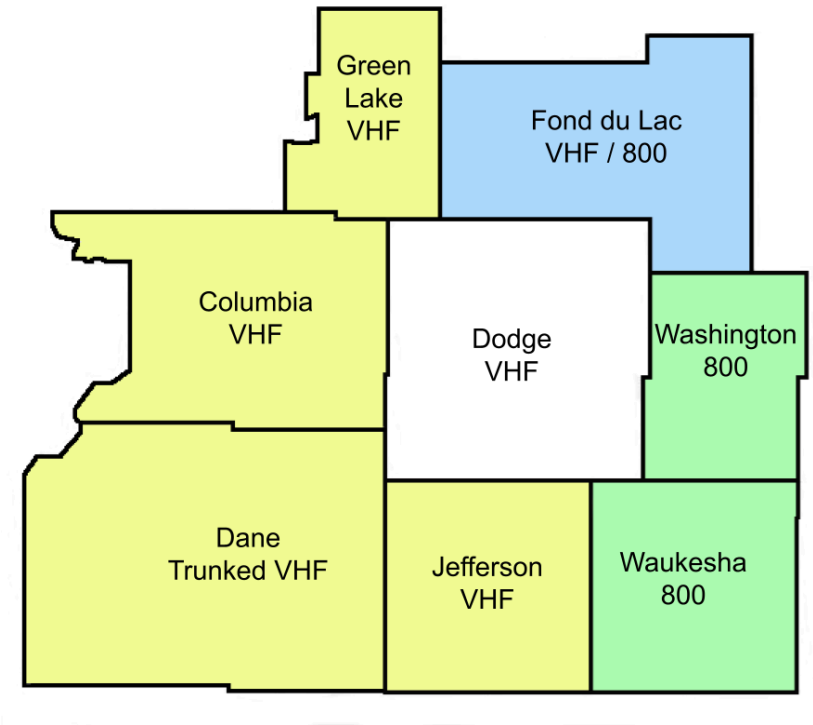
The following table identifies the FCC radio licenses in use within the County's VHF radio system.

FRN	Call Sign	User	Frequency	Expiration Date
0002683514	KB75930	EM5	155.325 MHz	01-08-2031
0010735986	KFY426	Fire	154.325	12-09-2033
0010515690	WPLX469	Paging	154.445	04-01-2033
0002155281	KTS527	Highway	151.155	04/24/2032
0010325751	KSB421	Sheriff 1	154.785	02-17-2033
0009982128	KUB996	DOLAW1	155.745 MHz	04-27-2032
0010325751	KSB421	DOSO 4 (digital)	151.4225	02-17-2033
0010515690	WPLX469	Backup paging	154.445	04-01-2033

FCC License Information

2.2 Mutual aid summary

There are a number of mutual aid and interoperability challenges for users both inside and outside of Dodge County.



Surrounding Counties and Frequency Bands

2.2.1 Neighboring Counties

As shown in the figure above, the county is surrounded on the west by primarily VHF systems and on the east and to the north by 700/800 MHz systems. Dane County uses VHF P25 trunked digital and encrypted channels making simple VHF intercommunications more difficult.

700/800 MHz systems can present another challenge of operability typically requiring users to carry multiple radios or employ multiband radios that can communicate on both frequency bands and in different modes such as analog or P25. The communication challenge with surrounding counties is not only an issue with differing frequencies, but also an issue with differing technologies. Users have expressed that it is becoming increasingly more difficult to communicate with neighboring counties.

There is also the need to communicate with the Wisconsin State Patrol that is currently using VHF and 700/800, and now moving to the new 700/800 MHz WISCOM2 P25 System .

County	Agency	Frequency Band
Dodge	Countywide Police Dispatch	VHF
Dodge	Sheriff Dispatch	VHF
Dodge	Fire/EMS Paging	VHF
Dodge	Fire Dispatch	VHF
Fond du Lac	Sheriff, County Fire	VHF
Fond du Lac	Fond du Lac City Police and Fire	VHF/800 Mhz
Jefferson	Law enforcement, Fire, EMS	VHF
Green Lake	Sheriff, Fire, EMS	VHF/800
Columbia	Sheriff, Fire, EMS (WISCOM 800 Mhz)	VHF/800
Dane	Law Enforcement, Fire, EMS	VHF P25 Trunked
Dane	WISCOM	800 Mhz
Washington	Law Enforcement, Fire, EMS	700 Mhz
Waukesha	Law Enforcement, Fire, EMS (WiPSN 800 Mhz)	800 Mhz

Neighboring agencies and frequency bands

2.2.2 Within the County

There are challenges within Dodge County as well. The City of Water Town is using a 800 MHz trunked system. The City of Beaver Dam is using a VHF system while Beaver Dam police are utilizing the Dodge County VHF system. Currently the fire department switches to the state designated fire ground frequencies when involved in an incident. These fire ground frequencies are for portable radio to radio communications and do not utilize a repeater. They are also not monitored by dispatch. It is a common request among firefighters that dispatch be able to monitor the fire ground channels when needed.

During the recent tornado, Clearview had no connection to the rest of the county. Cellphones and outside communications were not working and personnel did not have any direct communication with first responders.

2.2.3 Jail and Courthouse

There are also communications problems within the jail and portions of the courthouse. The jail is using a UHF system, paired with in-building coverage issues for the county VHF portables and communications become difficult in critical areas where detainees are being escorted .

2.3 Channel / Talkgroup Limitations

User interviews and site visits supported the need and desire for multiple channels or talkgroups in the case of a trunked radio system. Given that agencies are striving to achieve countywide communications via the VHF simulcast system, they still are limited to specific channels. The majority of users expressed that they were limited in their operations by the lack of channel resources during the recent tornado outbreak in May of this year. The existing seven channels were overwhelmed and hindering effective communications.

Having a system that is expandable would allow agencies to have their own channels/talkgroups. Along with the lack of capacity, users commented on the lack of interoperable communications between county agencies, and the desire to make it simpler and more efficient.

3 Site Visits

During the week of May 6th thru May 8th, TUSA met with representatives from Dodge County to kick-off the project and proceed with gathering information for the needs assessment report. TUSA conducted tower site visits to inspect the infrastructure used for the county radio system. This included VHF repeater sites, as well as the Sheriff's Office (SO) and dispatch center.

TUSA's radio infrastructure site inspections are comprehensive and include an assessment of not only the radio equipment itself, but also important supportive equipment such as:

- Microwave/wired/fiber backhaul.
- Equipment shelters
- Tower structures
- Generators
- Maintenance and workmanship
- UPS/battery backup systems
- Site compound organization
- Site electrical and equipment grounding
- Overall site installation quality

These inspections are not only completed to understand the condition of the current infrastructure, but also verify if any of the current facilities or infrastructure are reusable for future use. Important findings and workmanship observations are presented in the pages that follow. The site issues are identified with the goal of creating a hardened public safety grade system.

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3.1 County Dispatch Center

Address: 124 West St, Juneau, WI
Latitude: 43° 24' 26.94"
Longitude: -88° 30' 36.3918"
ASR#: 1282498
Tower: 50’ Free Standing
Shelter: Interior Room in the adjacent building
Generator: Building Generator
Fuel tank: Diesel tank incorporated with generator

3.1.1 Site Observations

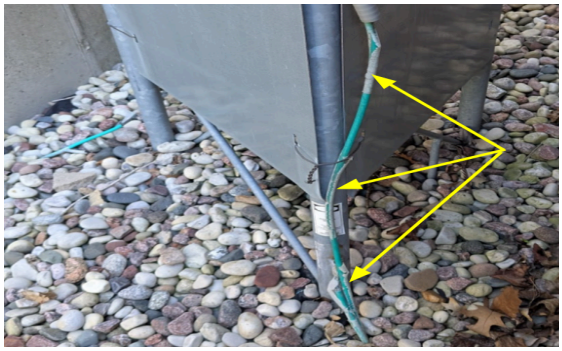
The dispatch area, equipment room, and server room are located inside the building. Backup power is provided by the building's Kohler diesel generator. The equipment in this building is connected via fiber to the Courthouse and Jail where there is an additional console. The core equipment to interface the consoles to the system is located here. There is also a fiber path to the Juneau tower site.



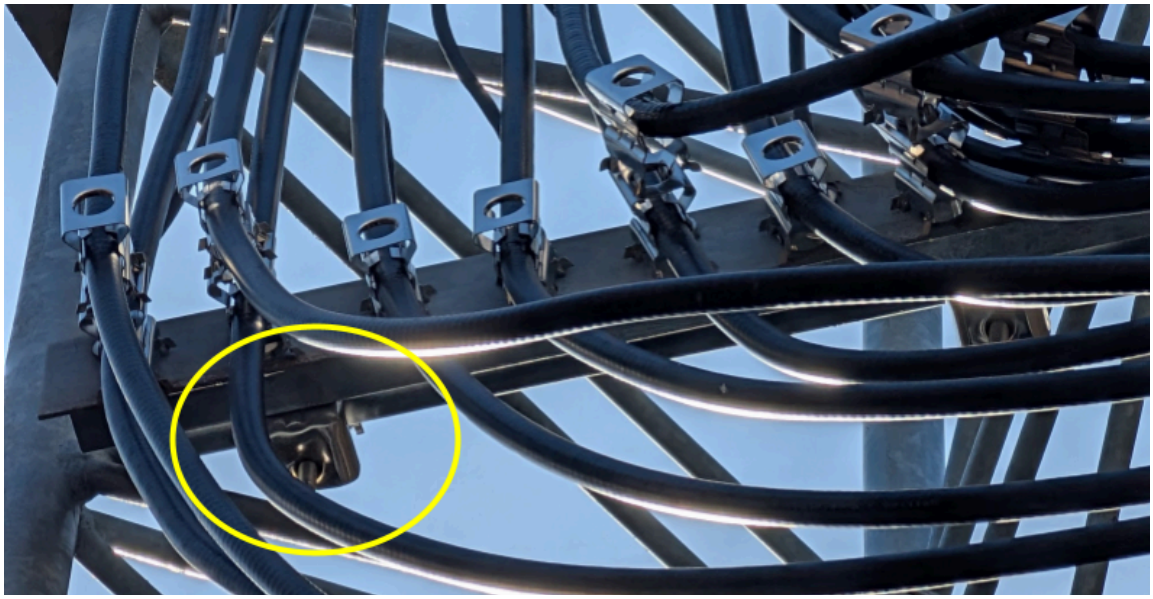
3.1.2 Issues Outside The Building

- The tower is using a jacketed copper wire that has become corroded. The corrosion within the wire creates a poor ground for lightning. The jacket on the wire allows water to be wicked up by the cable making it difficult to identify badly corroded sections. It is preferred to use a solid tined wire that is resistant to corrosion and can be more easily inspected.





- The ground busbar for Coax is not isolated from the tower. The busbar should have isolators that create isolation from the tower, and a separate ground wire should connect the bus to the buried ground ring at the base of the tower. The busbar is currently grounded with a tower clamp.



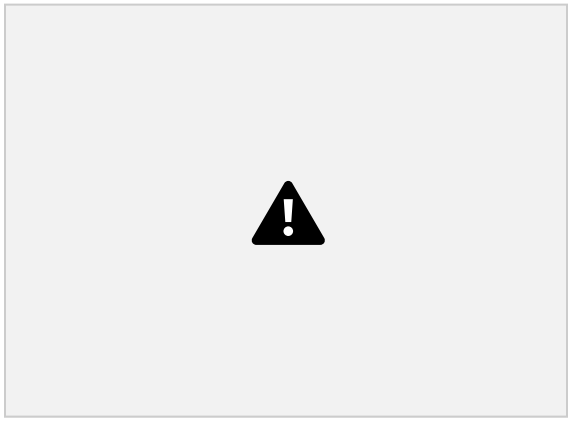
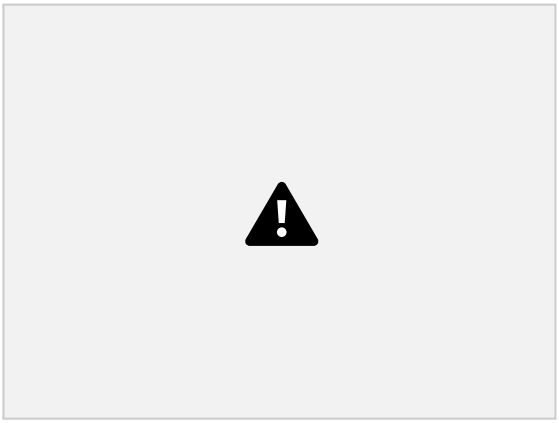
- There is not an external busbar for grounding where the coax cables enter the building. A ground wire is present and penetrates the building, but it should connect to a busbar and provide a ground point for the coax before it enters the building.



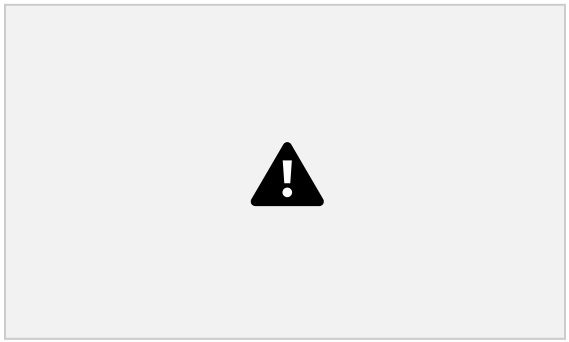
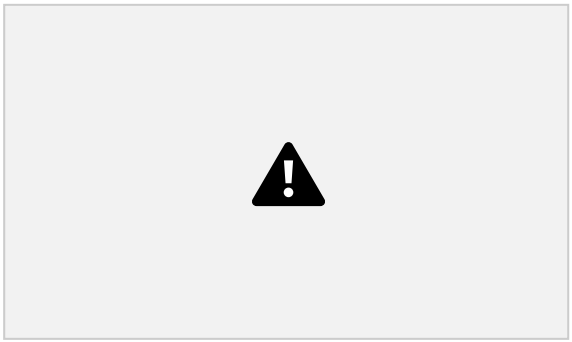
3.1.3 Dispatch Area

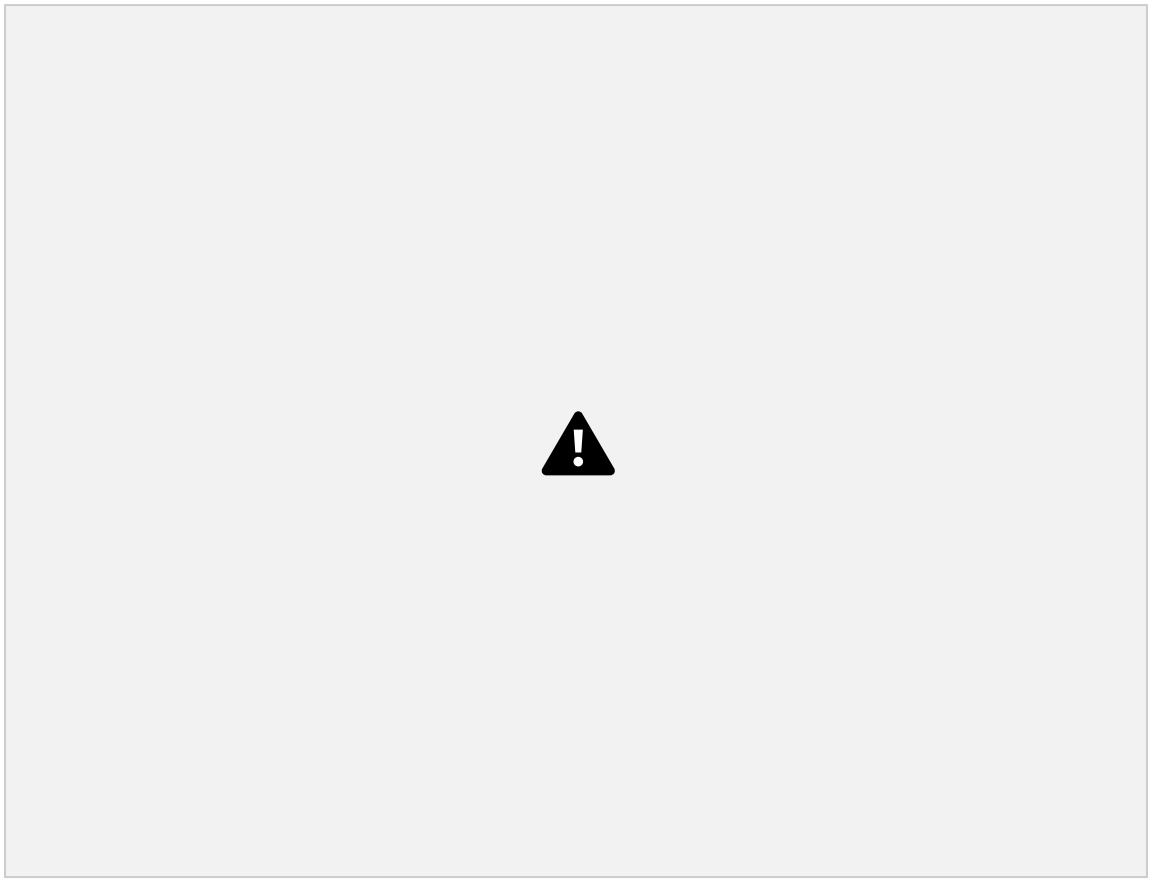
- The dispatch area has modern furniture, organized work areas, and provides plenty of space for accomplishing the required task. The following issues were identified with the installation of the communications equipment. Given that this furniture is more than 10 years old, it has been well maintained.

- The location of equipment and wiring is inconsistent between dispatch positions. For example the console PC is located and mounted differently from location to location.
- There seems to be a lack of grounding for the communications equipment. All devices should be grounded to the ground busbar provided for each console position. Grounding in a dispatch environment is critical due to the movement of chairs, furniture, and personnel that can create a static discharge to the equipment.
- Computer equipment is placed on top of the console furniture. There is adequate space in the cabinets below to allow proper installation. This creates clutter behind the console positions. Wiring needs to be better secured and organized. Power cables should be connected in the equipment bays to avoid being inadvertently unplugged.

- Wiring beneath the console positions is not secured and is hanging free. The wires are routed poorly, disorganized, and not properly secured. Wiring should be secured and organized in a manner that allows movement of the furniture but better avoids being snagged and damaged by the movement of the equipment and personnel.

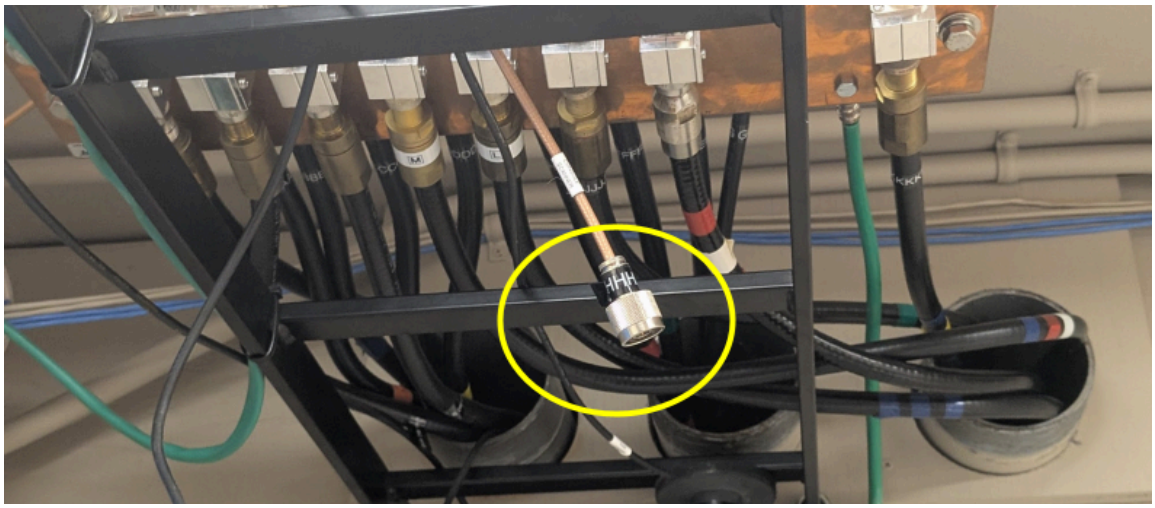



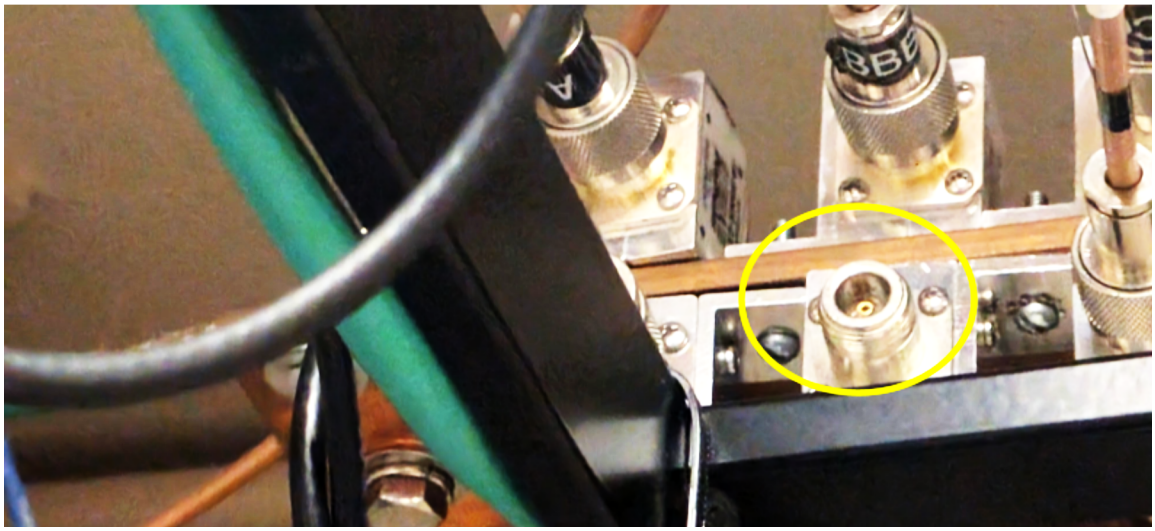


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3.1.4 Backup Radio Room

- The room is hot and has inadequate cooling. There is not an AC unit in the room itself. Cooling the equipment is important to proper operation and longevity.
- There are unterminated cables and lightning arrestors where the coax cable comes into the room. Open connectors on outside antenna cables can allow noise and interference into the equipment room affecting the performance of the equipment. This is especially prevalent in the VHF band.

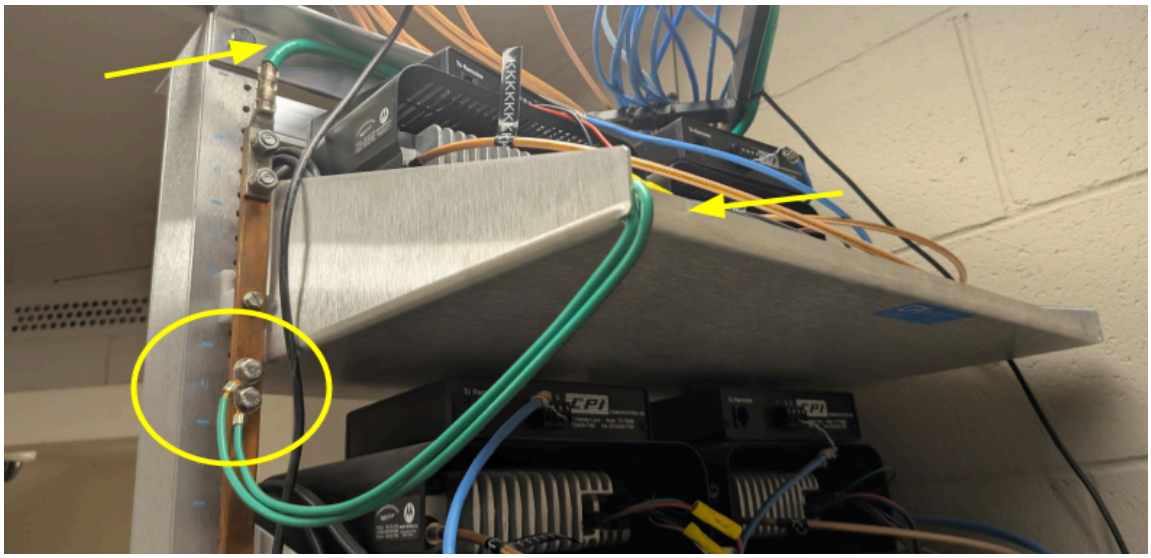




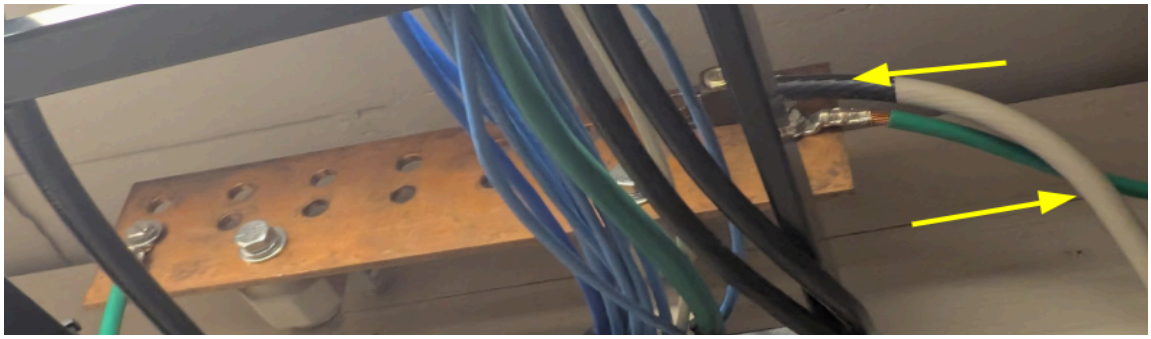
- There is not a halo ground in the room. A ground wire should be routed around the perimeter of the room to provide additional grounding and assist with dissipating energy should in the occurrence of a lightning strike.

- Lightning arrestor ground bar is tied to the outside ground. It should be connected as a sub ground busbar from the MGB (Master Ground Busbar). All sub busbars should connect back to the MGB.

- Sharp bends in the ground wires at the radio equipment rack. Single holed lugs are used to connect the ground wire to rack ground. Dual holed lugs should be used to prevent the ground from working loose and are considered as standard best practices.



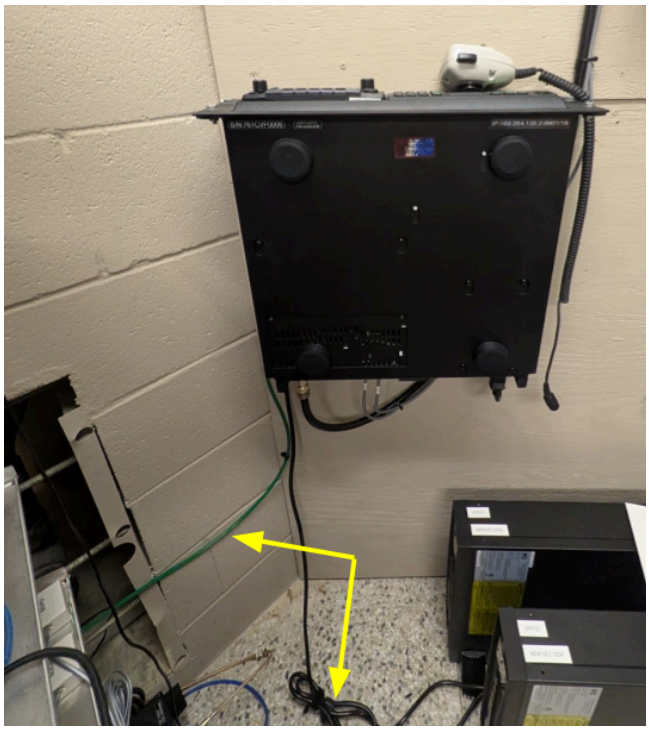
- There are ground wires that route outside the room and it is not certain where they are connected. This creates a potential for ground loops that can cause devastation to equipment if the outside tower receives a lightning strike. The grounding connectivity needs to be better identified to determine that there are not any ground loops and there is a single ground point in the room.

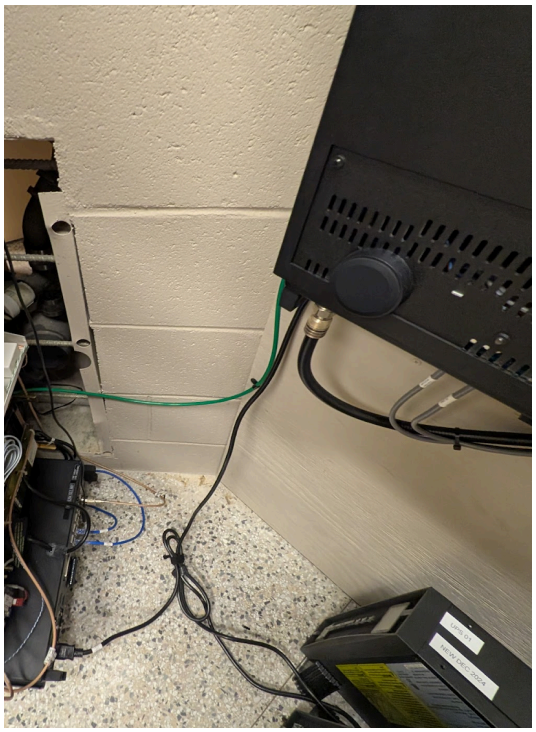


- The white jacketed ground wire should be marked with green tape. A double holed compression lug should be used to connect the ground wire to the MGB. All ground lugs connected to the MGB should have double holed lugs.



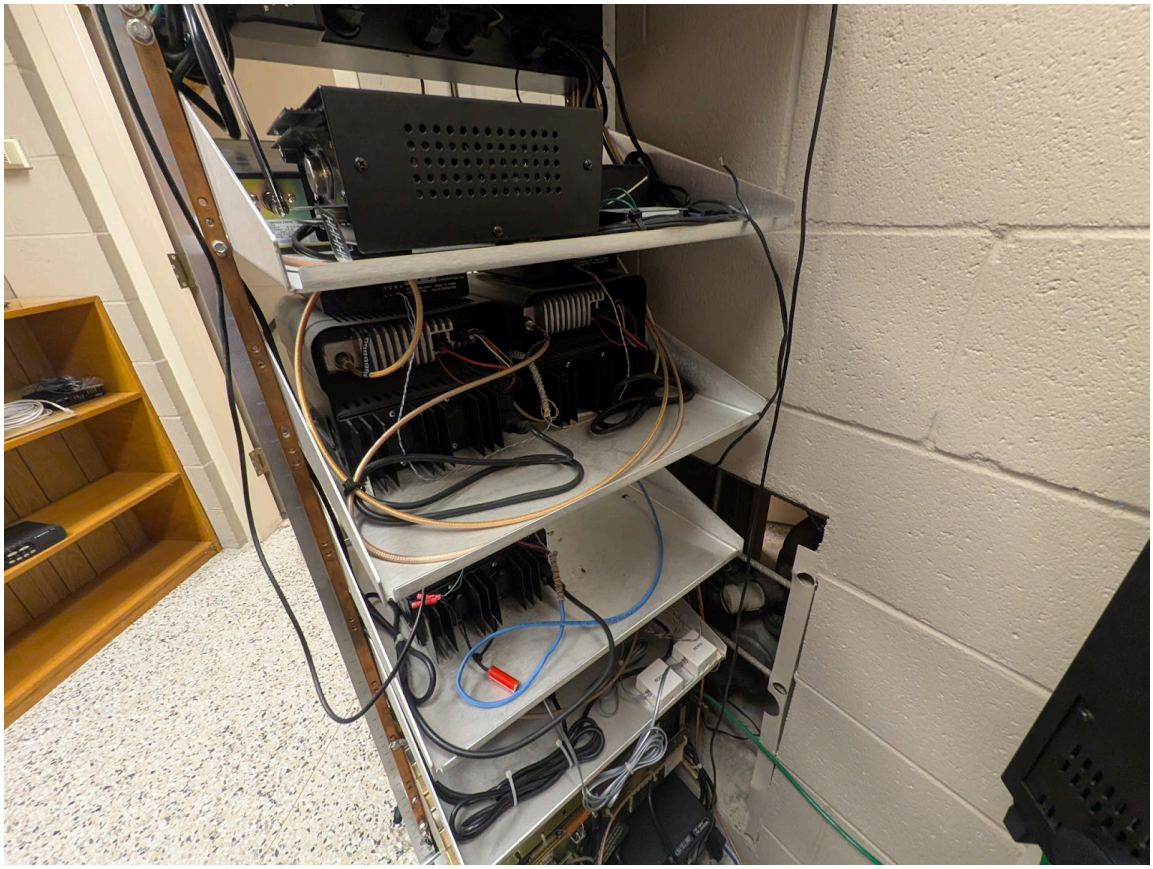
- There is a wall mounted control station that is grounded to the radio rack. The cabinet should have a dedicated ground. The power cable is not secured and lying on the floor creating a tripping hazard and power interruption to the equipment.





- There is no grounding for the equipment on the telco board. There should be a sub ground busbar and the equipment grounded to it. The black jacketed ground wire should be marked with green tape to signify that it is a ground. A double holed compression lug should be used to connect the ground wire to the MGB. All ground lugs connected to the MGB should have double holed lugs.

- Not all of the equipment in the radio rack is grounded.



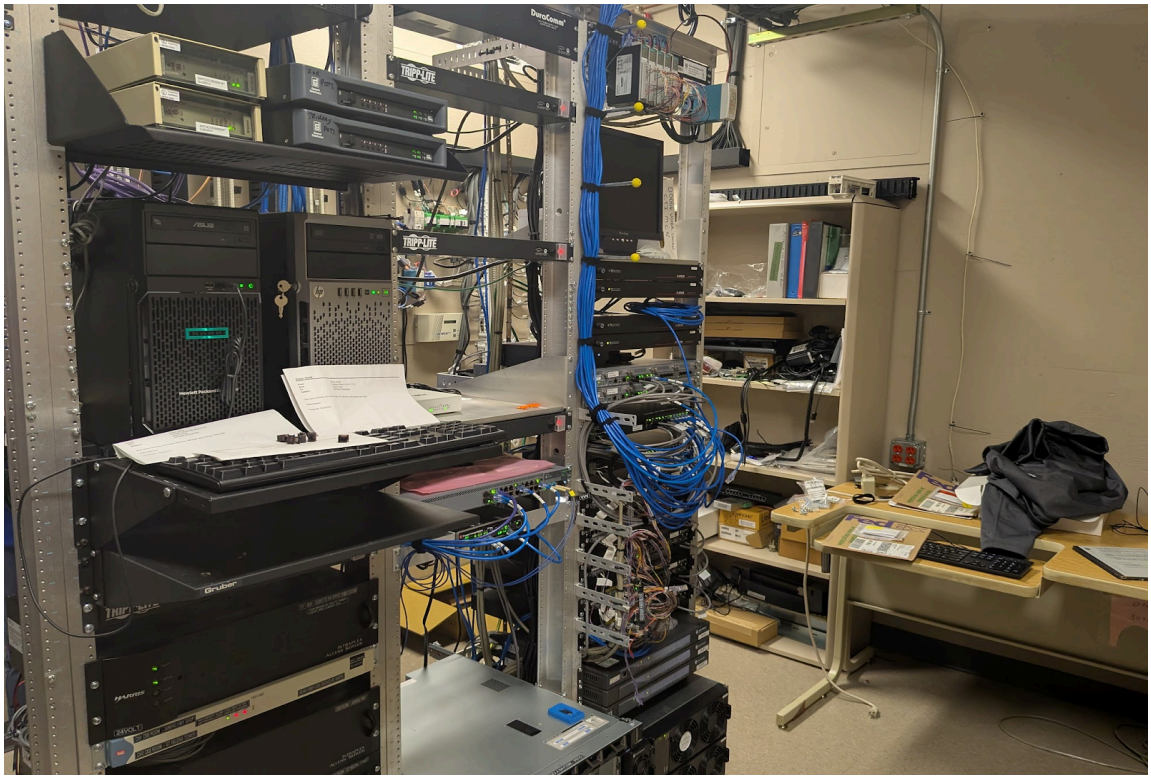
3.1.5 Server and Fiber Room

- There is a ground bus bar in this room, but none of the racks and equipment are grounded to it. The black wire sould be marked with green tape.

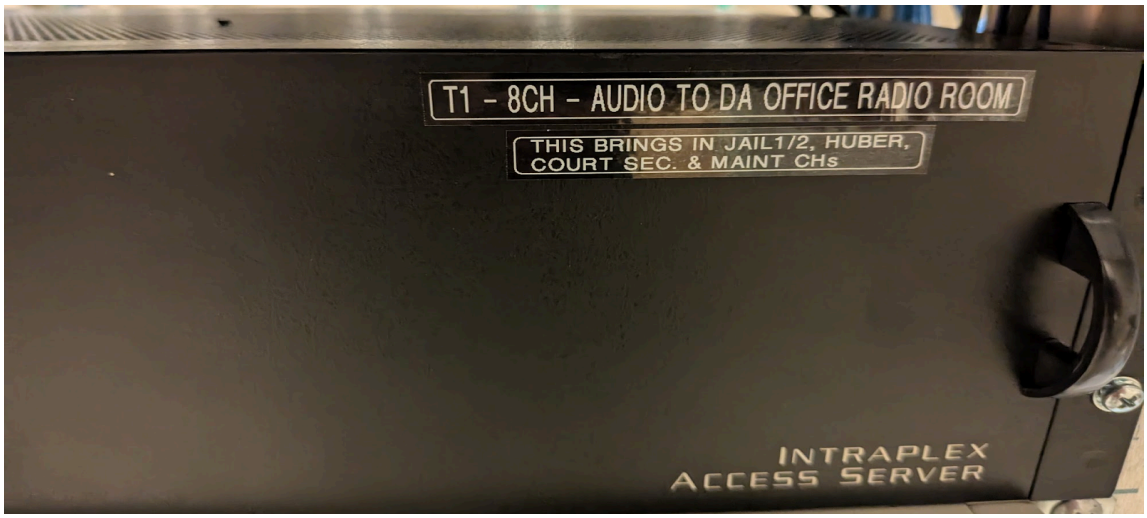


3.1.6 Dispatch Server Room

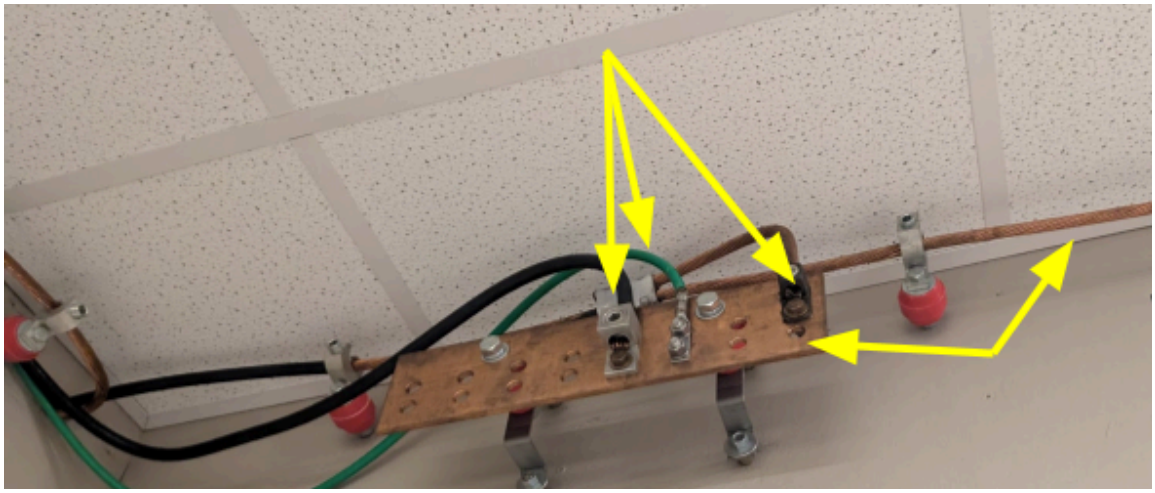
- The core server that connects the consoles to the VHF system is located here along with the CCGW (conventional channel gateway). The gateway has a wired connection routed to the radio room. The core of the system is connected to the remote sites through a fiber to the St. Helena microwave network.



- Intraplex mux are used to combine the analog signals into an ethernet connection. This allows the digital audio to be routed through the core and to the consoles. These mux boxes are far past manufacture end of life and parts are becoming very difficult to acquire.



- All grounding should adhere to best industry practices. Some examples of questionable grounding issues are as follows.
    - Connection of the halo ground to the master ground busbar. Crimp wire lugs are preferred over mechanical lugs.



- The communications box on the wall was not grounded with the provided ground wire.



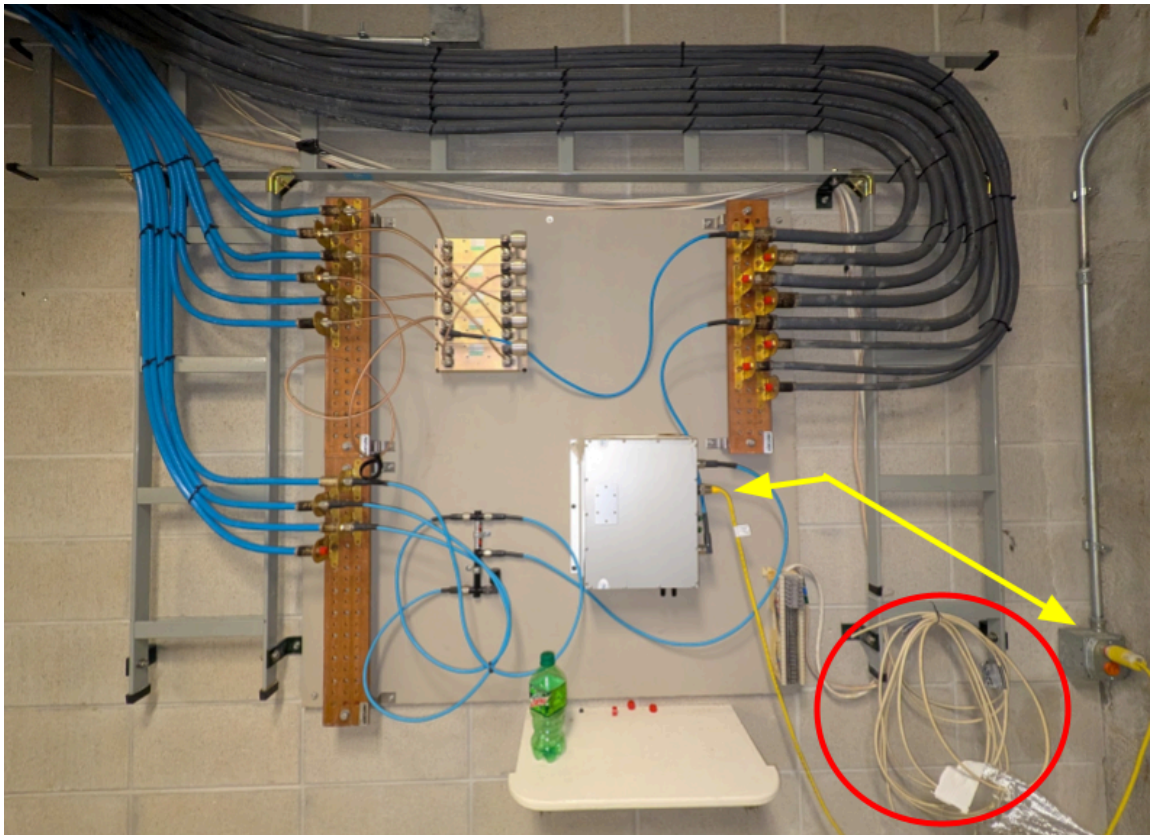
- The Halo ground runs outside of the room and it is not certain what it connects to. The grounding should be investigated and determine how it is interconnected to avoid ground loops.

3.1.7 Jail and Courthouse Building

There is equipment in the Jail and courthouse building. A BDA (Bi-Directional Amplifier) in the basement, and interoperability equipment on the upper floor.

- The BDA equipment in the basement is neatly installed and Ground busbars are provided for the coax termination, but none of the equipment is grounded. A common ground point could not be identified in the room.
    - The fiber optic cable connecting the system is loosely bundled and not secured or protected.

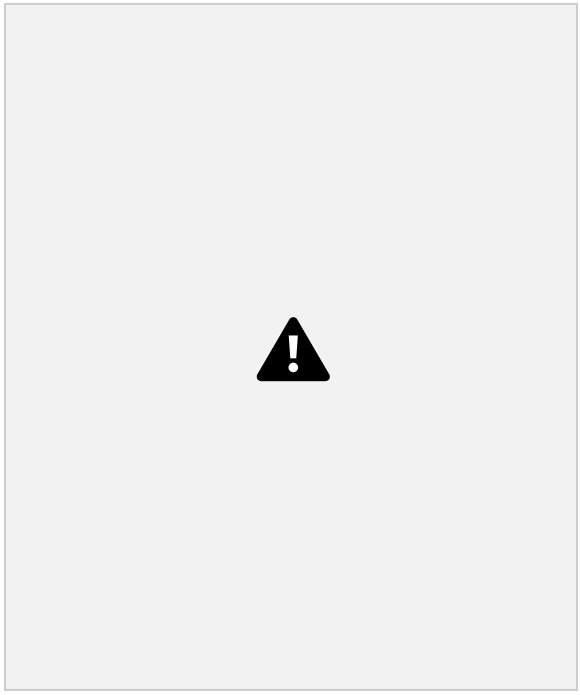
- The power cord is hanging free and needs to be secured to avoid being inadvertently unplugged.

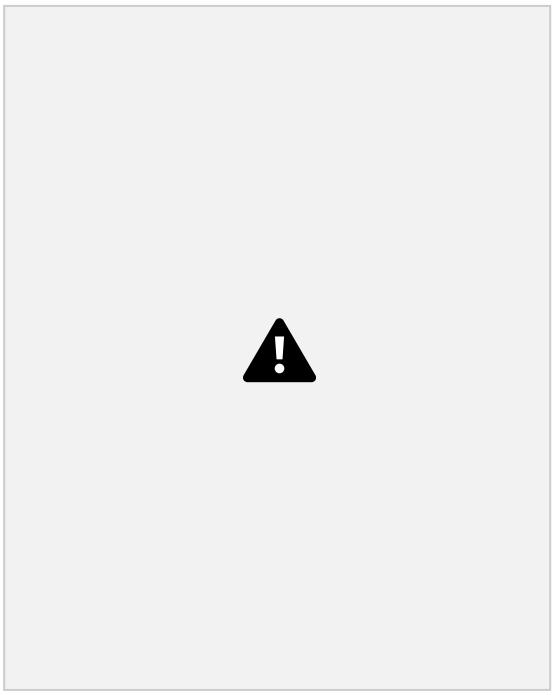


- The equipment on the upper floor of the court house provides extended coverage inside the building coverage along with some interoperability.

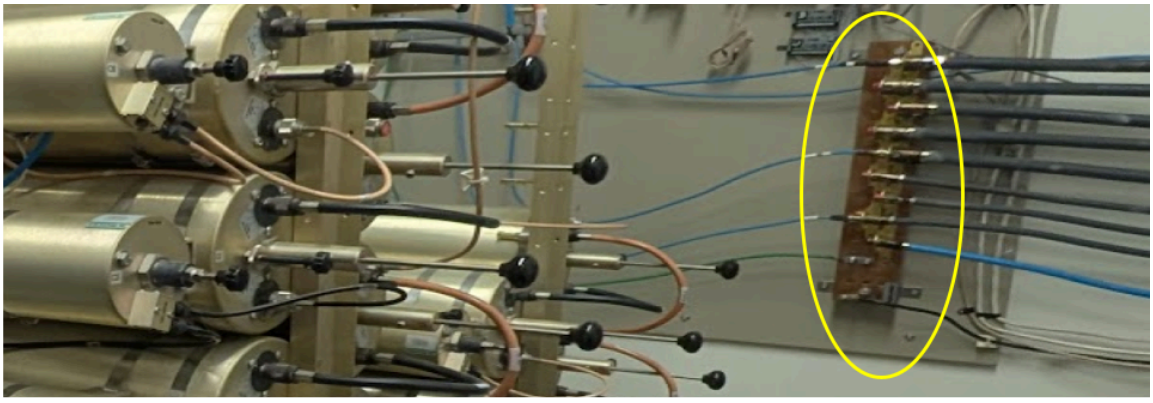
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- Cables are poorly routed and not secured. In many places the cables are hanging and creating stress on their connections.





- None of the equipment appears to be grounded and creates a concern for lightning damage. However, there is a ground provided on the MGB located on the telco board where the antennas are grounded.
- There are no lighting arrestors provided for the external antennas.



- The ground wire on the MGB uses a single holed mechanical lug. This should be replaced with a dual holed crimped lug.

3.2 Ashippun Tower

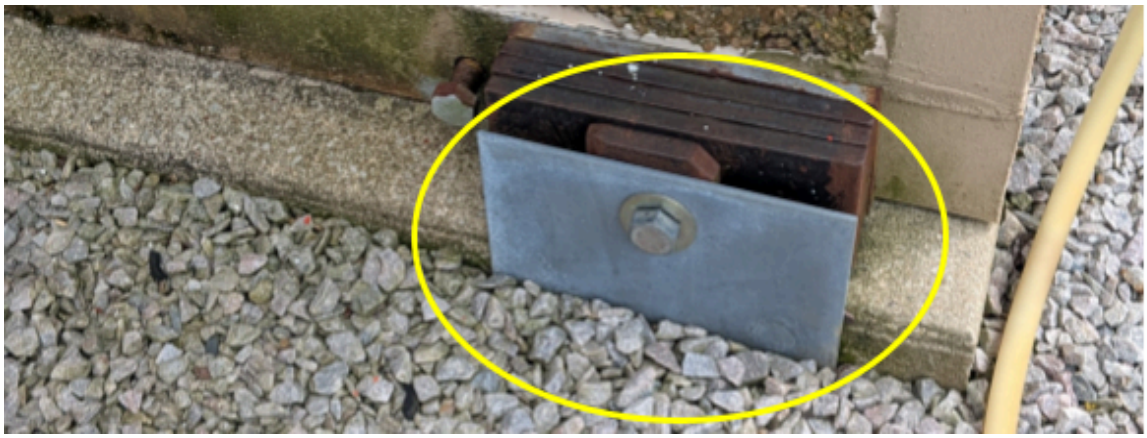
Address: 2289 Cleveland Rd, Neosho, WI
Latitude: 43° 15' 9.756"
Longitude: -88° 30' 36.3918"
ASR#: 1282498
Tower: 300' Free Standing built 2013
Shelter: Concrete communications shelter
Generator: Generac unknown kW
Fuel Tank: 250 Gallon propane built 1988

3.2.1 Site Observations

This site is approximately 3 miles north of Ashippun off of highway 67. The tower is about 12 years old.

3.2.2 Issues Outside the Building

- The shelter mounting points should be grounded

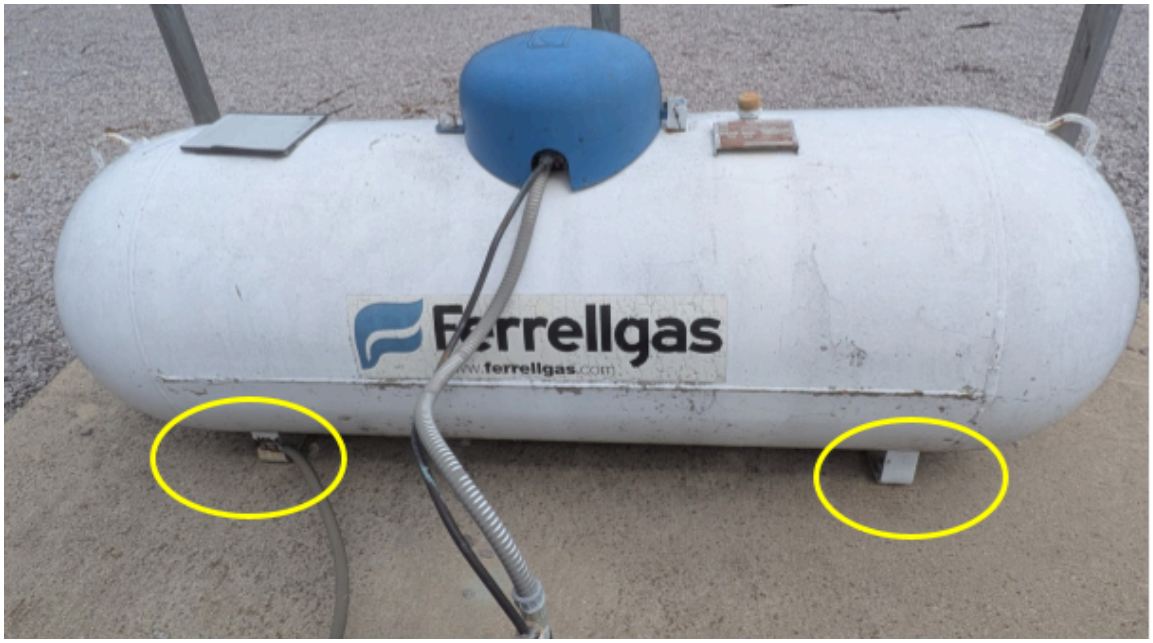


- AC units are old and prone to failure causing equipment to overheat. A plan to replace the units is recommended.

- The roof membrane has separated and blown off the shelter building. This leaves the building vulnerable to water penetration and potential equipment damage.



- The propane tank is not anchored to the concrete pad, propane tank to move in high winds and damage the fuel lines to the generator, or create a hazardous propane leak.

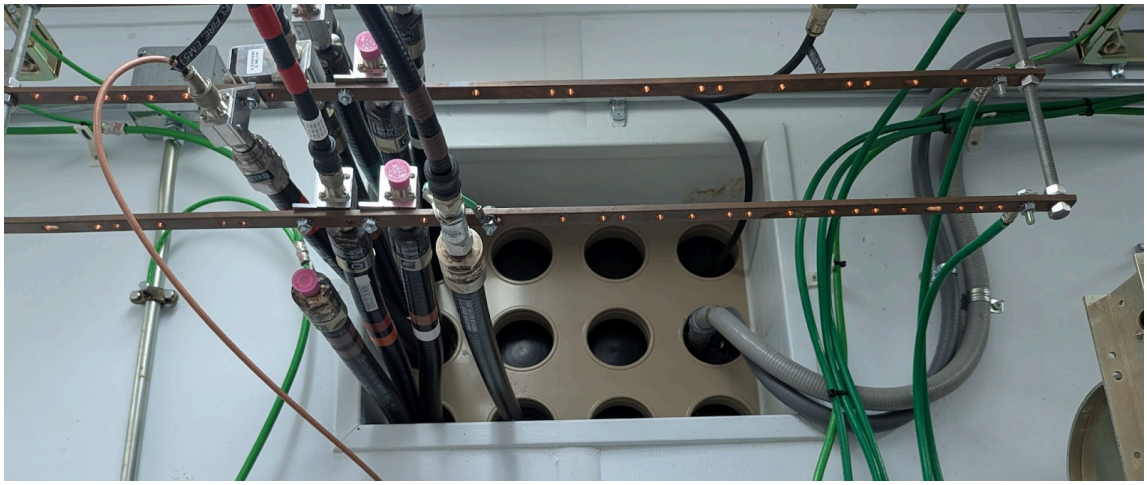


- The tower light sensor is not grounded creating a potential for lightning to enter the building.



3.2.3 Issues Inside the Building

- The unused coax cables need to be grounded and terminated. Any coax cables that are not grounded where they enter the building are an entryway for lightning.

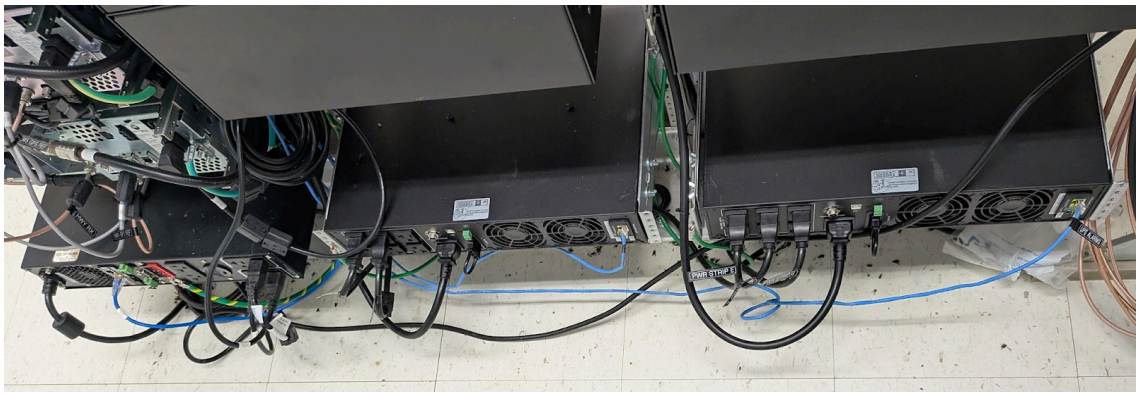


- Only 2 of the equipment racks are grounded. Each rack should have a ground that is connected to a home run ground that in turn is grounded to the MGB (master ground busbar).

- The transmit combiner and receive filter racks are not grounded.

- There should be a ground busbar on the telco board that is connected back to the MGB.

- There are AC power cables routed across the floor. This presents a trip hazard and a inadvertently unplugged power cable will disable equipment.



- Extension cords are used for UPS power. The power cord for the UPS should plug directly into the AC receptacle. A twist lock plug is recommended to avoid being unplugged.



3.3 Beaver Dam Fire Department



Address: 205 S Lincoln Ave, Beaver Dam, WI
Latitude: 43° 27' 16.6788"
Longitude: -88° 50' 1.6398"
ASR#: N/A
Tower: 120' Free Standing unknown build date
Shelter: equipment is located inside the building
Generator: Uses the building generator

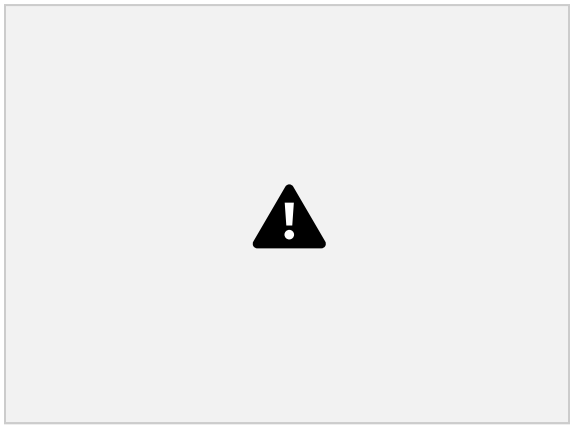
3.3.1 Site Observations

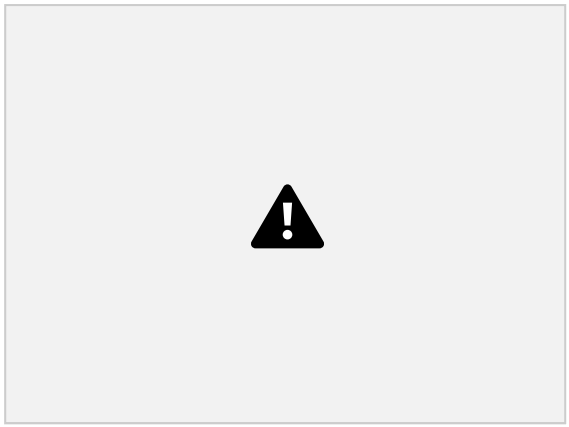
The tower is located in the parking lot located behind the Beaver Dam fire department and uses the building generator for backup power. The four site simulcast VHF system operated by the City of Beaver Dam is also located on this tower.

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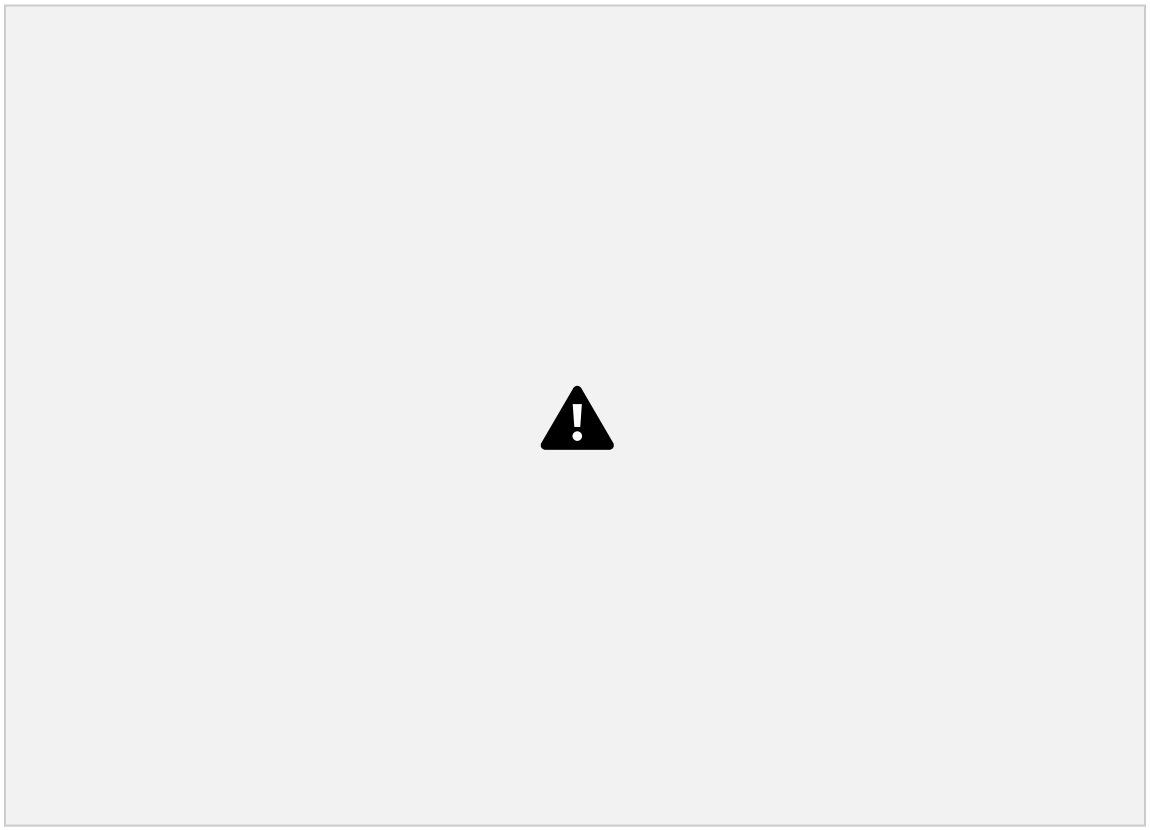
3.3.2 Issues Outside the Building

- Tower Grounding
    - Ground wires use mechanical clamps that corrode and lose their effectiveness. All tower grounds should be exothermically bonded to the tower.

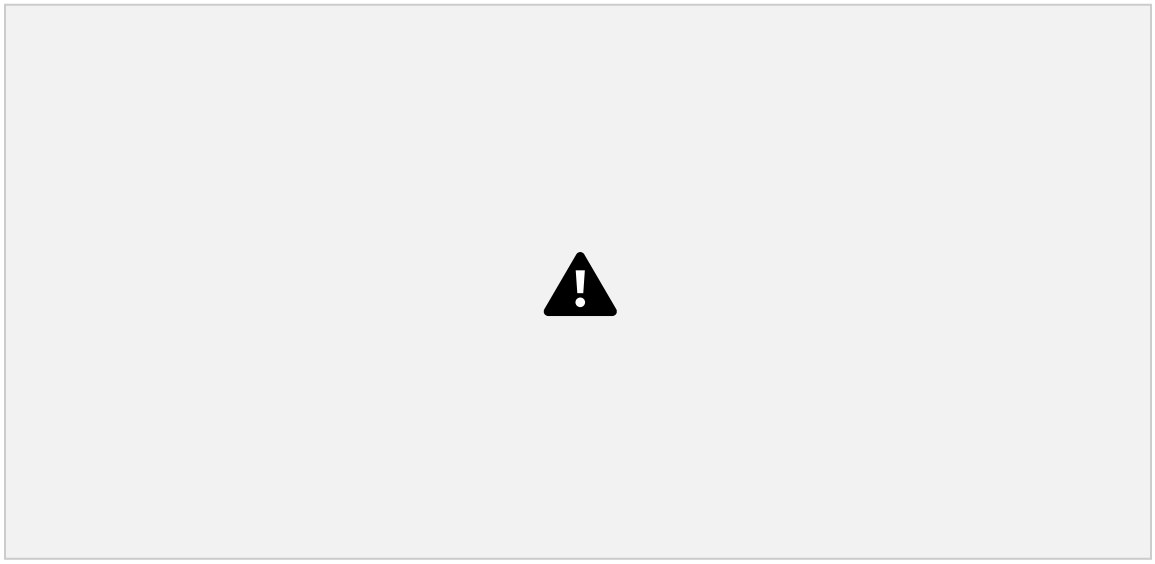




    - Only 2 or the 3 tower legs are grounded.

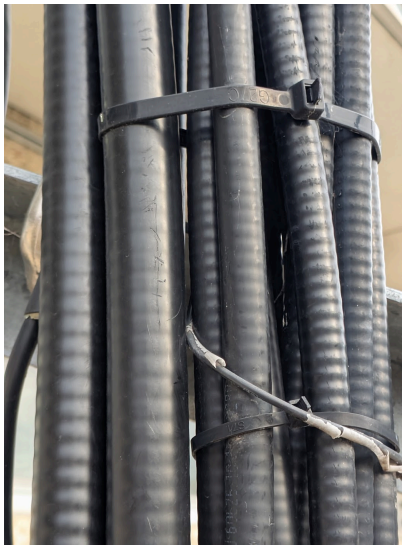


- Coax cable grounds are connected directly to the tower. The cables should be grounded using a busbar that is isolated from the tower and utilizes its own ground.



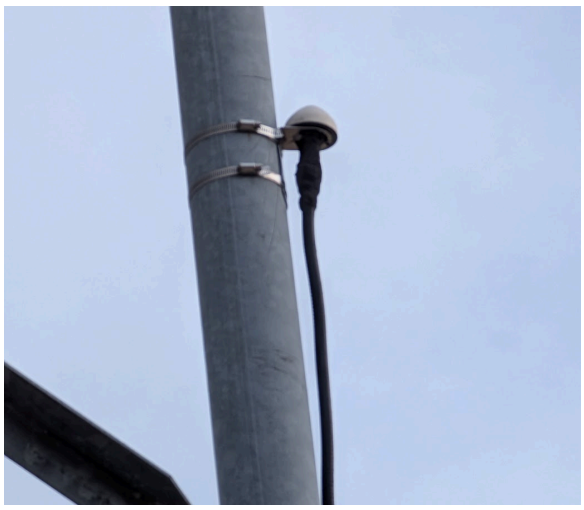
- Not all of the coax cables are grounded before they enter the building.

- The coax cables are not properly mounted to the tower. Plastic cable ties are used that can break down when exposed to sunlight.





- GPS Antennas Not optimally installed and could cause fading resulting in timing issues with the simulcast system.

- A water gutter is attached to the tower creating a lighting hazard that could result in a building fire or unwanted electrical surges.

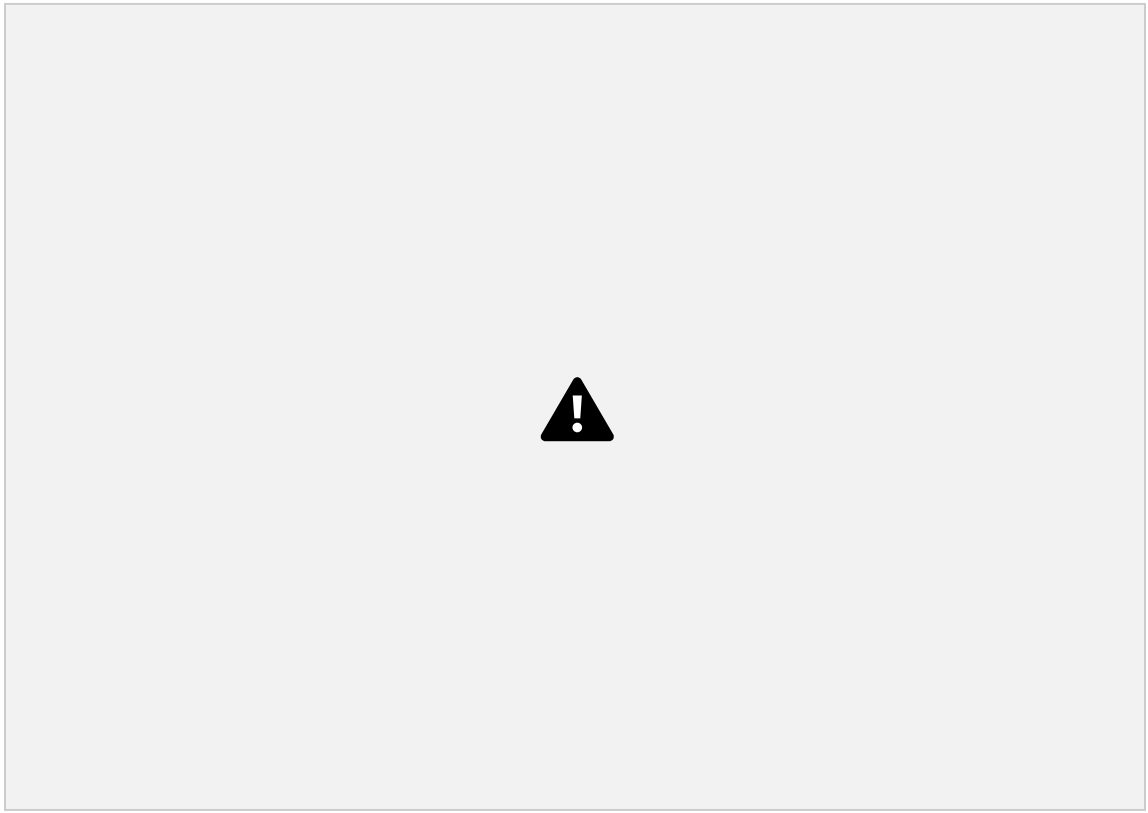



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- There is a small tower that is not grounded and attached to the building. This creates an additional opportunity for lightning.

3.3.3 Issues Inside the Building

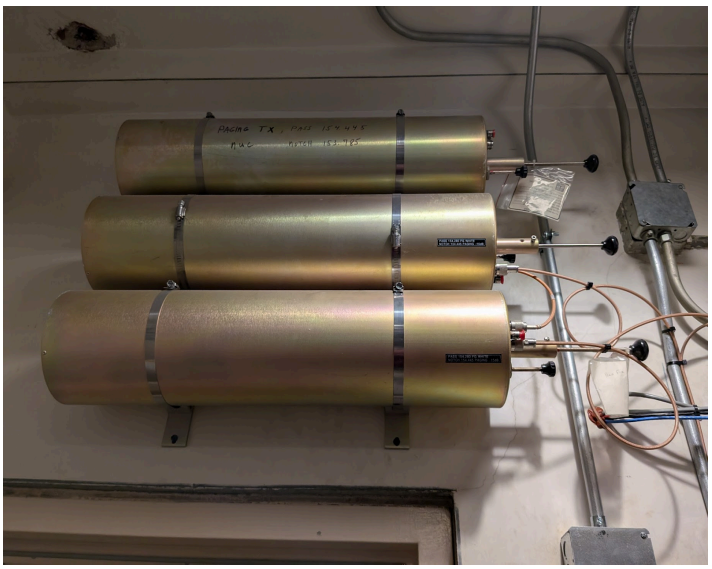
- Questionable master ground point. It is uncertain where the MGB is actually grounded to.



- The cabinets are grounded to a ground busbar shared in the second cabinet. Each cabinet should have an individual ground connected to a home run ground wire that in turn is connected back to the MGB.

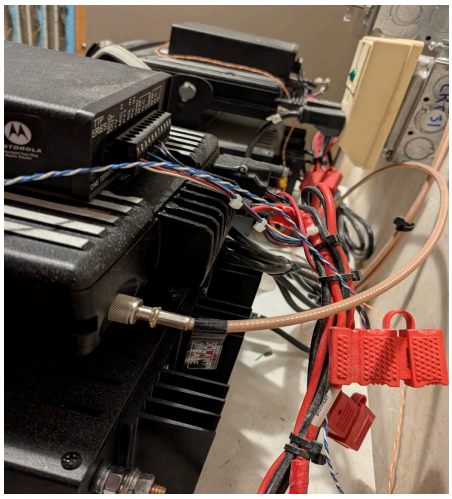
- Ground for the CCGW Rack is connected at the center of the rack and should be grounded at the top. The ground for this rack is not connected to the same master ground point as the other equipment.

- Could not find a ground on the combiner rack. None of the filtering cans are grounded.



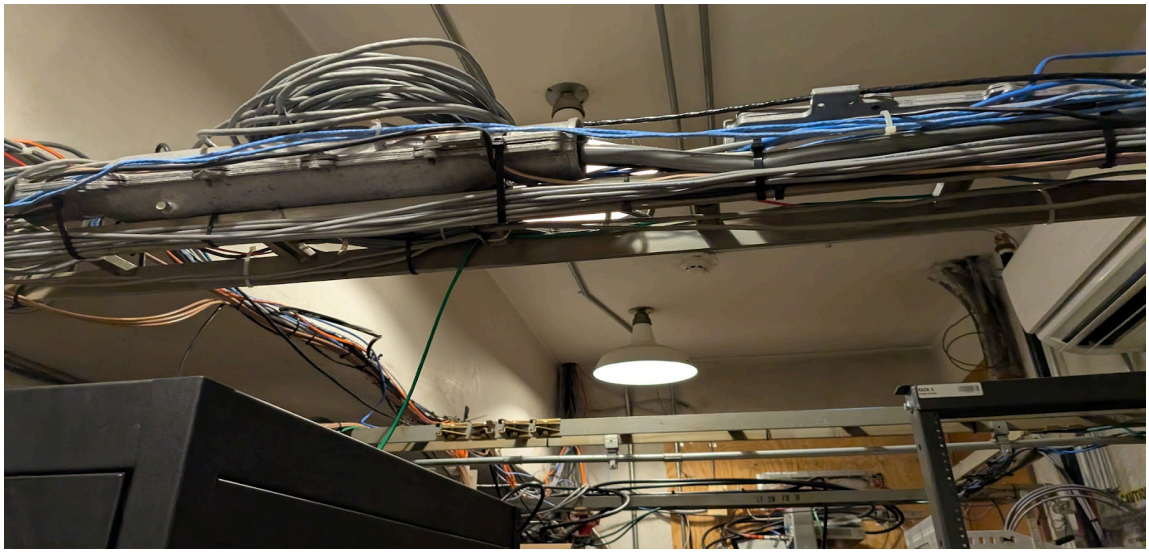
- The mobile radios for fire are not grounded



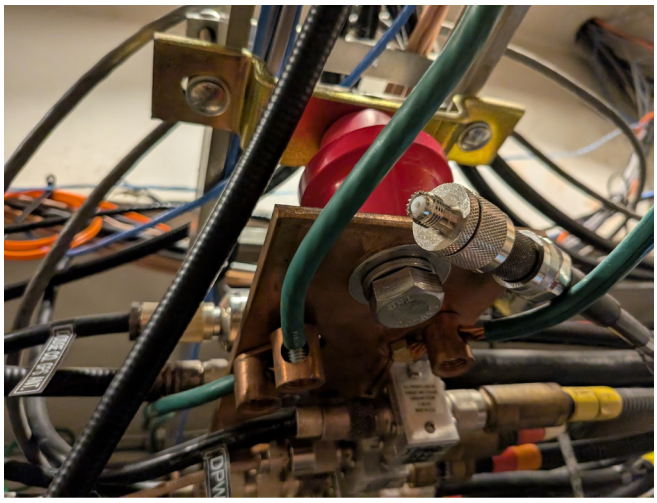


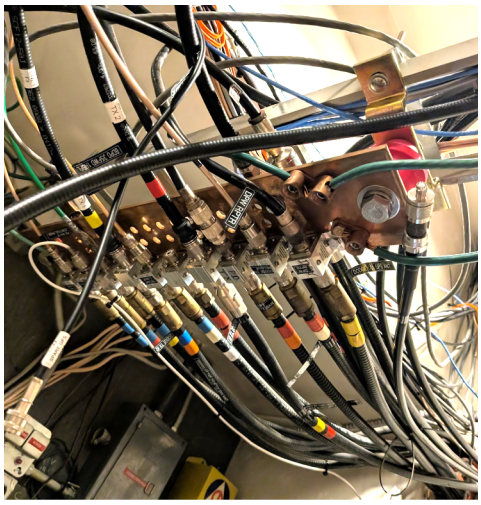
- GPS Units using a single power supply. Each unit should have a separate power supply to allow for redundancy.
- There is a fire suppression system automatic with a panel alarm in the room. The smoke detector in the equipment cabinet that is tied to the house alarms, but not the site fire alarm panel.

- There is very poor cable management throughout the room and inside the cabinets.



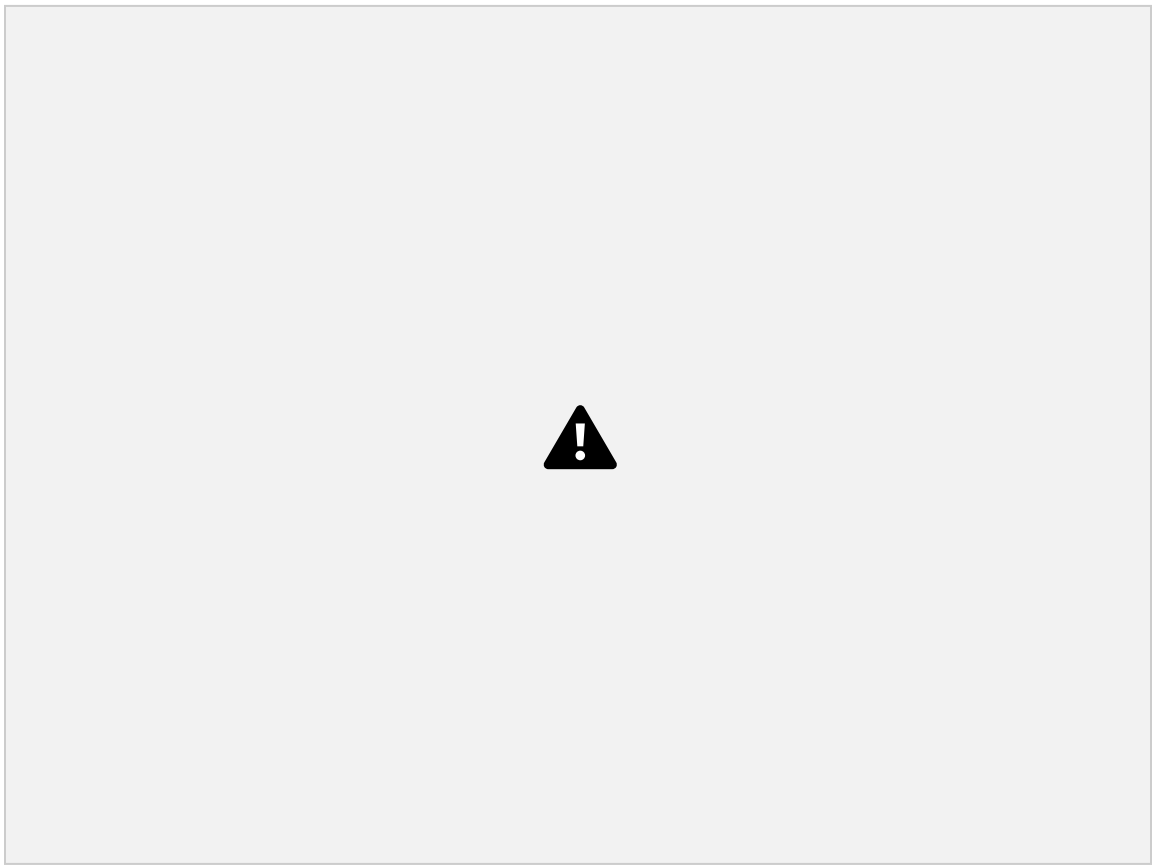
- Mechanical clamps are used on the antenna ground busbar and cables are not terminated. Ground cables on the busbar should use dual hole crimp lugs.





- The is a single air conditioning unit to cool the equipment. The room is hot and the cooling is not adequate. It is recommended that the cooling be upgraded to accommodate the heat load of the room.
- There is a single DC power supply for microwave radios. It is preferred that each microwave unit have a power supply to provide redundancy.
- The RADWIN box in the microwave rack is not grounded.

- The telco board should have a ground busbar that is connected back to the master ground busbar. None of the equipment on the telco board is grounded.



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3.4 Fox Lake Tower



Address: 1079 Mill Rd, Fox Lake WI
Latitude: 43° 33' 4.7622"
Longitude: -88° 55' 22.3104"
ASR#: 1246924
Tower: 300' Free Standing 2006
Shelter: Standard prefab concrete building
Generator: Generac 38 KW
Fuel Tank: 1000 Gallon Propane

3.4.1 Site Observations

This site is located approximately 1.5 miles south of Fox Lake on Mill Road. The tower is almost 20 years old. This site is a leased site that is shared with other systems such as a JVC Kenwood ATLAS P25 system.

3.4.2 Issues Outside the Building

A ground could not be identified on the generator. The only external connection is the propane fuel line. The generator should be grounded to the compound ground ring.

- The propane tank is sitting on concrete blocks and is not anchored into the ground. This could allow the propane tank to move in high winds and damage the fuel lines to the generator, or create a hazardous propane leak.



- There are multiple ground points on shelter corners. Modern grounding standards call for a single ground point where the coax cables inter the building.



- Ground wire conduit on the tower busbar is moving freely and needs to be secured. Excessive movement during a storm or high winds can cause the exothermic weld to break and the ground to fail.

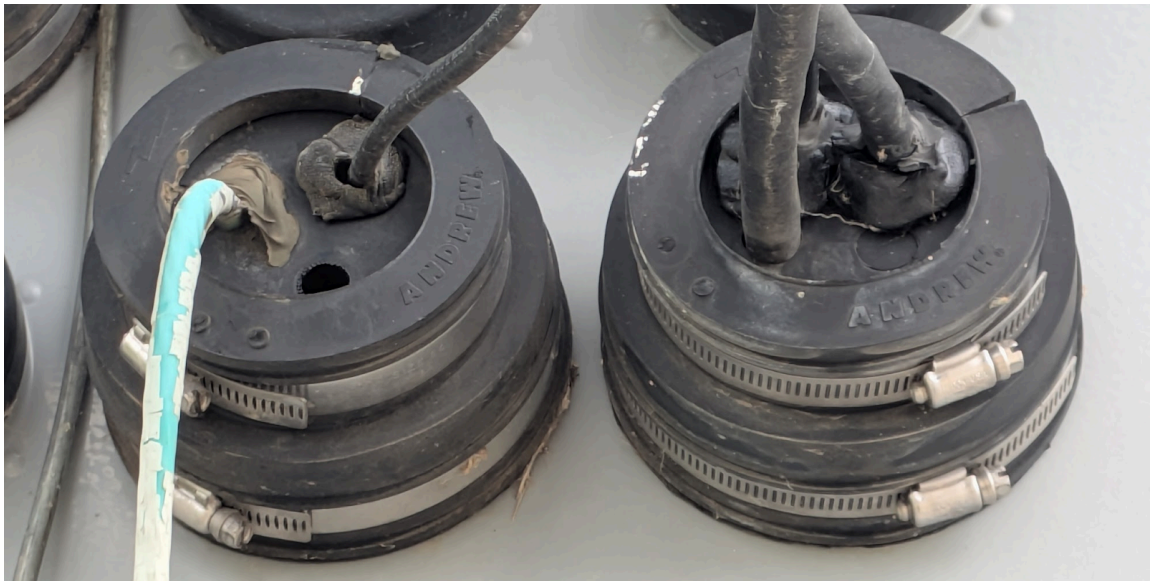


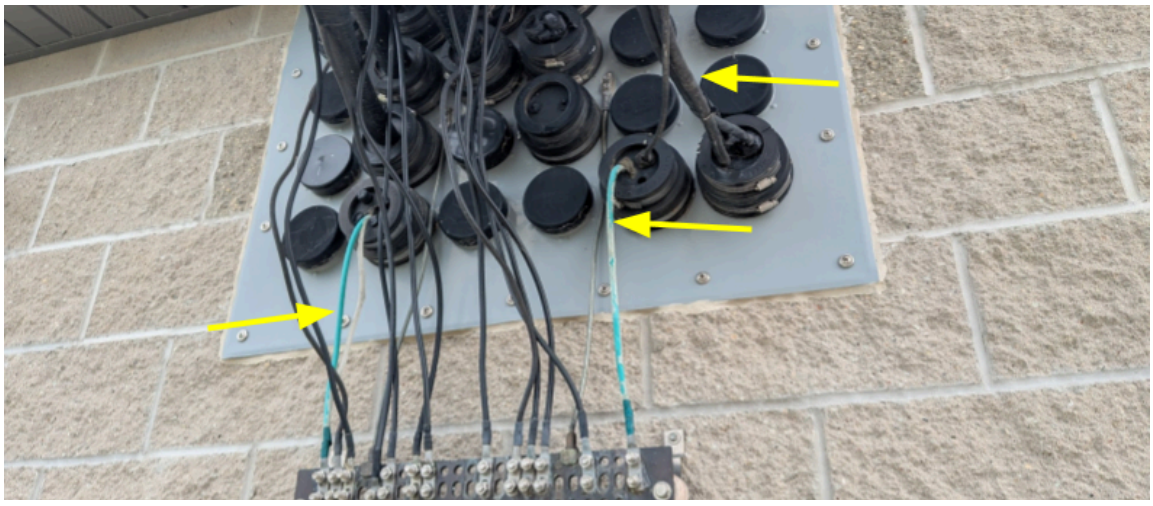
- There is a nest in the coax cable entering the building. This could collect moisture and encourage corrosion or leaking into the building.



- Coax cables entering the shelter are not grounded. All coax entering the building should be individually grounded before and after entering the building.

- There is a ground wire with a green jacket on the outside of the building breaking down allowing the wire to become corroded.
- The ground between the external and internal busbar is connected with a green jacketed wire through the peep. There should be a separate ground wire for each individual ground busbar connected back to the compound ground ring.





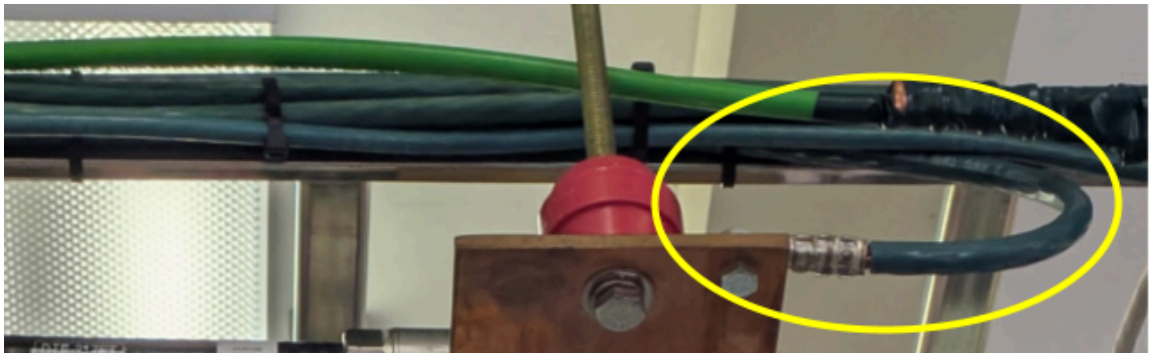
- Not all of the holes in the coax cable boots are plugged. There are coax cables that are cut off to plug the holes. A proper boot plug should be used.

- One of the AC units has been replaced due to age. The second AC unit is old and prone to failure. It is recommended that the second unit is replaced.

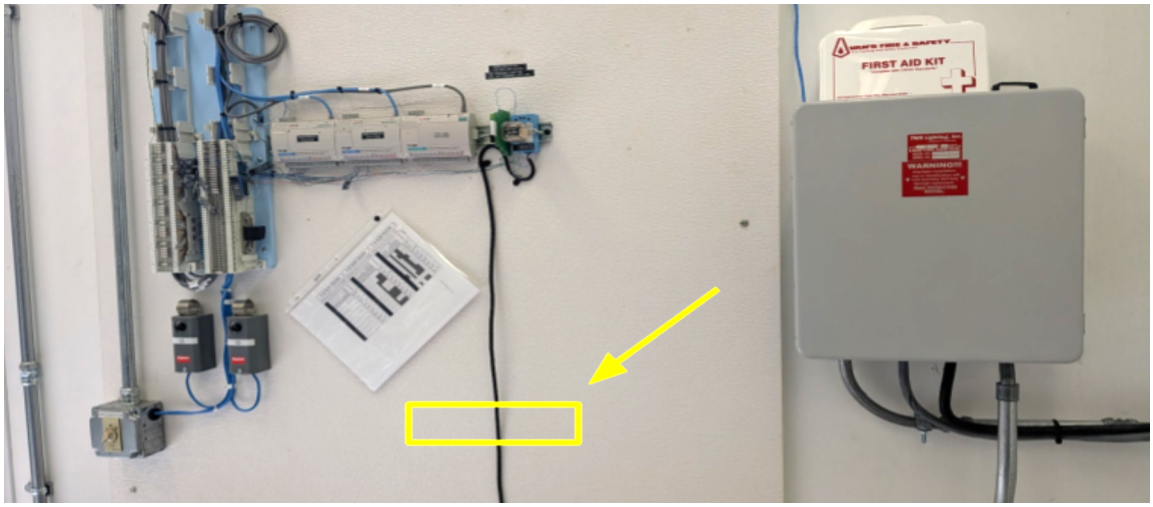


3.4.3 Issues Inside the Building

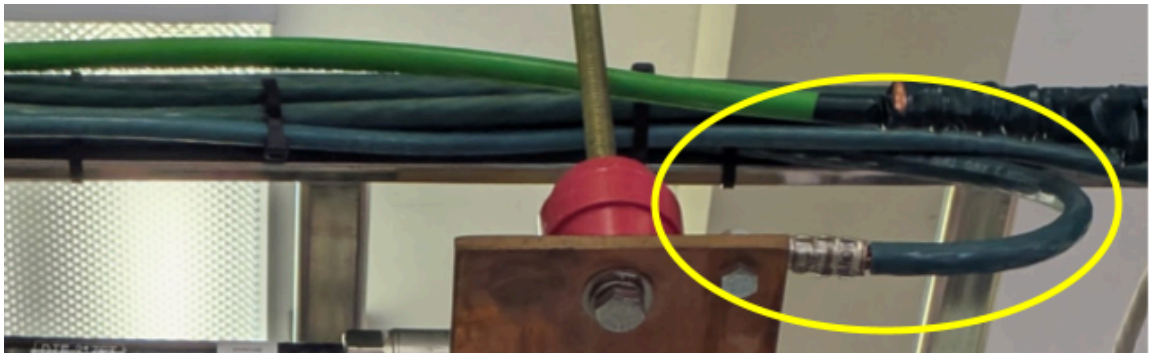
- There are unterminated coax cables coming into the site. This provides a route for interference and lightning damage.
- The building door is not grounded to the door frame and the halo ground.
- Metal objects such as the generator switch, breaker panel, and tower light box are not grounded.
- The ground wire connecting the lightning arrestor busbar to the MGB has a' 180° bend in the wire. All ground wire should have sweeping curves to allow lighting energy to follow it.



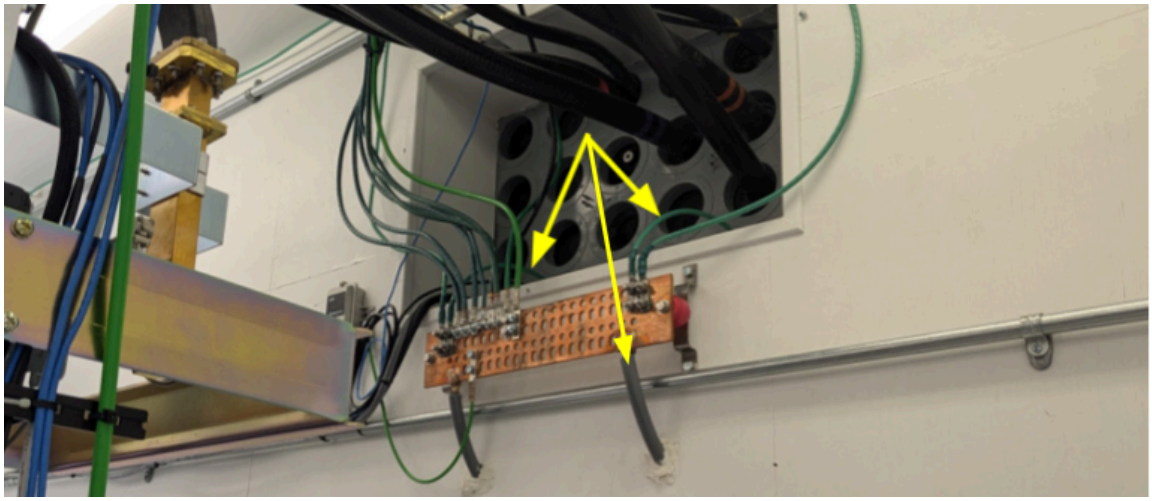
- There should be a break on the opposite side of the room from the MGB.
- There should be a sub ground busbar for the equipment on the demark panel with a direct wire run back to the MGB.



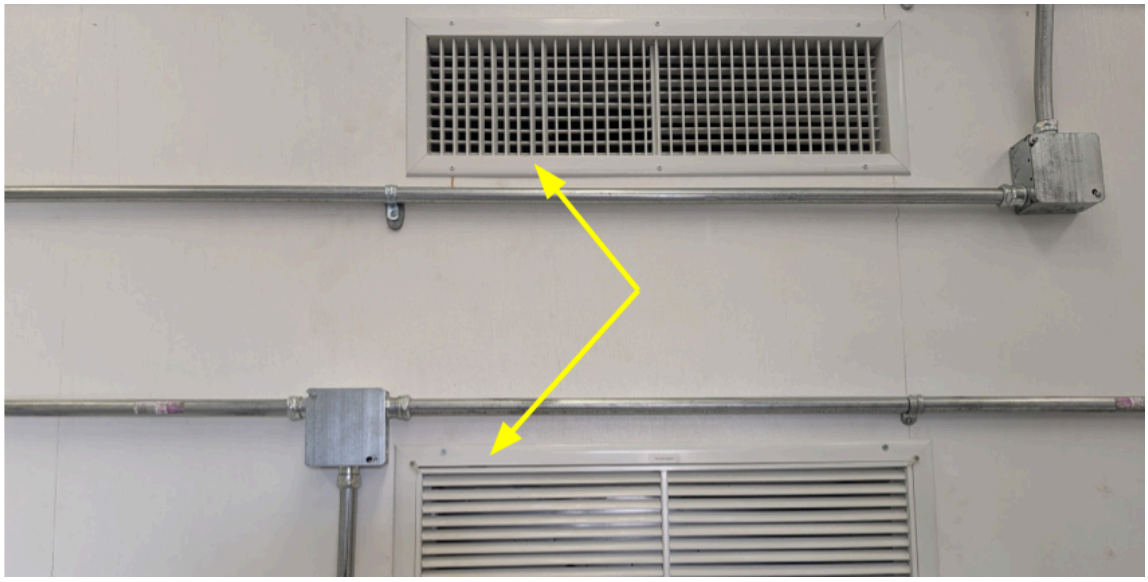
- The ground wire connecting the lightning arrestor busbar to the MGB has a' 180° bend in the wire. All ground wire should have sweeping curves to allow lighting energy to follow it.



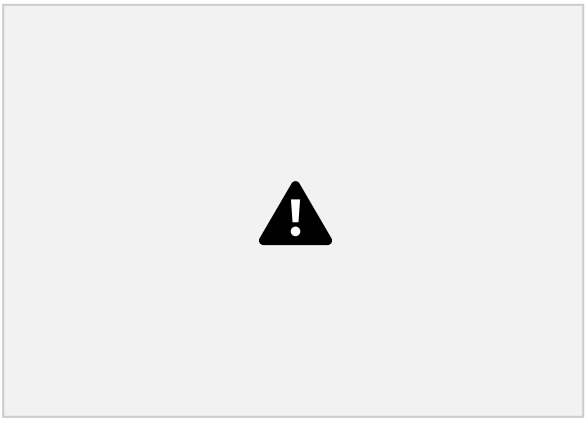
- There are multiple ground points between the inside and outside coax entry ports. The inside and outside busbars should be independently grounded to the outside ground ring. There are single hole lugs used to attach the ground wire to the busbar. All ground lugs should use dual hole lugs where possible to prevent the ground wire from twisting and causing a single connection from coming loose.

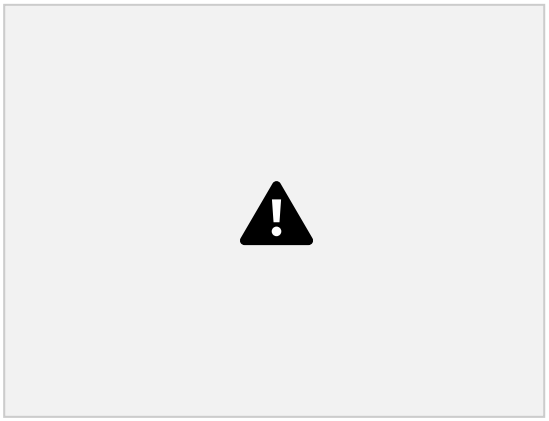


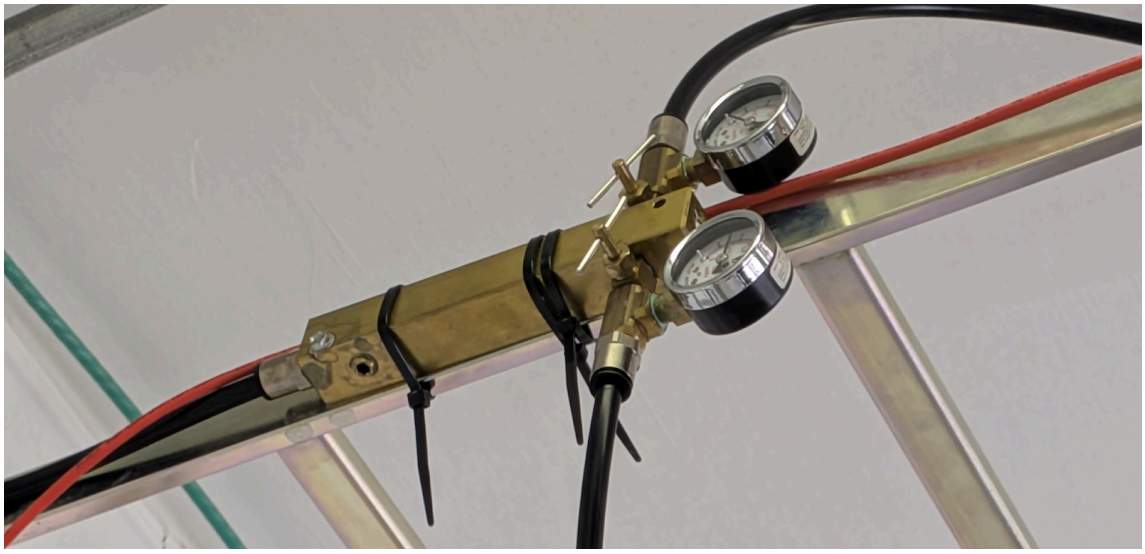
- AC vents not grounded. All metal boxes, vents and equipment inside the building should be grounded.



- The dehydrator unit for the microwave coax is sitting on the floor and not properly installed. There are also signs of water damage on the tile in the corner. This along with equipment setting on the floor can lead to failure or electrical shock.

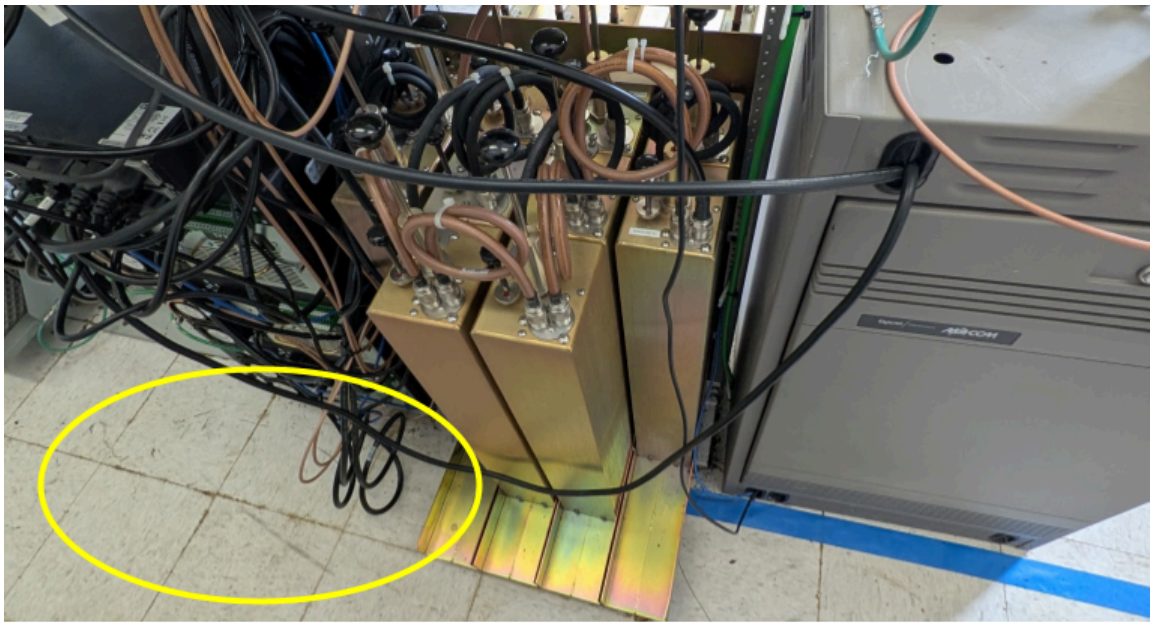






- There are multiple issues with the rack grounding.
    - There are multiple ground points on some of the racks creating ground loops.
    - Not all of the racks grounded. Each rack or cabinet should have its own ground to a home run wire that is connected to the MGB.
    - County racks not properly grounded. There needs to be a separate ground for each rack to a home run ground that is connected to the MGB. For example rack #2 equipment is grounded to Rack #3.

- There are coax cables routed across the floor that are susceptible to be stepped on and crushed. All coax cables should be routed overhead in the cable ladder to prevent the cable and connectors from being damaged.



- The UPS using extension cords connect to AC power. The UPS should be directly connected to the AC receptacle and use a twist lock type plug.

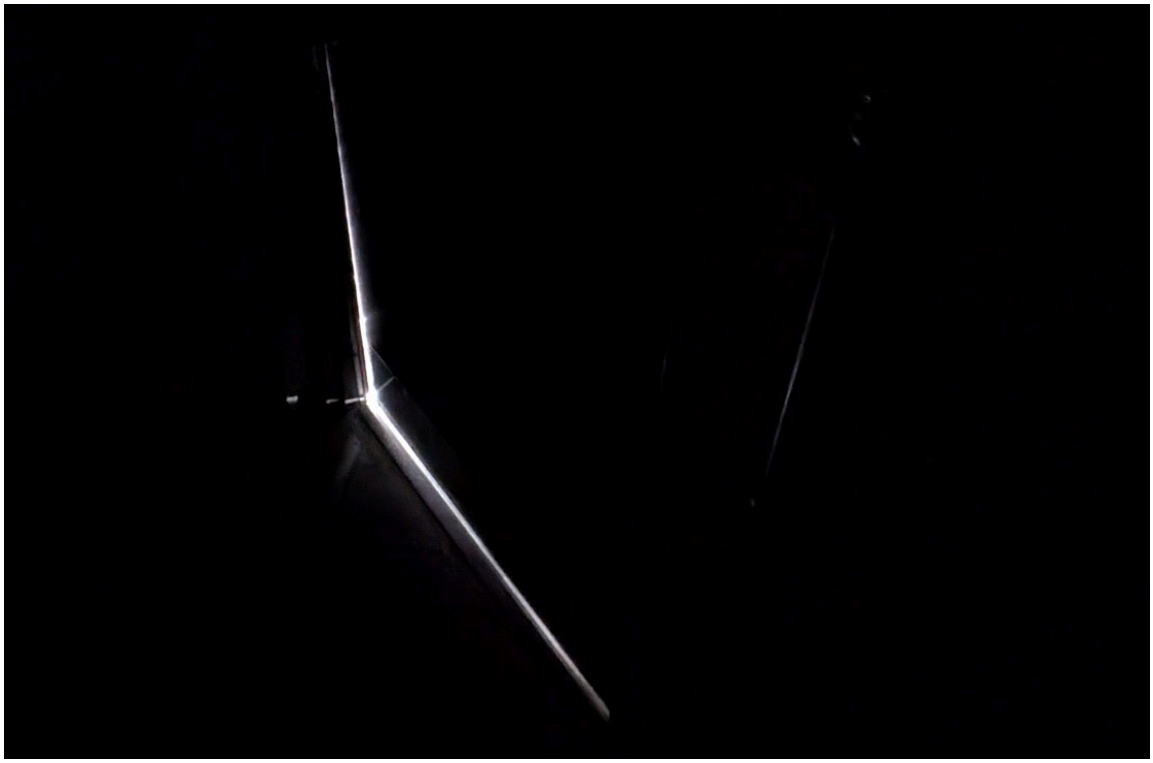




- The MARC repeater controller shelf is not grounded.



- The door to the building does not seal when closed. Light is visible at the bottom of the door frame when closed. This can allow pests and water into the equipment shelter.



- Safety Equipment is lacking. There is not a fire extinguisher or an emergency eye wash kit (there are open batteries in a rack). There is a basic first aid kit.

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3.5 Juneau Highway Department



Address: 211 E Center St Juneau Wi
Latitude: 43° 24' 33.5658"
Longitude: -88° 42' 3.7002"
ASR#: 1035575
Tower: 175’ Self Supporting, built 2005
Shelter: Interior room in the building
Generator: 22 kW residential type
Fuel Tank: 200 gallon propane

3.5.1 Site Observations

The tower is located behind the Dodge County Highway Department Office in Juneau. This tower is approximately 21 years old and there are multiple cellular carriers as well as a Motorola Smartnet system sharing the space. The simulcast repeaters are connected from this site location to the dispatch server room via fiber.

3.5.2 Issues Outside the Building

- The backup generator is a 22KW Residential type generator. A commercial generator that can better handle extended run time and loading should be used for more reliability.
- The propane tank is not anchored to the ground and could shift in high winds.

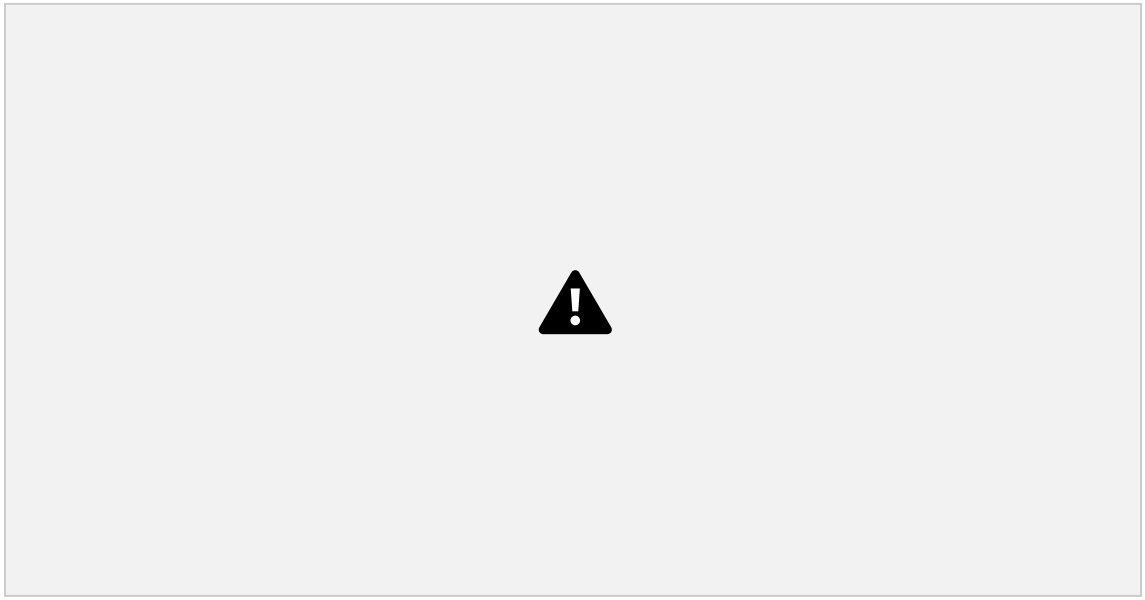
- The ground busbar at the bottom of the tower should be isolated from the tower structure.



- There is a piece of antenna structure that spans from the tower to the building to support the coax cable. A proper ice bridge should be used to protect the coax cables from falling ice. This structure should be isolated from the tower and the building to prevent an additional path for lightning.

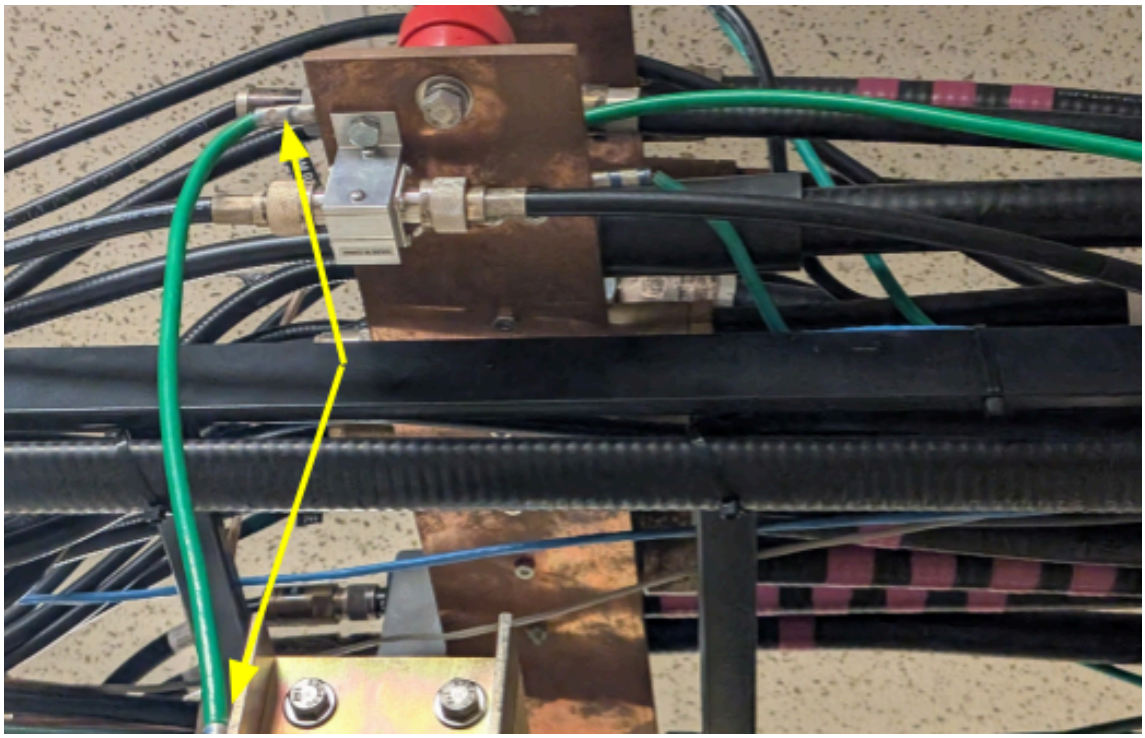


- There should be a ground busbar on the outside of the building at the coax entry port. Currently the coax cables are not grounded outside the building.



3.5.3 Issues Inside the Building

- The combiner rack is connected to the lightning arrestor ground busbar. The rack should be connected to a home run ground that is in turn connected to the MGB.



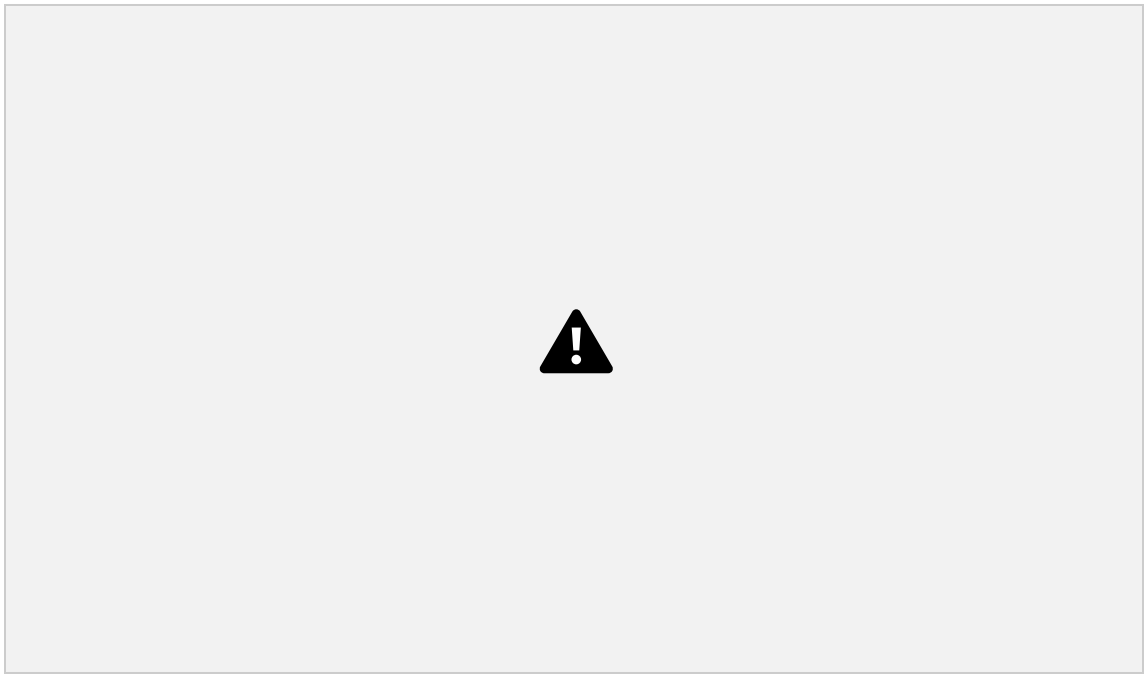
- There is a home run ground in the cable tray, but the racks are daisy chained together. Each rack should have its own ground and connected to the home run ground wire that in turn is connected back to the MGB.

- There is a Motorless Smartnet system that shares the space where the county equipment is installed. None of these cabinets are not grounded and can create a hazard for lightning damage within the equipment room.

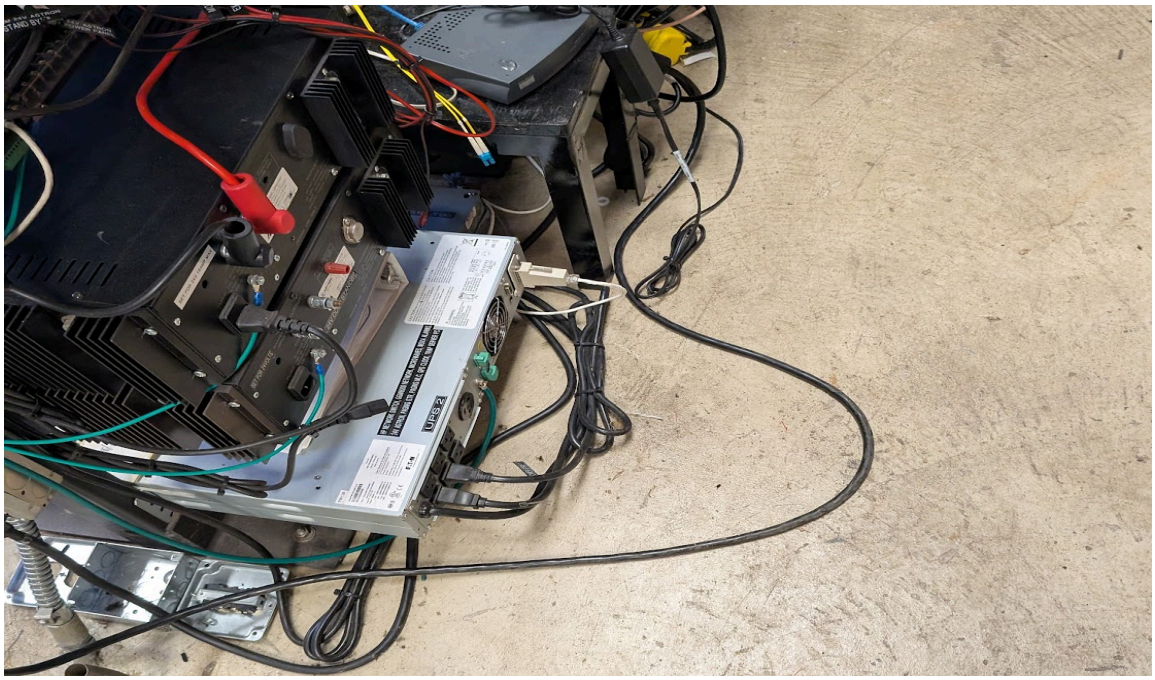


(Remainder of page intentionally blank)

- The microwave rack and microwave equipment is not grounded..



- Power cables are routed across the floor and could be stepped or tripped on. This could create an opportunity for power to be disconnected from the equipment or UPS.



3.6 Knowles Tower



Address: W1287 South Ave, Knowles WI
Latitude: 43° 34' 10.9302"
Longitude: -88° 30' 14.3244"
ASR#: 1248573
Tower: 250' Free standing build in 2006
Shelter: Cinder block building
Generator: Generac 25 KW
Fuel Tank: 2,500 gallon propane

3.6.1 Site Observations

The tower site is 1 mile south of the Knowles Fire Department Behind the St Luke Lutheran Church, The tower is approximately 20 years old.

3.6.2 Issues Outside the Building

- The electrical Meter and vents to generator room are not grounded. All external metal components need to be grounded to the compound ground ring.

- The shelter doors are not grounded. The door frame to the generator room is not grounded.
- The dusk to dawn light sensor for the tower lights is not grounded.



- The site is grounded at each corner of the building. Current industry practices require a single ground point at the coax entry point of the building.



- The ground busbar at the bottom of the tower is not isolated from the tower structure.

- There are multiple ground points between the outside and inside busbar. This creates ground loops and does not meet industry standards. The inside busbar should not be grounded through the port for the coax cables. The access panel should also be grounded to the outside busbar.

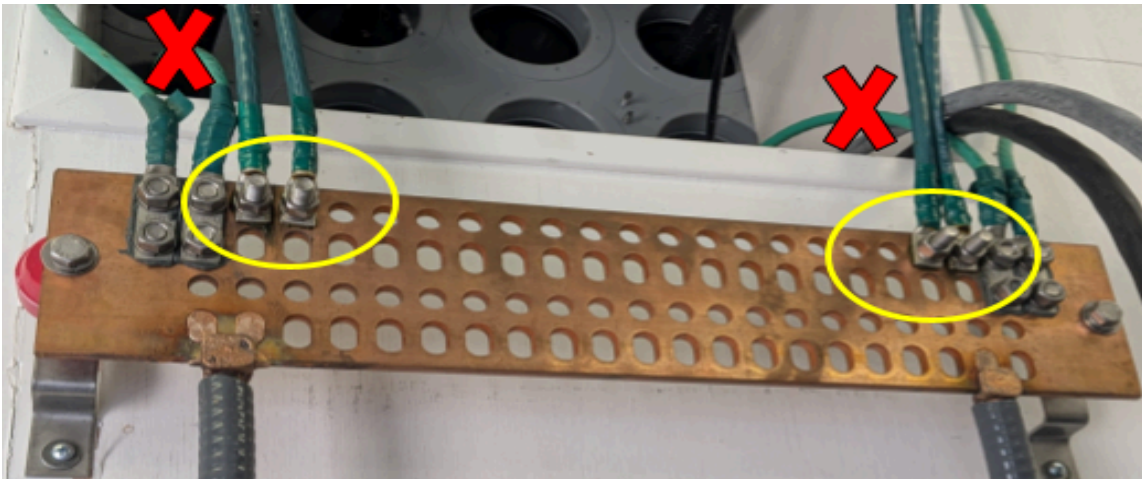


- The propane tank is sitting on concrete blocks and not anchored into the ground. The tank was manufactured in 1989 and is becoming badly corroded. This could lead to a leak or failure of the tank. It is recommended that the tank be reconditioned or replaced.

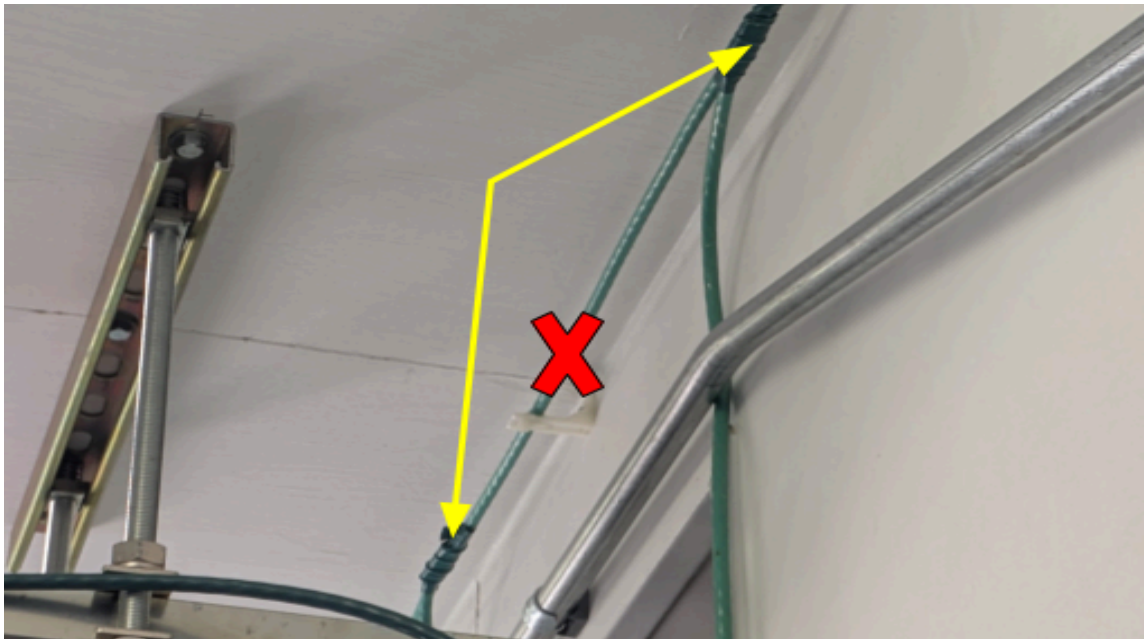


3.6.3 Issues Inside the Building

- Grounding
  - The Inside and outside ground busbars are grounded together in multiple locations creating a ground loop.



- There needs to be a break in the halo ground wire opposite of MGB.



- The cable ladder is not grounded to the ground busbar.
- The generator transfer switch, electrical panels, AC vents, and other metal parts are not grounded.

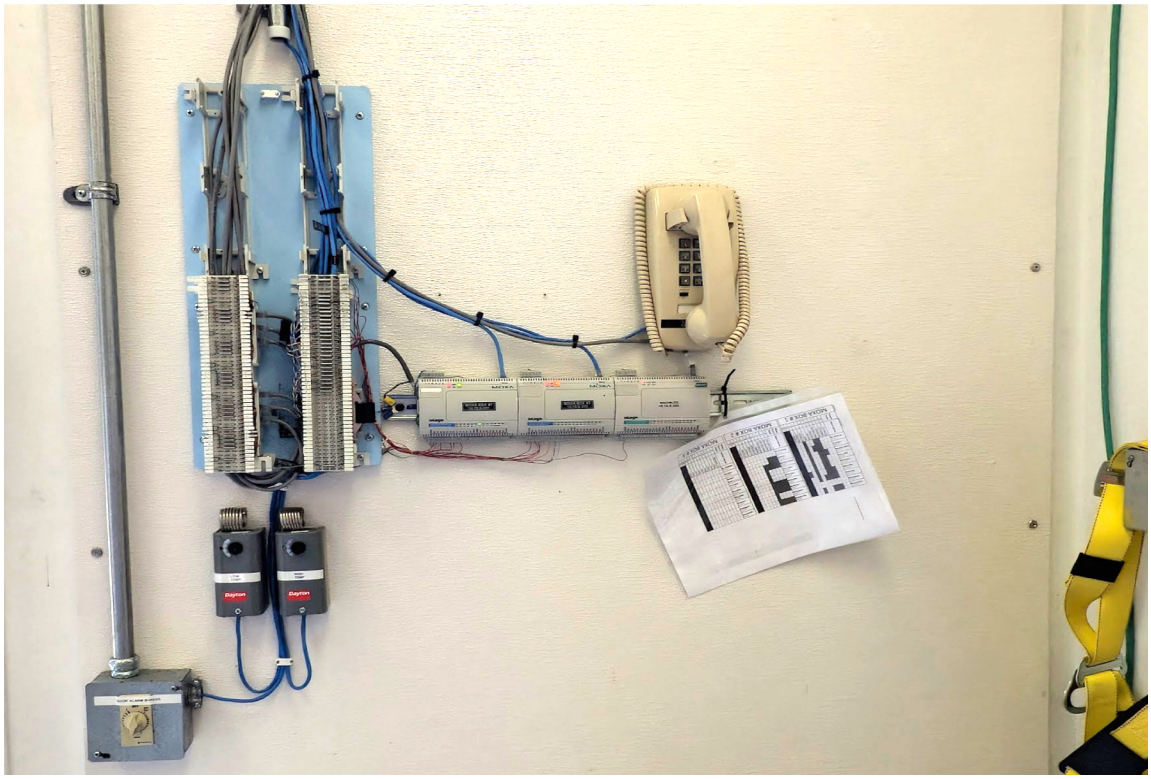




- Ground wires on the lightning arrestor busbar are bent into 180. All ground wires should use sweeping bends to better route lightning energy.



- There is not a sub ground busbar on the There should be a sub ground busbar on the telco panel and the equipment should be grounded to it.



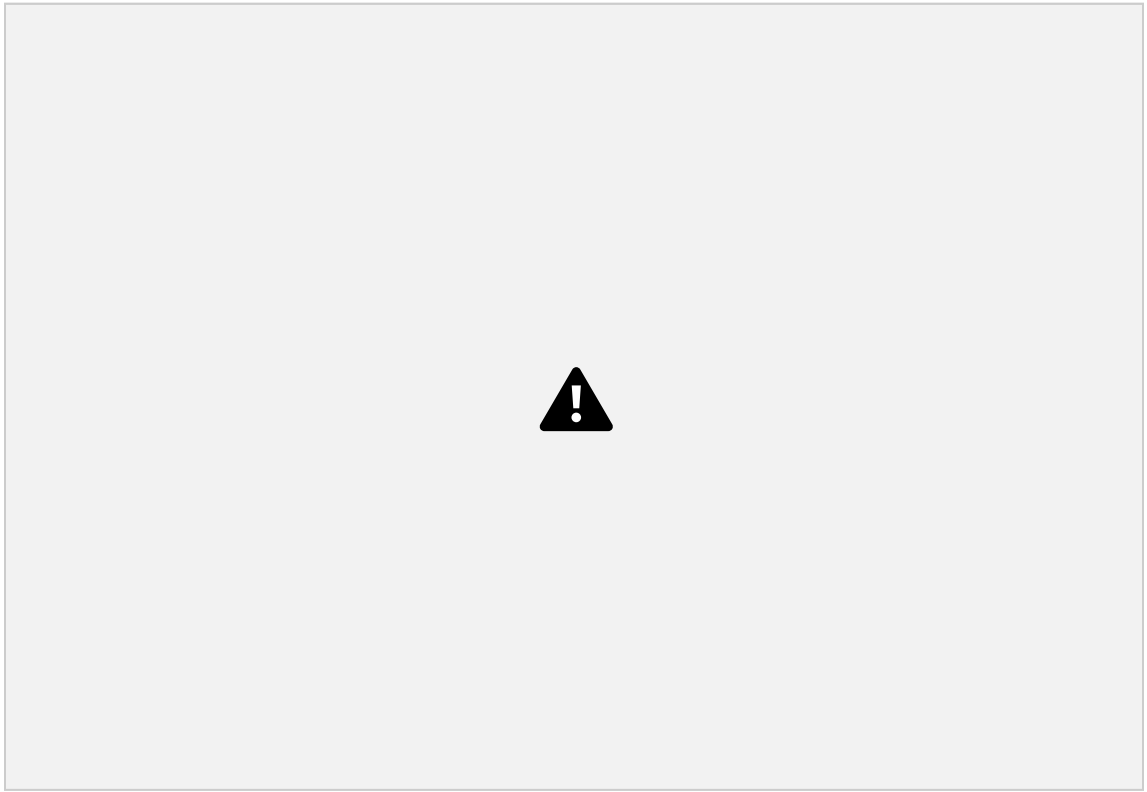
  - Combiner and rack #3 are grounded to rack #2. Each rack should have its own ground connected to a home run ground wire that in turn is connected to the MGB.

  - The amateur radio VHF repeater is not grounded.

  - The vents and electrical boxes are not grounded in the generator room.

- The 2nd RF filter rack is not bolted to the floor or grounded.

- UPS units 1-3 are connected to the outlet using extension cords. Best practices require the UPS power is connected to the outlet using twistlock plugs.



- The Exalt microwave units are powered by a single power supply and create a single point of failure. A separate power supply should be used for each unit. DC power wires should be better protected.

- The temperature control sensor wire is not protected and the probe needs to be secured.

- The vents and electrical boxes are not grounded in the generator room.





3.7 Mayville Water Tower



Address: 595 S. Clark St., Mayville, WI
Latitude: 43° 29' 13.1496"
Longitude: -88° 33' 24.8862"
ASR#: N/A
Tower: Approximately 200' Water Tower
Shelter: Equipment is in the base of the tower
Generator: Generac 22 kW residential type
Fuel Tank: Natural gas service

3.7.1 Site Observations

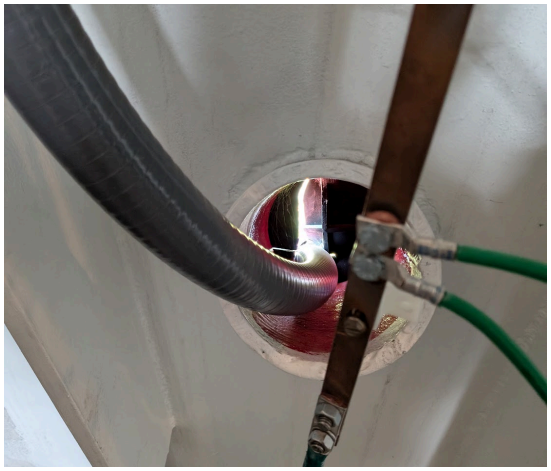
The water tower is located on the south side of Mayville just west of Seneca Foods Corporation. The radio equipment is located in the base of the water tower.

3.7.2 Issues Outside the Building

- The backup generator is a 22K Residential type generator. A commercial generator that can better handle extended run time and loading should be used for more reliability.

- The generator power cable is not sealed where it enters the building. This can allow rodents, pests, and the elements into the area where the equipment is located.





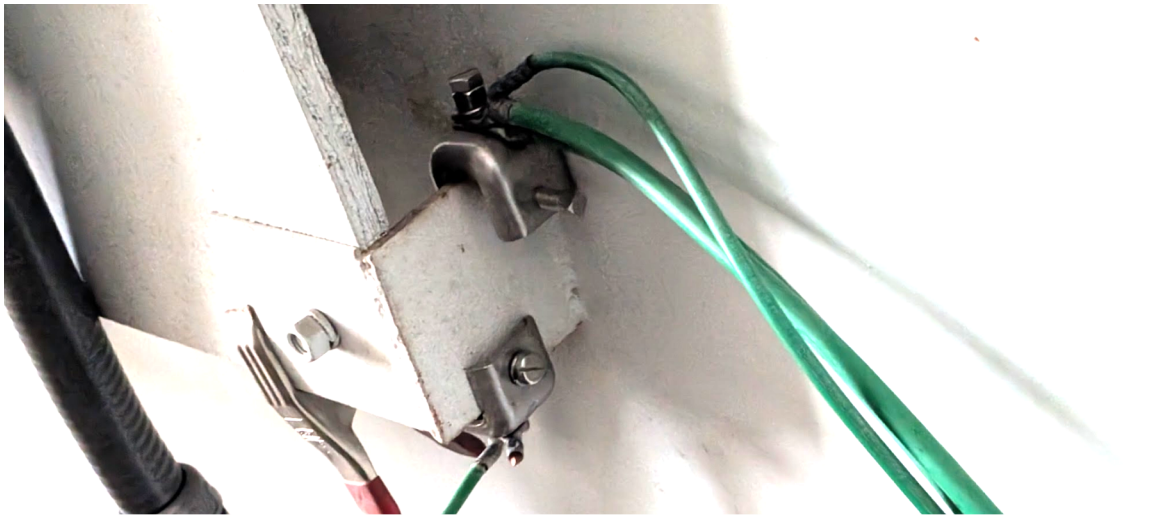
3.7.3 Issues Inside the Building

- The environment for the equipment is dusty and damp. The cabinets are sitting on the concrete floor inside the base of the water tower and acceptable to damage if there is a water leak. It is best practice to house the equipment in a shelter outside of the water tower where the environment can be controlled.

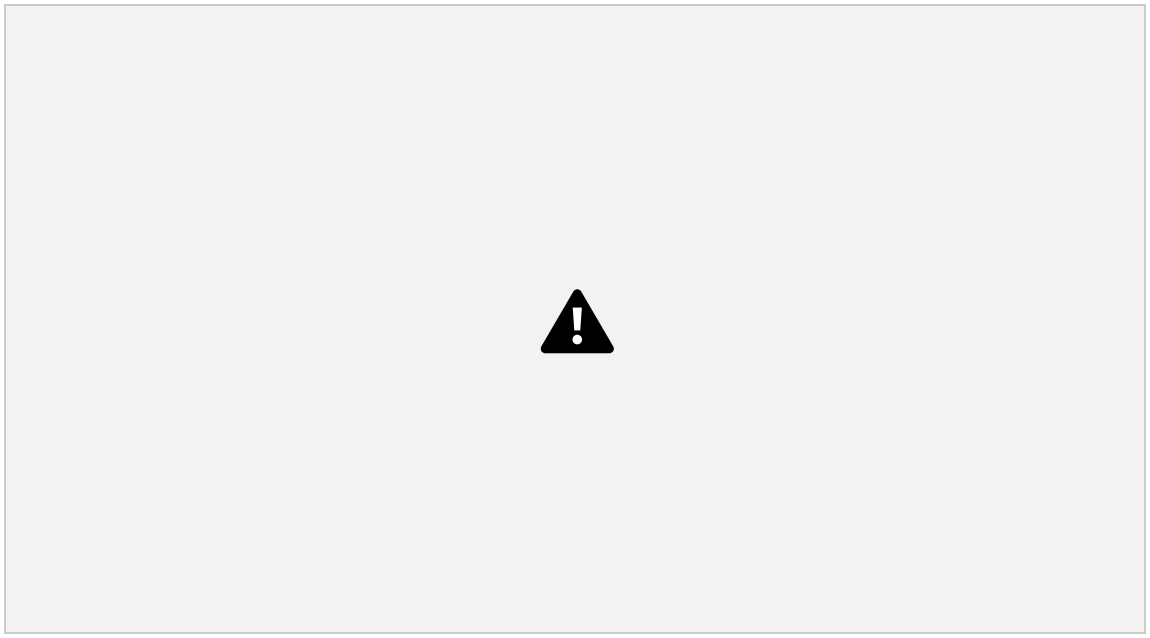


- The dark red paint on the outside of the tower heats up the area where the equipment is located and the space is hot. The heat inside the base of the water tank along with the heat generated by the equipment puts stress on the repeaters, GPS receivers and microwave. There is not an air conditioner unit, fan, or any other form of cooling.
- Equipment, coax cables, and equipment are grounded to the water tower structure with tower clamp. This creates multiple ground points for the equipment. A MGB should be used and exothermically bonded to a point on the water tower.

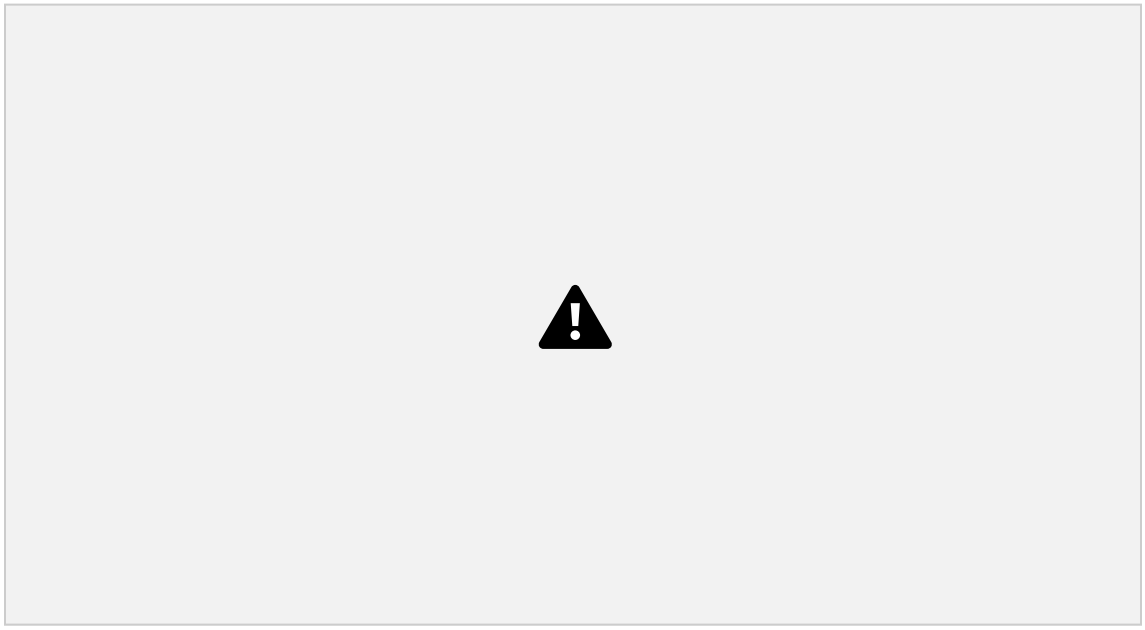




- The electrical breaker panel and generator transfer switch are not grounded.



- The equipment is grounded to the cabinet rail. A separate ground cable or bar should be used to properly ground the equipment.



3.8 Reeseville Water Tower



Address: 300 Watertower Lane Reeseville, WI
Latitude: 43° 18' 8.0202"
Longitude: -88° 50' 58.9194"
ASR#: N/A
Tower: 300 ft water tower
Shelter: Inside the base of the water tower
Generator: 22KW Residential type
Fuel Tank: 250 gallon propane

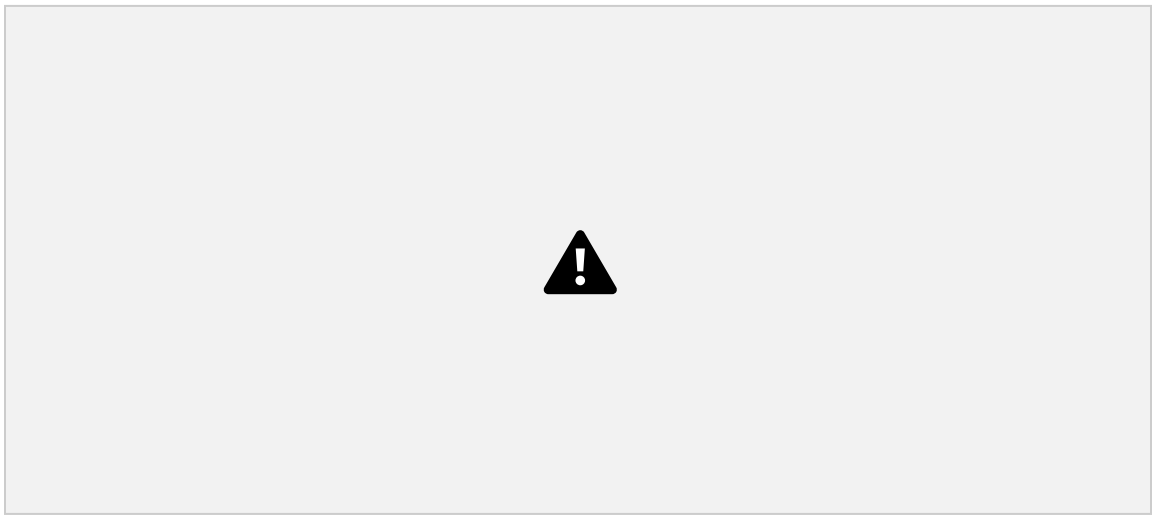
3.8.1 Site Observations

The equipment is housed in cabinets within the base of the water tower. At the time of the site visit, the fuel line between the generator and propane tank was being installed.

3.8.2 Issues Outside the Building

- The backup generator is a 22KW Residential type generator. A commercial generator that can better handle extended run time and loading should be used for more reliability.

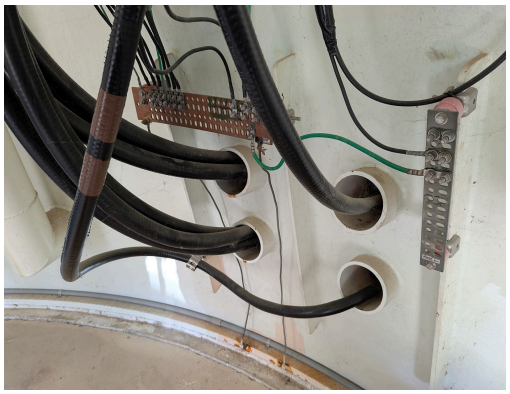
- The generator and propane tank are not grounded. The propane tank is not anchored to the ground.



3.8.3 Issues Inside the Building

- The environment for the equipment is dusty and damp. The cabinets are sitting on the concrete floor inside the base of the water tower and acceptable to damage if there is a water leak. It is best practice to house the equipment in a shelter outside of the water tower where the environment can be controlled.

- The MGB is properly done with exothermic bonds to the tower.





- The combiner rack and cabinet is not grounded. None of the equipment cabinets are grounded.

- One of the fans in the repeater cabinet is not working and the equipment is getting very hot. The interior of all the equipment cabinets are hot. This creates unwanted stress on the equipment.

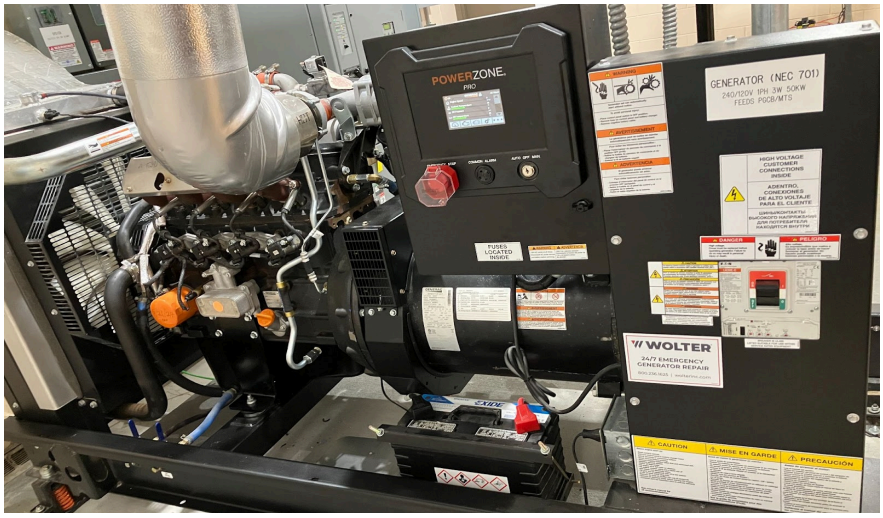
3.9 Rubicon Tower

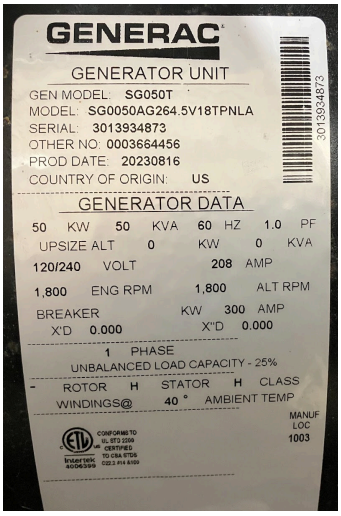


Address: W1522 Grant Rd, Rubicon WI
Latitude: 43° 20' 53.2458"
Longitude: -88° 28' 16.3884"
ASR#: 1042727
Tower: 350' Guided
Shelter: Cinderblock type building
Generator: 50KW Generator
Fuel Tank: 1000 gallon propane

3.9.1 Site Observations

The tower site is located approximately 1 mile north west of the town of Rubicon. This site is owned by the state and there are a number of other tenants on the tower. The site is backed up with the generator provided at the site location. There is a 50 kW Generac Generator used to provide backup power for the equipment.





3.9.2 Issues Outside the Building

- The tower guy wires are not grounded or bonded together. Best practices require that the guy wires are grounded together and to the anchor.



- The gate and the fence are not grounded.
- Equipment boxes and vents on the exterior of the building are not grounded.



- The ground on the propane tank is corroding



- The grounds to the tower legs should be bonded to the tower using exothermic welds. There are signs of corrosion degrading the quality of the ground.





- The coax cables for the county equipment are not protected by the ice bridge. The support posts for the existing ice bridge are not grounded.

- There are coax cables that are not grounded at the entry port to the building. This creates an opportunity for lightning to enter the structure.

- The air conditioning unit is not grounded. There appears to be only 1 large air conditioning unit providing cooling to the building, and no redundant unit.



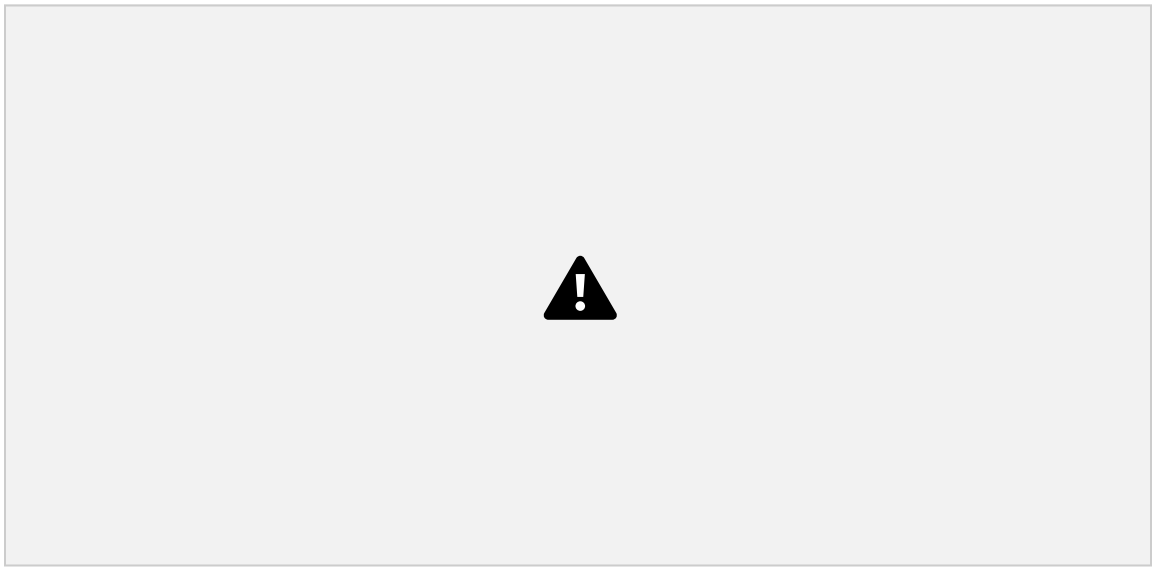
- The entry door is not grounded.

- The propane tank is not anchored to the ground.

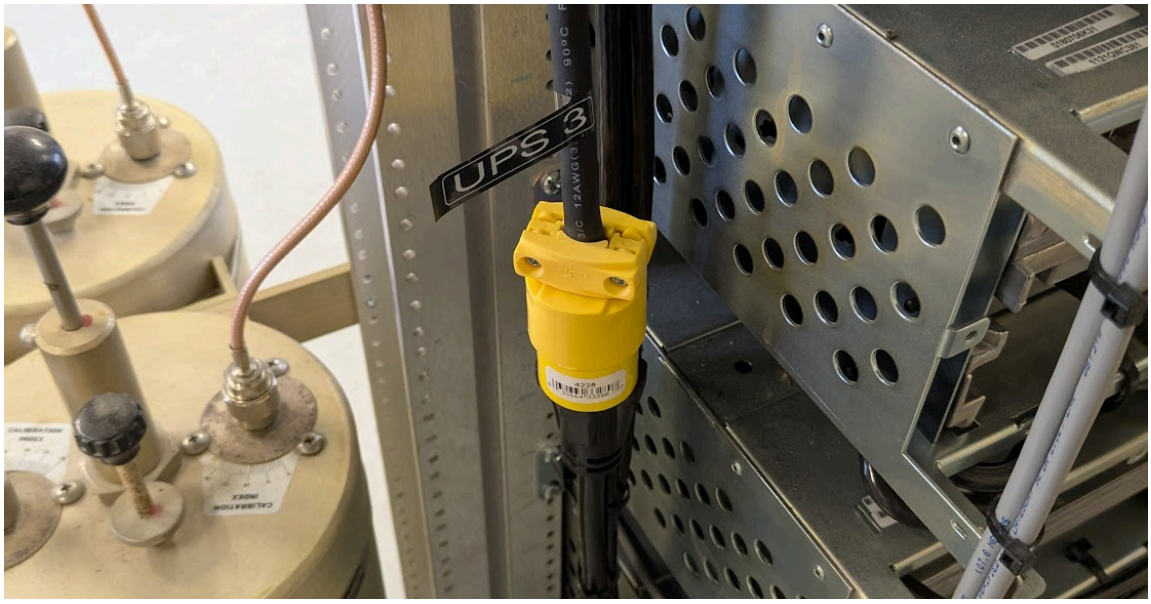
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3.9.3 Issues Inside the Building

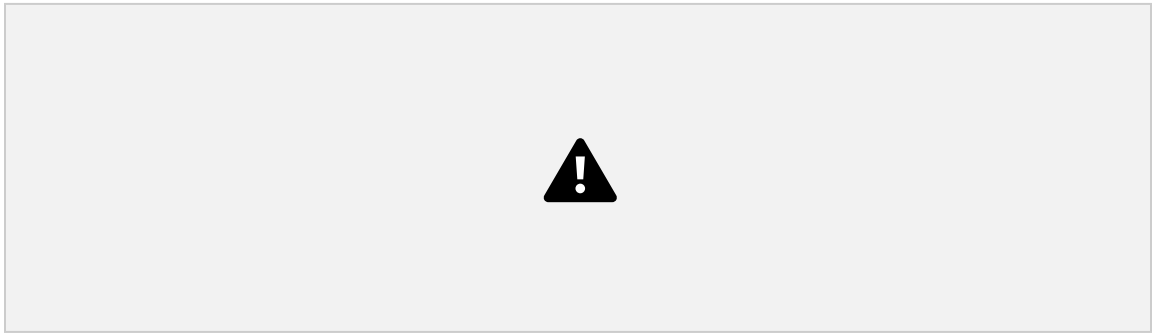
- There are power cords routed across the floor. This creates a tripping hazard and the possibility of power being unintentionally disconnected.



- UPS units are connected to the outlet using extension cords. Best practices require the UPS power is connected to the outlet using twistlock plugs.



- The combiner rack ground is using a single hole lug. All rack grounds should use a double hole lug.



- The combiner rack is grounded to GPS rack and equipment in the telco rack is grounded to GPS rack. The telco rack is also grounded at the top creating a ground loop. All racks should have an individual ground connected to a home run ground that in turn connected to the MGB. All equipment should be grounded within its own rack.

- The CODAN Equipment is not grounded.

- Best practices require that coax cable should be routed overhead in the cable ladder.



3.10 St. Helena



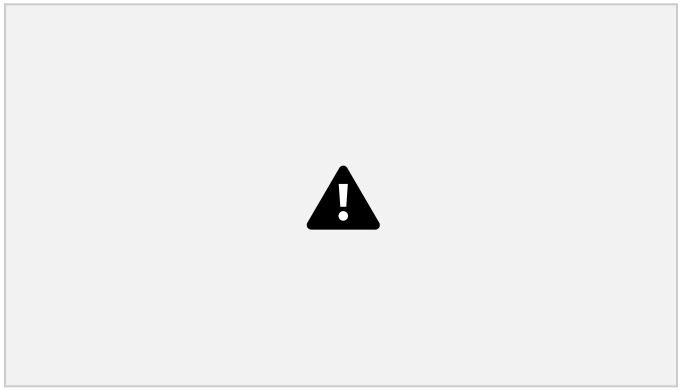
Address: North 5084 St Helena Road, Juneau WI
Latitude: 43° 22' 41.2782"
Longitude: -88° 38' 54.2142"
ASR#: 1035574
Tower: 300' Free Standing built in 1983
Generator: Guardian 22K Residential type
Fuel Tank: Approximately 500 Gallons

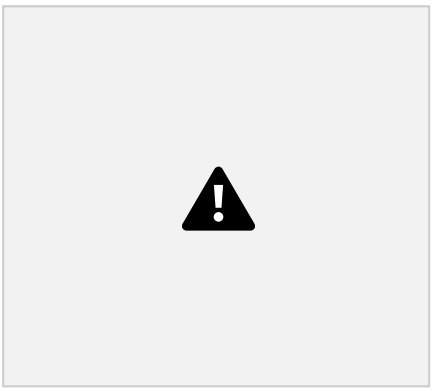
3.10.1 Site Observations

This tower site is located approximately 4 miles south east of Juneau near Sinissippi Lake. Console and simulcast audio is routed to this site from the county administration building located Juneau.

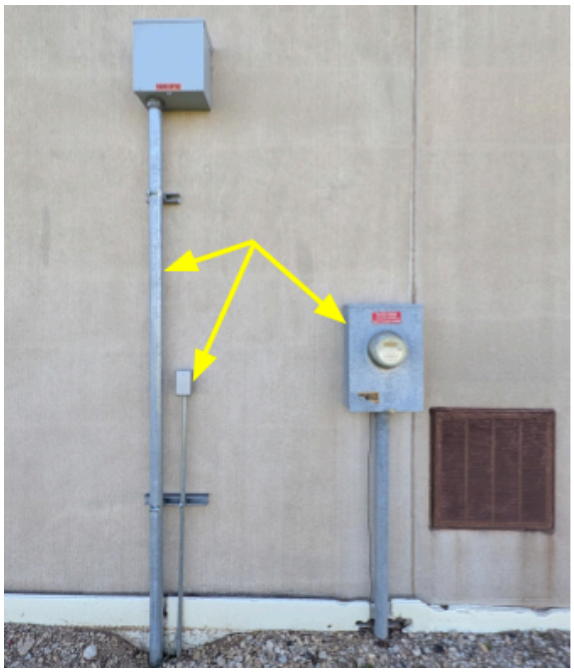
3.10.2 Issues Outside the Building

The propane tank is not grounded and secured to the ground. The paint on the tank is peeling off exposing the tank to corrosion. It is recommended that the tank be reconditioned or replaced.



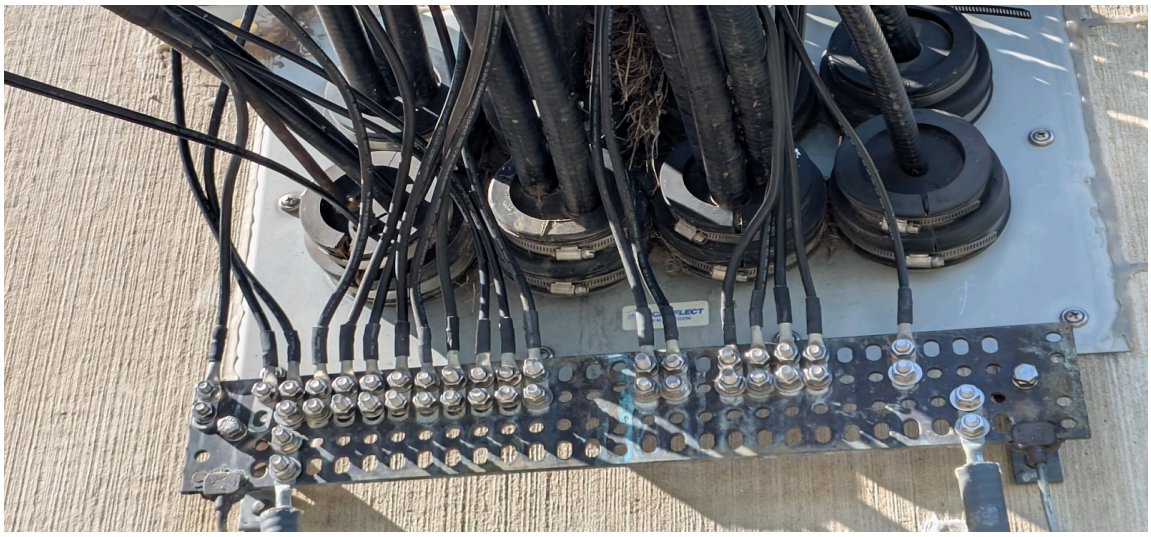


- Equipment on the outside of the shelter is not grounded. All metal components need to be grounded to the site compound ground ring. The photo sensor for the tower lights that is mounted to the building is not grounded.





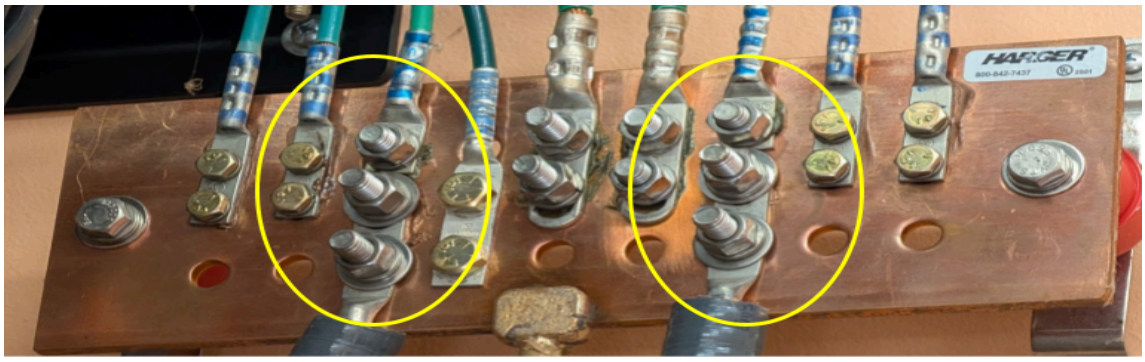
- Not all coax cables running into the building through the entry port are grounded creating an opportunity for lightning to enter the building. There is a lug that is missing a bolt.



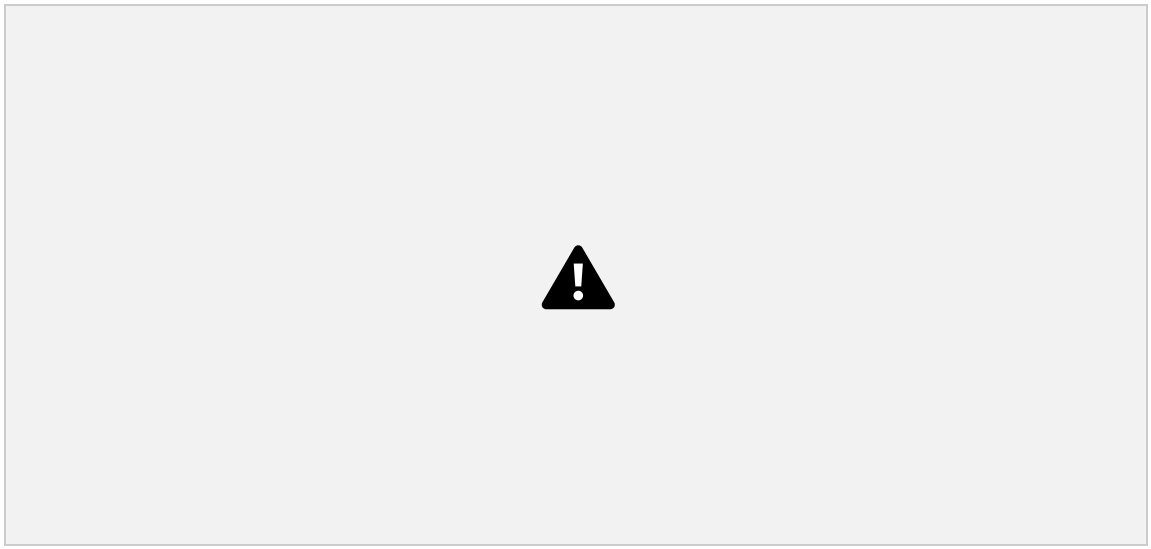
- The backup generator is a 22K Residential type generator. A commercial generator that can better handle extended run time and loading should be used for more reliability.

3.10.3 Issues Inside the Building

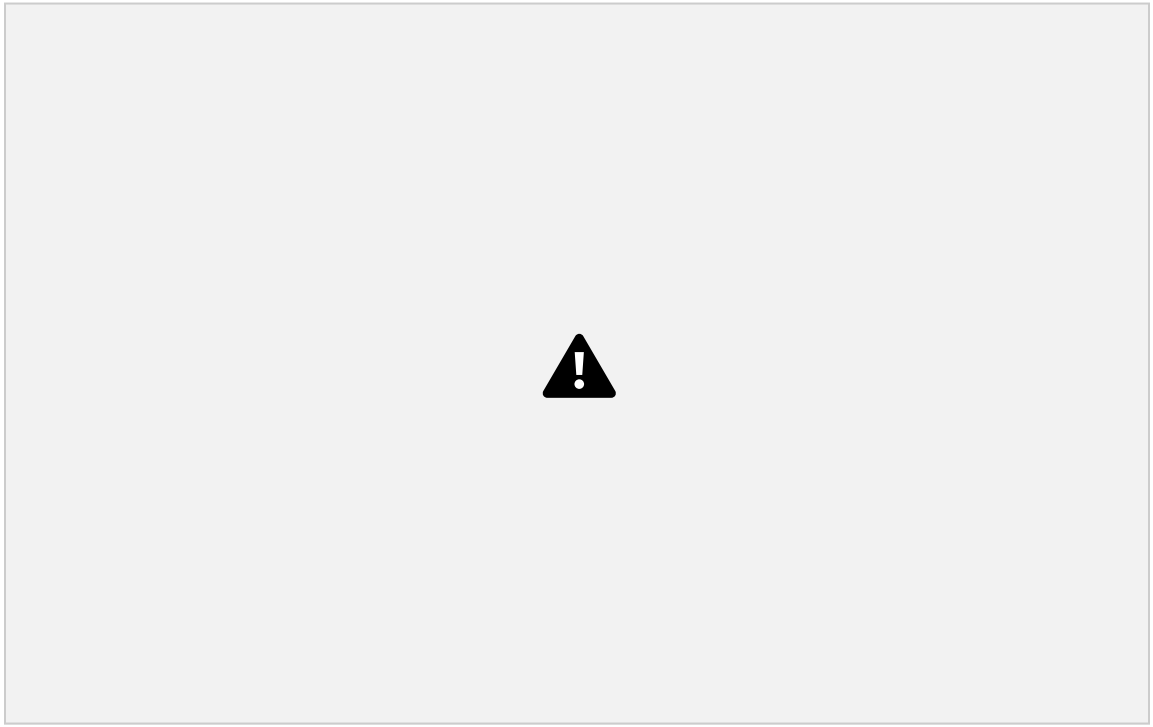
- Grounding
    - The building is lacking a halo ground.
    - Entry doors are not grounded.
    - The MGB has ground wires that are using a single hole lug. All grounds on the busbar should use crimped double hole lugs. If there is no space on the front side of the busbar, it is acceptable to mount them to the back side with lugs sharing the bolts.



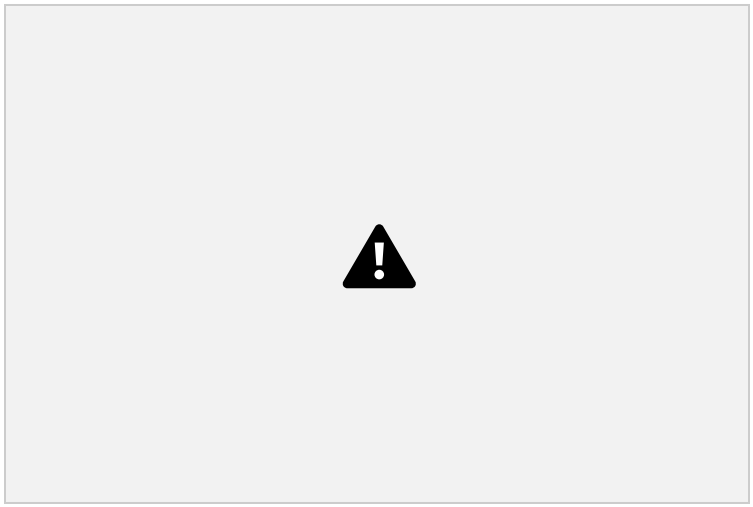
- Electrical boxes and other equipment are not grounded.



- There is no sub ground busbar on the telco board and none of the mounted equipment is grounded. A busbar with a dedicated wire connected to the MGB should be installed.



- Wall mounted RF cavities are not grounded,

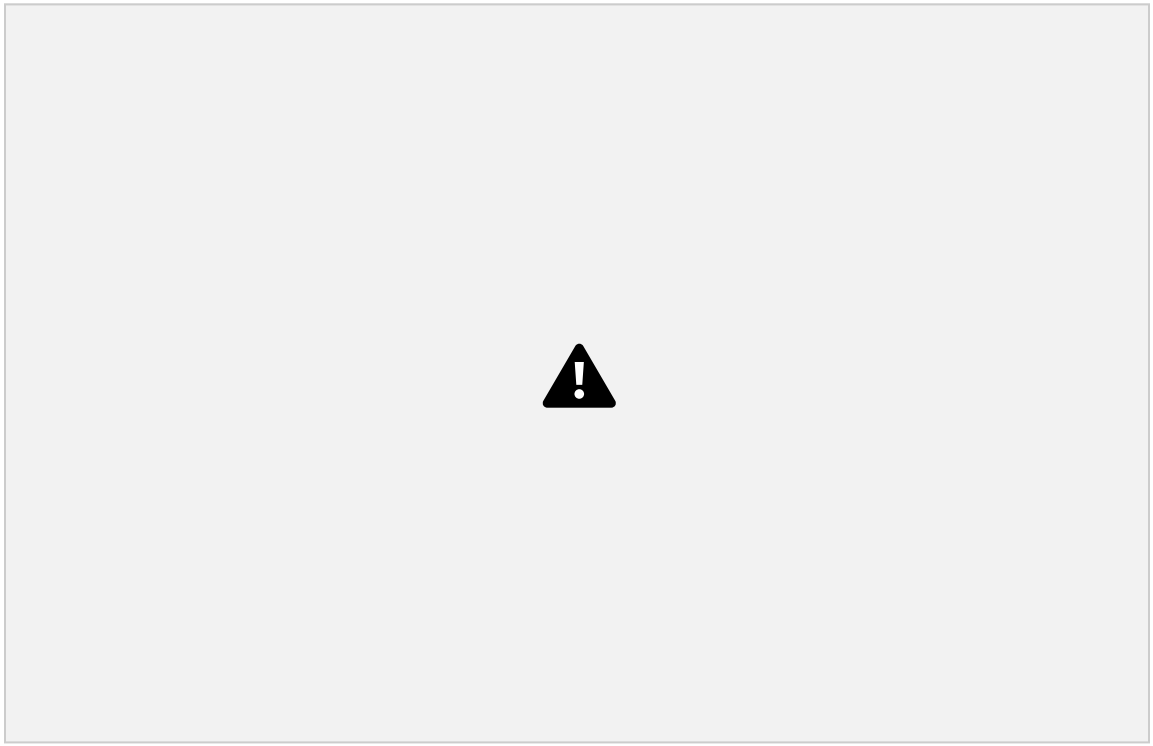




- The dehydrator for the microwave coax is not grounded.

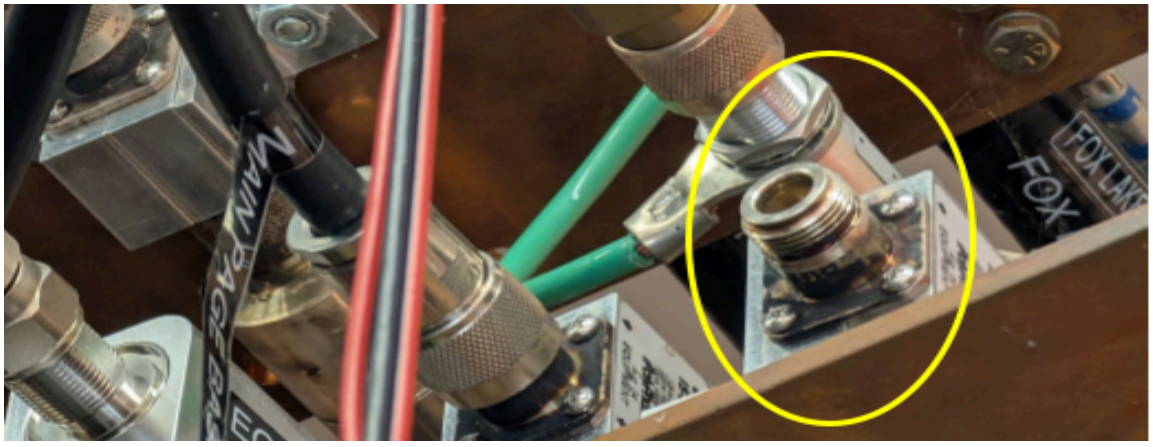


- Equipment in rack 4 and 5 is grounded at rack 3 and rack 4. Racks 1 and 2 are not grounded. Each rack should have an individual ground connected to a home run ground wire that in turn connected back to the master ground busbar.
- Microwave shelves and equipment are not grounded.



- None of the equipment in cabinet #1 is grounded.

- There are lightning arrestors that are unterminated. This creates two issues, the opportunity for lightning to enter the building, and an entry point for external RF noise especially in the VHF band.



- There is a single air conditioning unit that provides no redundancy for cooling. If there is a failure, the equipment can easily overheat leading to equipment failures.
- The UPS is using an extension cord and should be plugged directly into a twist lock type plug.
- The Intraplex Mux equipment is no longer manufactured and new parts are not available. This equipment is well past its end of life and parts are becoming increasingly difficult to find.



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3.11 Site Visit Summary

There were common issues that were observed after completing the site visits. These issues consisted of equipment grounding, end-of-life equipment, aging equipment and overall site and system maintenance. The quality of the site compound varied greatly from location to location.

3.11.1 Equipment Maintenance

Records show that the last preventive maintenance performed on the system was in 2020. Preventive maintenance on tower site equipment as well as user radios is key to keeping a system working at peak efficiency. Another aspect of preventive maintenance is keeping the facilities clean and maintained. Dust flowing through fans in the electronic equipment can reduce equipment life significantly.

3.11.2 Site and Equipment Grounding

The quality of the tower site grounding ranged from good to very poor. Bad grounding practices leaves expensive equipment vulnerable to lightning damage. There are many instances where the grounding is missing or connected to a manner that creates ground loops. Overall, grounding is one of the main deficiencies of the tower sites.

Grounding practices have improved and changed over time. It is recommended that the grounding of the equipment at the tower locations be updated and improved to meet industry standards and best practices. These standards and best practices are outlined in documents such as the recent revisions of the L3Harris Site Grounding and Lightning Protection Guidelines AE/LZT 123 4618/1 or Motorola R-56 Standards and Guidelines for Communication Sites.

3.11.3 Installation Standards

The installation standards vary greatly from location to location ranging from poor to acceptable. The grounding, neatness or lack of properly dressed wiring, and grounding is not consistent among the tower sites.

There are many situations where abandoned coax cables are routed into the sites and are not terminated or grounded. Abandoned or unused coax creates a conduit into the site for possible lightning damage and interference. The VHF equipment that is being used by the county is very susceptible to interference and noise that can be generated by these practices.

3.11.4 Equipment Environment

The environment that the equipment is operating in varies greatly from location to location. There are site locations that have clean buildings with redundant air conditioning systems that provide a good environment for the equipment. There are sites that do not have redundant air conditioning or no cooling at all. For example, the water tower sites are very dirty and harsh environments without any cooling. The harsh environments can significantly shorten the performance and longevity of the equipment. It is best practice in the industry to provide a clean and properly cooled environment with redundant air conditioning.

3.11.5 Aging and End-of-Life Equipment

A majority of the towers used in the system were built in the 1980s and are nearing 20 years old. The tower may be fully functional, but can create maintenance issues and cost in the near future. The air conditioning units that are used in the prefabricated concrete type shelters are aging and prone to failure. It is recommended that an aggressive schedule is implemented to update these units.

There is equipment in the locations visited that are beyond end-of-life (EOL) such as the intraplex mux. This EOL equipment is no longer manufactured, supported, or repaired by the manufacturer over time parts will become more difficult to find. Adding in poor grounding practices increases the risk. It is recommended to replace end-of-life equipment with modern more reliable and efficient equipment.

3.11.6 Generators

Residential 22 KW generators are used at many of the sites. These types of generators are not designed to run under load for the long periods of time that are required by a modern communications site. Running air conditioning, radio equipment, and backup battery banks creates significant loading and requires a larger commercial grade generator. The cost of the residential generators may be attractive, but down time that could result during a critical event due to a generator failure degrades the effectiveness of a public safety grade radio system.

3.11.7 Safety Equipment

It was noted when visiting the sites that there was a lack of safety equipment. The site locations should at a minimum have a fire extinguisher, first aid kit, and eyewash kit at sites that have battery banks.

4 Existing VHF Radio System Coverage and Assessment

TUSA developed a set of coverage maps for the County's current VHF radio system based on FCC-filed configuration data as well as performance specifications typical for VHF radio system technology. FCC data was used along with information obtained from tower site inspections and signal measurements taken throughout the county. The signal measurements were collected by using test equipment attached to the receive antenna at each tower site, and driving roads throughout the county. In addition, TUSA considered the normal use-case for user equipment devices by public safety officials (i.e., on-hip portable radios with speaker-mics). There are a number of issues that can affect the quality of the predicted coverage such as in-band noise, simulcast interference, and lack of preventive maintenance. During the interview process users expressed that experienced radio coverage is less than what is being predicted.

4.1 VHF Talk Out and Talk In

With VHF radio communication "talk in" and "talk out" refer to the two halves of a conversation where a repeater extends the range of radio signals. These terms are defined as follows.

- Talk In refers to the ability for the user radio to transmit a signal that is received by the repeater.
- Talk Out refers to your ability for the user radio to receive the signal transmitted by the repeater.

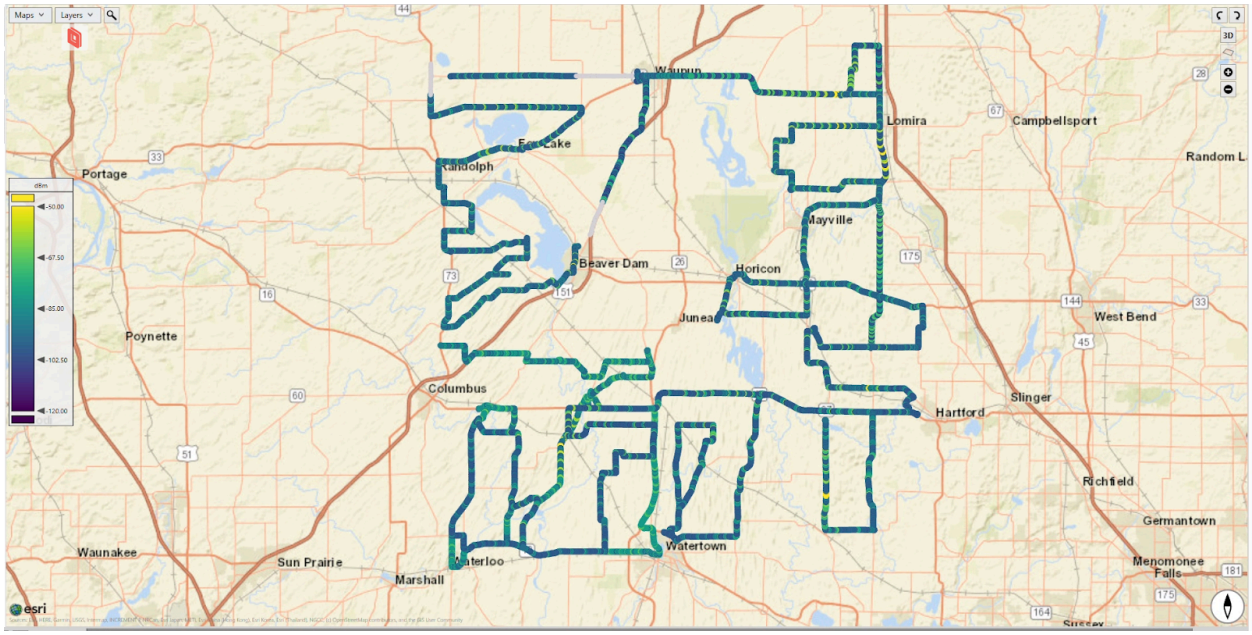
4.2 VHF Noise

These predictive maps also assume the system was designed with adjustments for the current VHF noise floor where the population of radio equipment would likely create in-band VHF frequency noise. This VHF interference degrades the optimum performance of the system and the talk in ability of the user radio equipment.

A portable radio can hear the repeater (good "talk out"), but the repeater can't hear the portable radio (poor "talk in"). The repeater's transmit antenna is very high and powerful, allowing the portable radio to easily receive its signal. However, the portable radio has a lower power output and a shorter antenna, making it harder for the signal to reach the repeater's receive antenna. The repeater transmitter can be heard clearly by the portable, but when the transmit button is pressed, the user on the other end won't hear the response. VHF talk in vs. talk out imbalance is about the difference in signal strength and quality between the portable radio transmitting to the repeater and the repeater transmitting to the portable radio. With VHF

systems that are working optimally this imbalance can be in the range of 10 dB. Other frequency bands (700/800 MHz) have the ability to use tower top amplifiers (TTA) to assist in balancing this noted difference.

Extremely high VHF in-band noise was consistently measured throughout the county and was approximately -93dB to -90dB. In some cases. For example in Water Town, the noise levels were measured as high as -73dB. A portable radio can typically receive usable signal levels in the area of -100dB. Given that the inherent VHF system imbalance is -10dB and the background noise is around -92dB, the portable radio is deafened by -20dB and therefore impacting the coverage of the end user portable equipment. During the interviews, users reported that they had minimal issues when using mobile radios. This is due to the ability of a higher powered radio with a more optimal antenna able to overcome the high noise floor and talk-in to the radio sites.



Drive testing data showing roads driven throughout the county

The tower site transmit signal that was measured when driving throughout the County with test equipment, has sufficient signal strength to provide a reliable portable signal. However, the measured noise floor also witnessed throughout the county created an environment that restricted and deafened the portable's ability to properly perform in a reliable manner.

The VHF noise that is experienced throughout the county comes from multiple sources such as electrical substations, LED lighting, industrial sources, and TDI (time delay interference) created by the simulcast technology. A properly engineered and timed simulcast radio system can minimize this TDI impact, but with inputting the current nine site system parameters into a

propagation model makes timing a system extremely difficult. TUSA can demonstrate that the current system may also be performing poorly due to the described TDI effect.

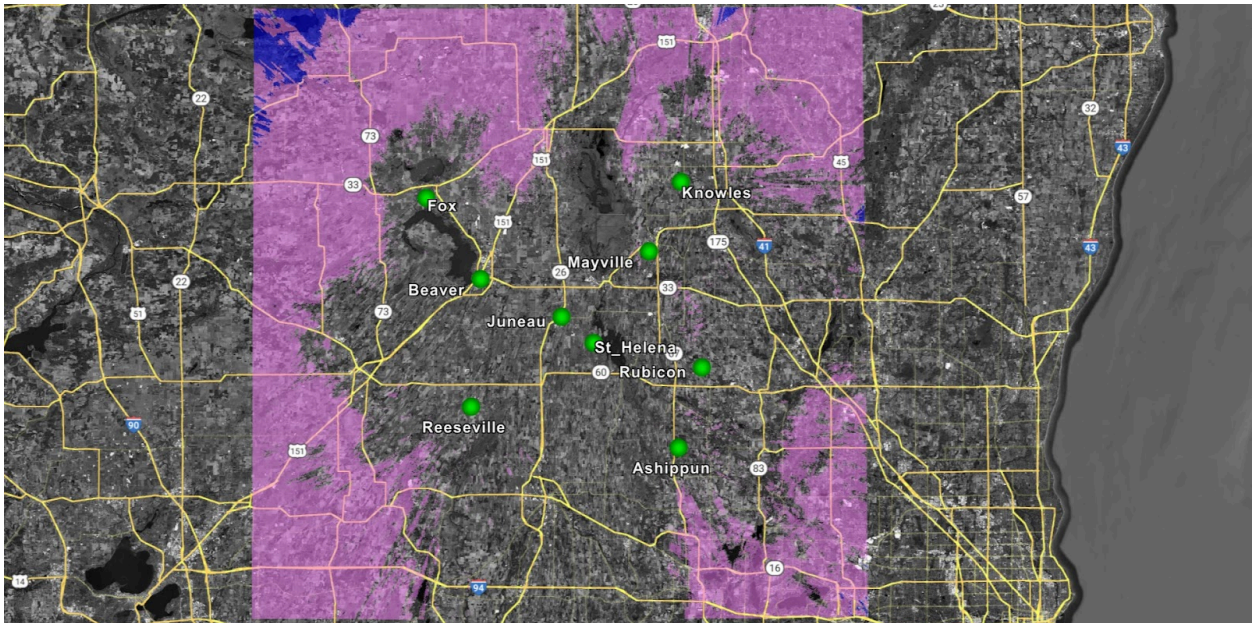
Another prominent source of noise and interference is the abundant amount of VHF systems being used by agencies within and outside of the county. As more VHF sites and channels are added to these systems, the greater the VHF noise floor. So as the county adds more tower sites to attempt to increase coverage, more noise is being added to the VHF band creating a counter effect to the needed coverage. As more TDI that may not be able to be timed correctly is generated, it creates a negative effect on coverage instead of anticipated improvements.

4.3 Simulcast Induced Noise

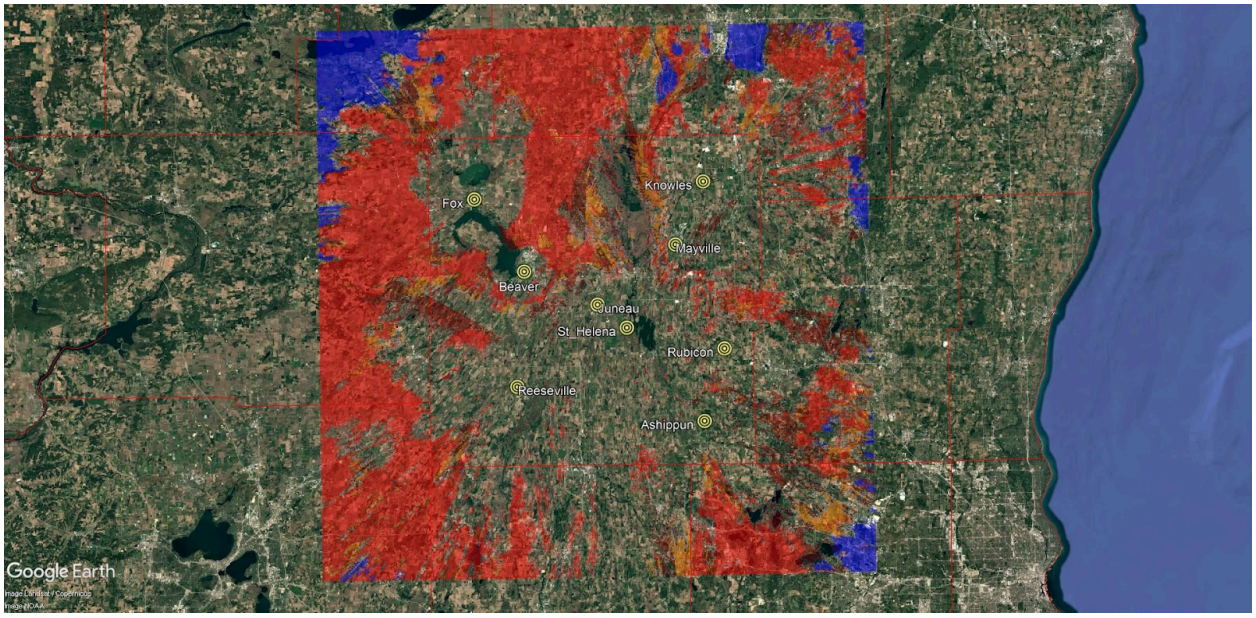
The nine tower sites of the county's VHF radio system are configured as a simulcast system. This means that all of the tower sites transmit at the same time on the same frequency and will interfere with each other. This is referred to as TDI or Time Delayed Interference and is inherent to all systems simulcasting on the same frequency, regardless of the frequency band.

The system uses GPS receivers to delay the signal between multiple sites to minimize interference. This can easily be done with a small number of sites, but becomes increasingly difficult to do as more sites are added. With the nine sites that are in the county, this becomes a daunting if not impossible task since a tower on one side of the county can interfere with a tower on the opposite side of the county. TUSA calculated the Time Delay Interference (TDI) shown in pink on the following image. The transmit towers are represented as the green orbs.

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Time Delay Interference (TDI) shown in pink.



Time Delay Interference (TDI) enhanced further.

4.4 Preventive Maintenance and Aging End User Equipment

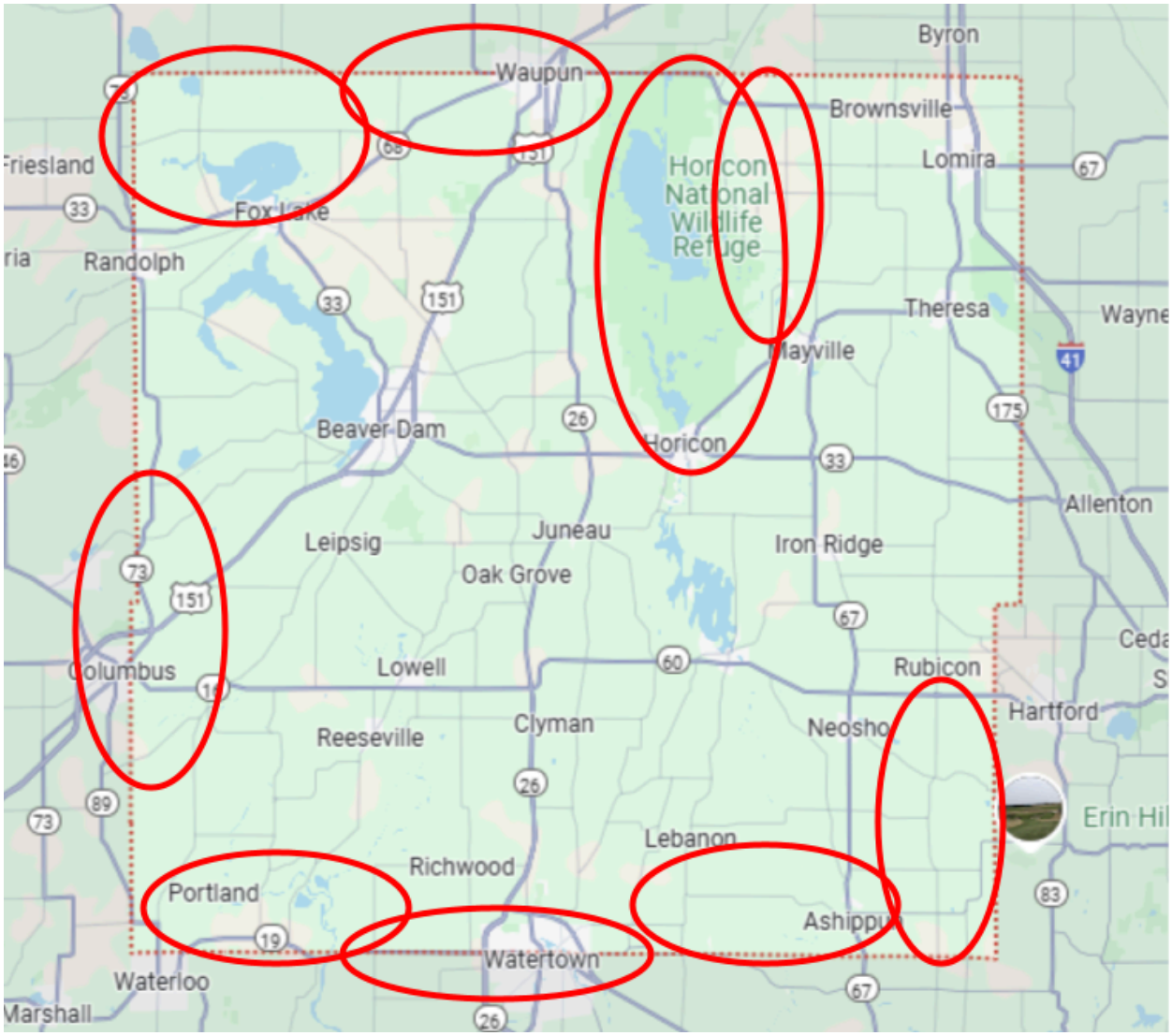
It must be understood that predictive coverage maps displayed in the following sections assume all antenna systems, portable and mobile radios, and RF site equipment are in proper working order with regular preventative maintenance being performed. The last recorded preventive maintenance data for the tower sites and supporting equipment was from 2020. During the user interviews it was revealed that the overwhelming majority of end user equipment does not or potentially never has received any preventive maintenance and is only serviced on an as needed basis, or when the equipment malfunctions completely. There is a large number of radios using the system that are 15 years or older.

TUSA highly recommends at a minimum, a preventive maintenance of all infrastructure equipment to including a sweep of all antenna systems to determine they are working optimally. This simple interim step will ensure best performance of the existing system while the County determines how to proceed with any future radio modifications and upgrades. Preventative maintenance should also be completed on all mobile and portable radio equipment to include antenna systems on the vehicles and batteries on the portable radios.

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4.5 Coverage Assessment

The previous TDI maps in section 4.3 reveal the challenges of portable coverage in areas throughout Dodge County. Users commonly identified the areas of poor coverage mostly around the outer edges of the county and are identified by the red circles on the following map.



Problem coverage areas identified by users

The Time Delay Interference that is shown in section 4.3, correlates with problem areas that are circled in red. The combination of the VHF in-band noise, simulcast induced time delay interference, along with the lack of preventive maintenance is creating noticeably reduced coverage for portable users.

It is apparent from the user feedback, that the system is not providing the predicted or needed coverage, especially for portable radios. There is a shortfall of radio coverage caused by the combination of extreme noise in the VHF band, simulcast induced noise, and poor preventive maintenance. This lack of coverage creates high risk for first responders.

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4.6 Desired Delivered Audio Quality (DAQ)

The Delivered Audio Quality (DAQ) criteria used in these coverage studies is DAQ 3.4, as defined by EIA/TSB-88D Wireless Communications Systems Performance in Noise-Limited Situations (Shown in the figure below). DAQ 3.4 is the minimum recommended for federal and public safety communications systems. DAQ 3.4 is defined as “Speech understandable with repetition only rarely needed. Some noise and distortion'' When gauged against legacy analog FM receiver performance testing, DAQ 3.4 is equivalent to the traditional 20dB signal/noise and distortion ratio, or SINAD measurement.

When a call is placed on the radio system, a transmitting channel is enabled, and audio information is broadcast from the transmitter site simultaneously. The resultant transmitted coverage is termed talk-out as the tower sites are then communicating out to distant portable and mobile radio subscribers.

DAQ	DESCRIPTION
5	Reception is very clear, and the message is perfectly readable. No background noise is present, and every word is understood.
4	Reception is clear, but with slight background noise. Message is readable and every word is understood.
3.4	Reception is clear, but with slight background noise. Message is readable and understood with few/occasional missing syllables.
3	Background noise is evident. Message is readable and understood even with missing syllables.
2	Background noise is prevalent. Message is readable with difficulty and requires repetition.
1	Evidence that transmission is being made. Voice message is barely discernible, and no words are understood. Unusable.
0	No transmission is heard. No activity on the channel is evident.

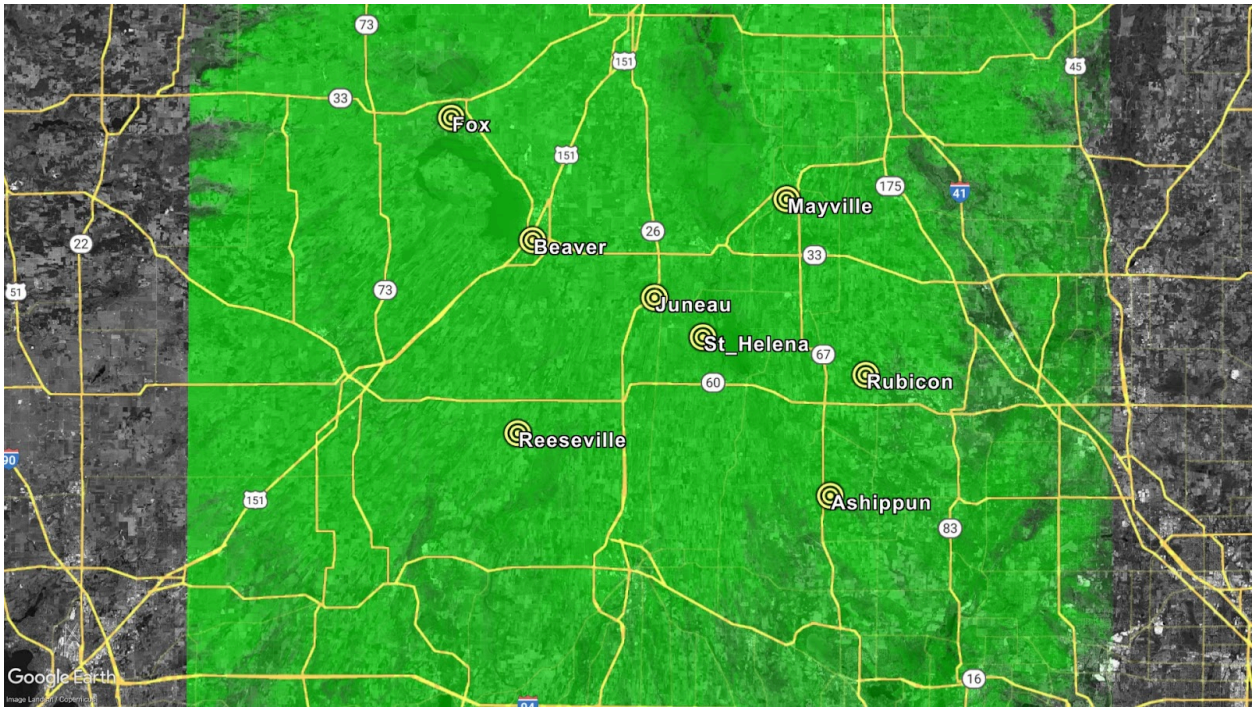
Delivered Audio Quality (DAQ) Index

4.7 Predicted Existing Coverage Maps

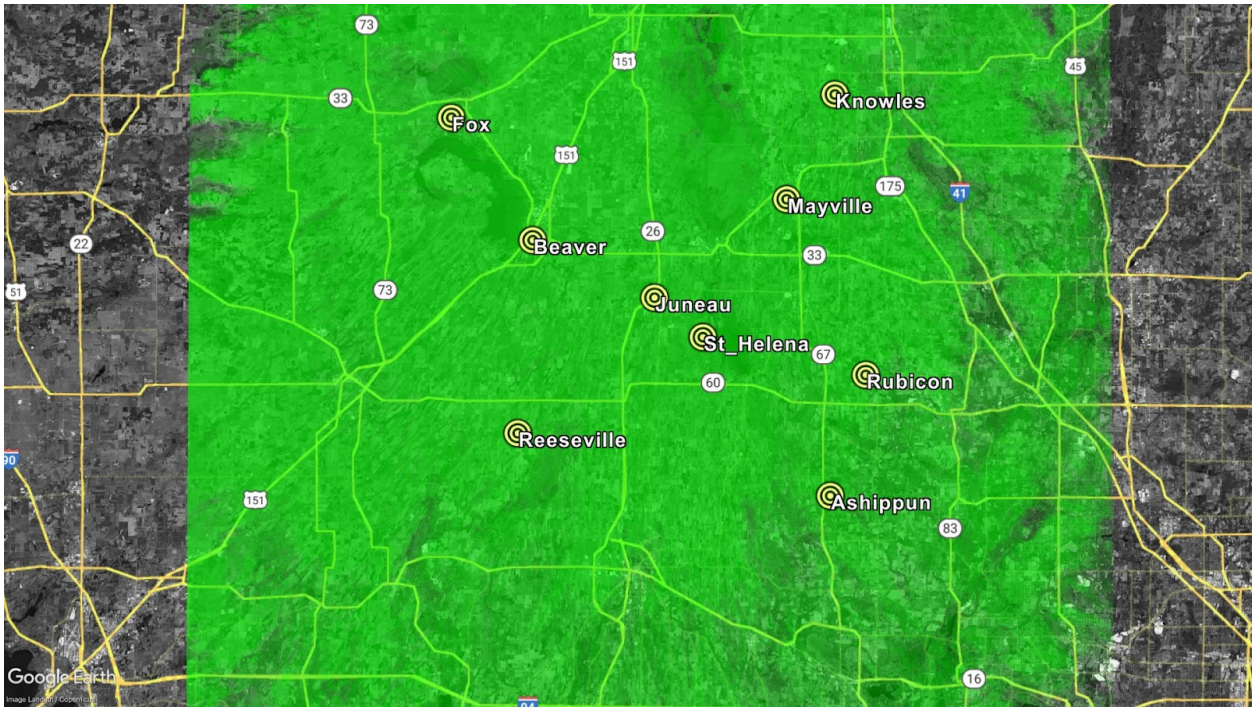
The following coverage maps predict the coverage that users should expect based on the obtained FCC information, the current systems timing delays, and antenna information from site visits.

4.7.1 Existing VHF Mobile Predicted Coverage

The predicted mobile coverage depicted in green is where the coverage/audio quality talk-in or talk-out is at or above DAQ 3.4. The areas outside of the green, are areas where the coverage is predicted to be below DAQ 3.4. These depicted areas illustrate performance that could range between broken coverage and no-coverage areas and are below the signal level thresholds needed to achieve an audio quality of DAQ 3.4. Throughout the user interviews, there was a recurring theme that these maps indicate the system's performance is less than predicted.



Predicted VHF Mobile Talk In



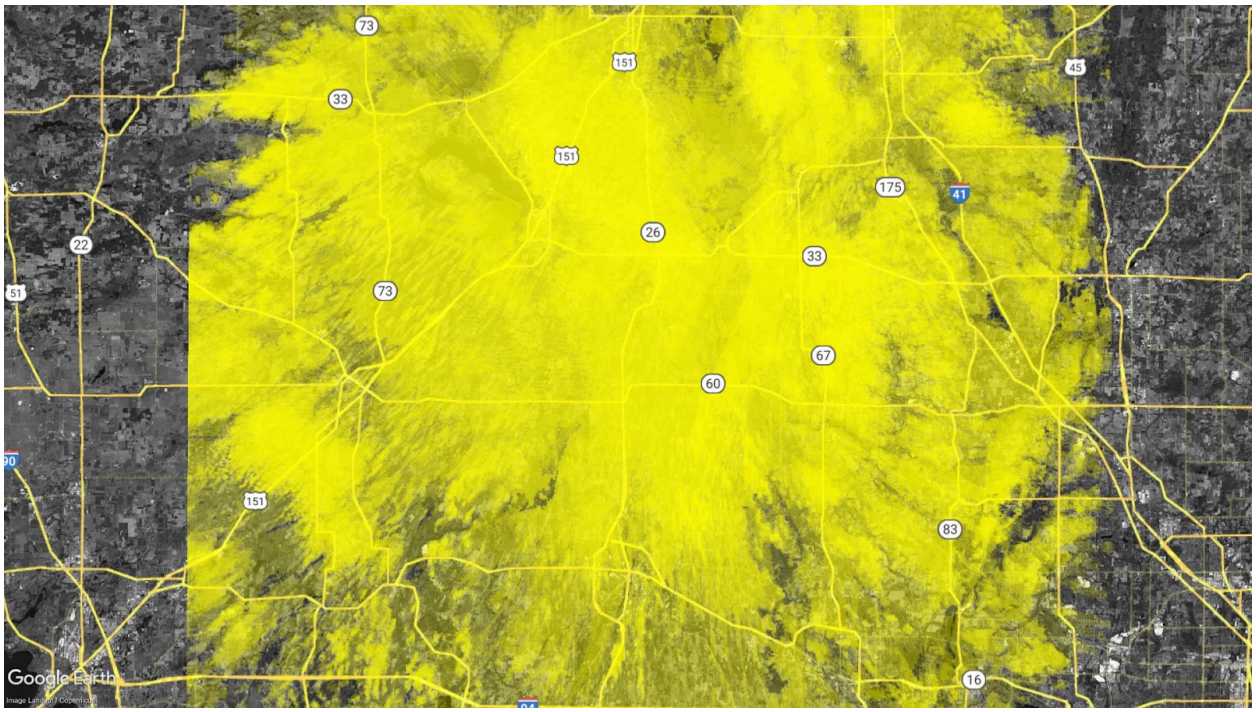
Predicted VHF Mobile Talk Out

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4.7.2 Existing VHF Portable On-hip / On-street Predicted Coverage

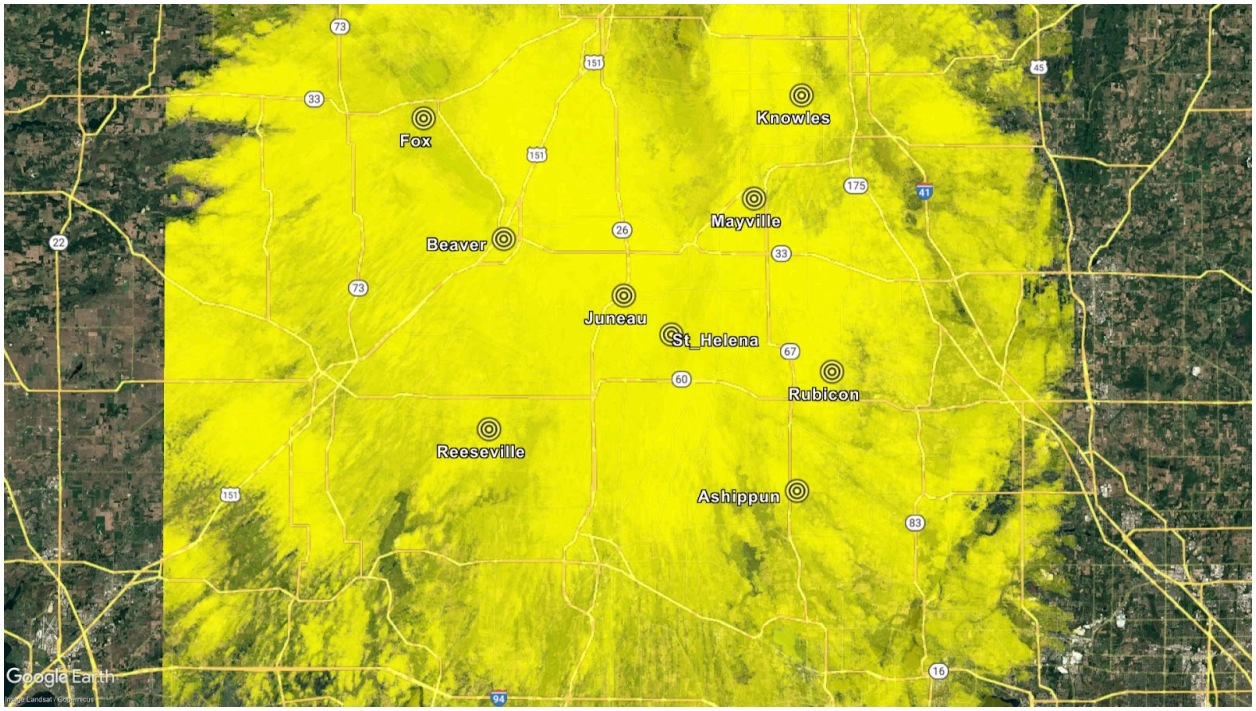
The predicted coverage depicted in yellow is where the coverage/audio quality for portable on-hip/on-street talk-out coverage is at or above DAQ 3.4. The areas outside of the yellow, are areas where the coverage is predicted to be below DAQ 3.4. These depicted areas illustrate performance that could range between broken coverage and no-coverage areas and are below the signal level thresholds needed to achieve DAQ 3.4 audio quality.

While these maps predict portable on-hip/on-street coverage based on standard noise and interference, the real-world experience is that the portable coverage is less than shown.



Predicted VHF Portable Talk-in Portable on-hip/on-street

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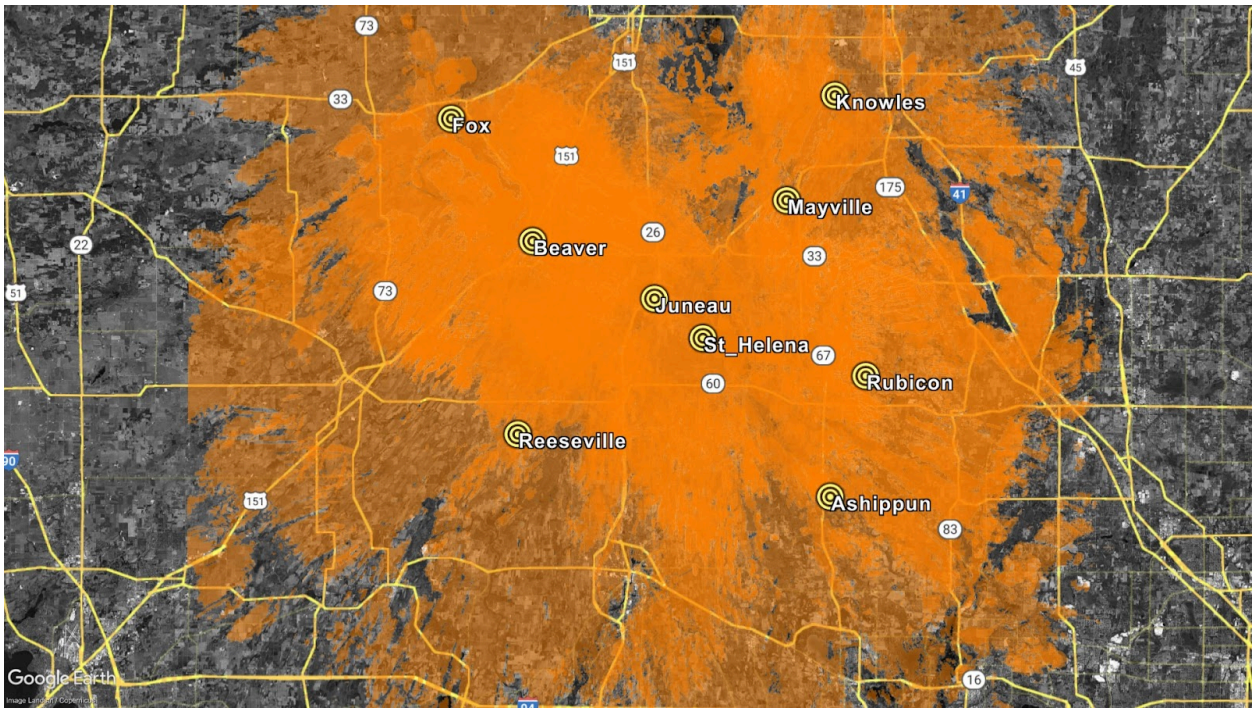
Predicted VHF Portable Talk-out Portable on-hip/on-street

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4.7.3 Predicted VHF Portable On-hip 10db Building Coverage

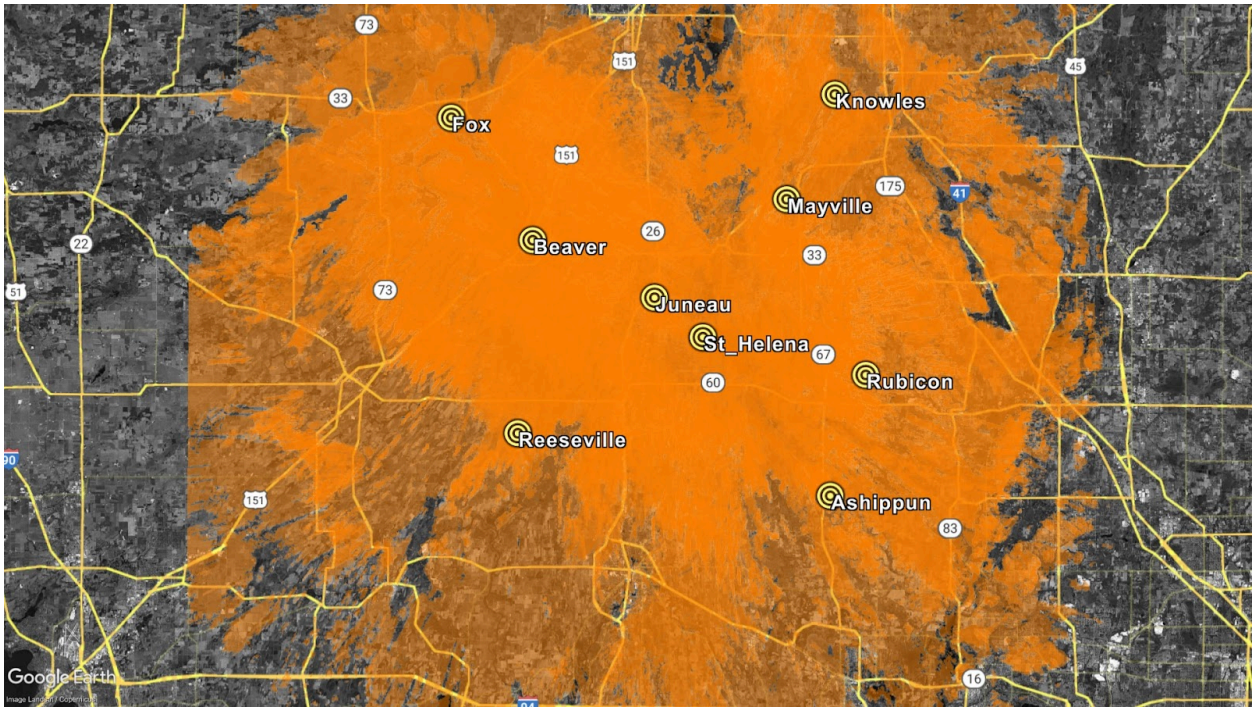
The following maps predict the existing portable on-hip radio coverage within 10db loss building structures as orange. As the loss value increases, the corresponding area where reliable coverage is predicted to occur, decreases.

The following are 10dB portable on-hip in-building Talk-in coverage maps for the Dodge County system. 10dB Portable Coverage is regarded as a standard single story wood frame house or other light building such as a small business.



Predicted VHF Portable on-hip Talk In - 10dB Buildings

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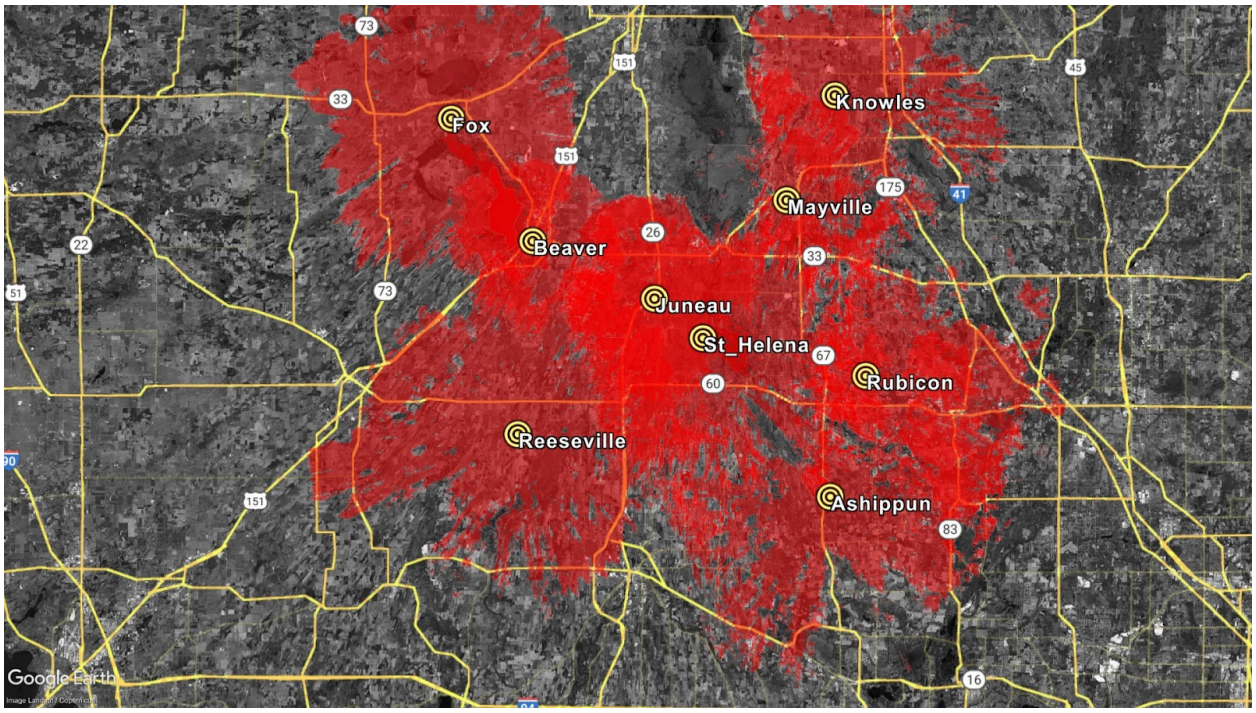


Predicted VHF Portable on-hip Talk Out - 10dB Buildings

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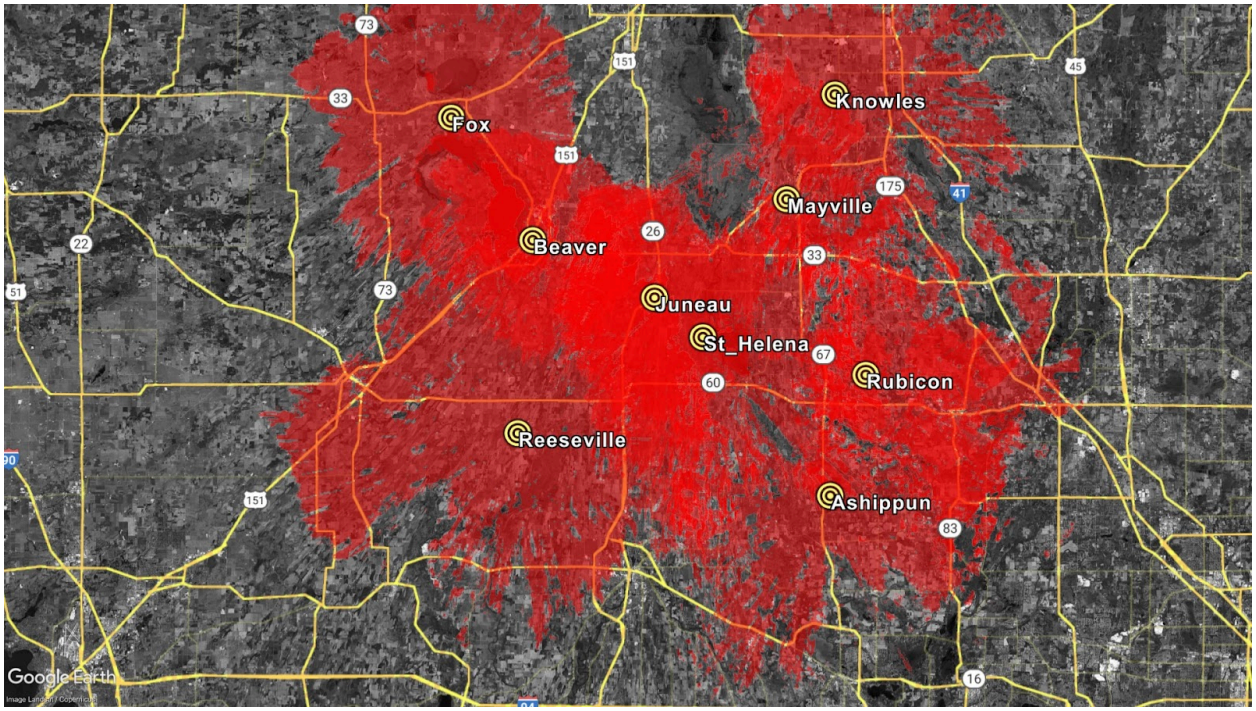
4.7.4 Predicted VHF Portable On-hip 20db Building Coverage

Predicted coverage maps, shown in red, are for 20dB buildings. A 20dB building is regarded as a denser industrial, hospital, or courthouse building. Schools typically fall into the range of a 20db building as well. With recent construction techniques to include glass and building materials, these buildings described can easily exceed the 20dB building definition when tested.



Predicted VHF Portable on-hip Talk In - 20dB Loss – Dense Building

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Predicted VHF Portable on-hip Talk out - 20dB Loss – Dense Building

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5 User Interviews and User Needs

Different agencies and departments often have different perceptions of how a radio system performs. For example, Deputies might have the best "big picture" view because they travel all over the county. These users are more aware of wide-area coverage challenges. However, a local volunteer fire department might have problems with in-building portable radio performance due to poor coverage, or communications challenges when on mutual aid calls.

Dispatch center operations might be hampered by inefficient/obsolete equipment, or ergonomic issues, or be short staffed. All of these unique things feed into what the user actually needs. The user interviews allow TUSA to develop a "picture" of how the radio system performs from the user's standpoint.

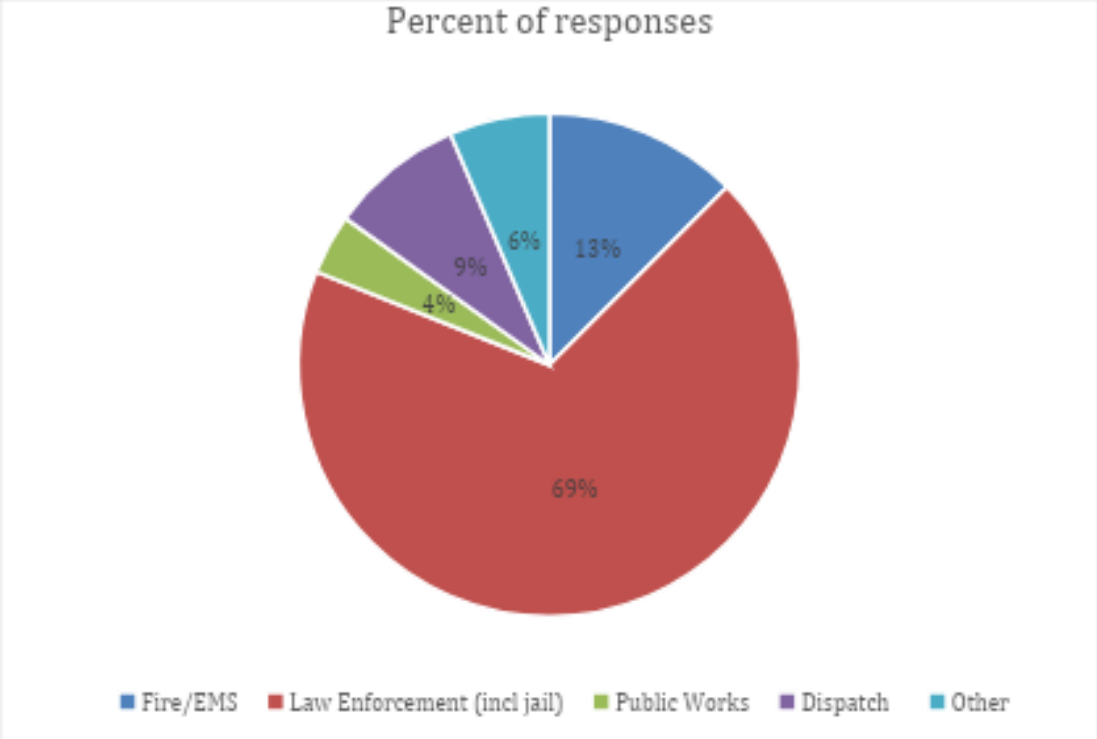
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5.1 User Interview Process

The user interview process was conducted using an online survey as well as in person interviews.

5.1.1 Online Survey

All project stakeholders were invited to complete the online TUSA survey, and we received 232 responses. As depicted in the chart below, most of the responses were from law enforcement (which includes corrections/jail).



Interview responses by agency

5.1.2 In Person Interviews

User interviews were conducted onsite and primarily at the Emergency Operations Center (EOC) on June 24th and 25th. During this period, members representing the following agencies attended interviews:

- Department heads (including EOC)
- Sheriff
- Local Law Enforcement
- Fire and EMS
- Dispatchers
- Road and Bridges and other county radio users

TUSA and these users/project stakeholders spent time discussing key issues that the respective users had with the current system as well as taking input each had on what they would like to see in the new system. These were small, highly interactive sessions which provided TUSA with a solid understanding of the current system.

5.2 Identified User Needs

The results of the online questionnaire and user interviews can be summed up into the following categories and priorities:

- Coverage
- Audio Quality
- Interoperability
- Training

The results of the online interviewing process was summarized and revealed the following,

- 71% reported the current system to be reliable when good coverage is available.
- 12% reported the current system to be unreliable, and while most of these responses were from law enforcement, Fire/EMS provided a proportionately equivalent number of reports of unreliability.
- Motorola hardware (XTS and APX) are used extensively and work well.
- Commonly reported concerns include:
    - Coverage in specific parts of the county
    - Coverage within buildings
    - Presence of static and unclear audio
    - Conflicts in using a channel (key ups, beeps, others talking, wait time)

- Channel limitations
- Interoperability among agencies and within the jail

The results of the in person intervening process is outlined in the following table.

Current System Likes	Current System Dislikes
Simplicity / Ease of Use	Coverage – mobile and portable devices have poor coverage in rural areas.
Encrypted channels available - supports citizen privacy and officer safety.	Dead zones - Mitigation via changing channels: may result in dispatch being out of the loop
Separate channel for paging - supports simultaneous dispatching.	Dispatch cannot monitor “state interop” fire ground channels.
Channel differentiation for agencies – avoid stepping on each other.	The Jail has dead spots, cross communication issues, penetration issues, feedback issues, and lack of communication at the sally port
Backup channels are open for special events as well as tactical needs	Transmission issues due to metal buildings and those with large concrete walls
The Motorola APX portables are reliable.	Interoperability - Difficulty communicating with adjacent counties
Portable Battery life is acceptable.	The quantity of channels is insufficient for large events. For example, the recent tornados.
P25 improved communication with Columbia County’s P25 digital VHF.	Lack of encryption for Fire/EMS.

	During the recent tornado, Clearview had no connection to the rest of the county.
	Radio training is minimal / insufficient - Fire needs to better trained/understand nomenclature.
	Lack of standardization - There are different processes and systems that hinder communications.
	FCC license concerns by the prior radio administrator. Are all the licenses current and available for all frequencies used in the county.

User likes and dislikes of the current system

5.2.1 User Interviews Summary

Coverage is the primary concern for nearly all users on the current system. Users stated that in-building coverage is highly problematic to nonexistent. There are dead areas and roads throughout the county where radio communications are not possible. Users repeatedly stated the lack of communications with dispatch is very dangerous and creates an officer safety issue.

Users commented often about interoperability and the ability to talk to surrounding county agencies, as well as other agencies such the Wisconsin State Patrol. There are concerts about communications with other agencies within the county, especially during emergency events.

5.2.2 Training

During the user interviews, personnel brought up training concerns. These concerns were not just how to use a radio, but the processes within dispatch and throughout the county. There is a desire to have more consistency to the radio communication protocols. Refer to section 2.1 Mutual Aid Summary.

6 Radio Technology Available Today

To fully understand the pros and cons of the various options available to Dodge County and its users, it is important to recognize the benefits and limitations presented by the technologies available today. The following is a brief overview of these technologies. This overview in no way attempts to touch on all the aspects of any of these technologies, but instead focuses on the features and limitations of each that directly relate to the County's situation.

The discussion also touches on the differences between analog and digital systems, as well as aspects of proprietary systems versus systems based on open standards. In addition, included is an overview of system configurations alternatives available to support wide-area coverage desired, i.e., multisite, simulcast and hybrid systems.

6.1 Analog Vs. Digital Systems

Since the late 1930's, public safety radio communication has used analog Frequency Modulation (FM) almost exclusively as its wireless communications technology. Analog FM is inexpensive, robust, and provides good voice quality given reasonable signal levels. In terms of disadvantages, while FM's strong signal voice quality is good, the quality begins to degrade rather quickly as communication distance increases. As users move farther and farther from the main transmitter site, and signal levels drop, static and other noise factors steadily increase until finally the received signal is rendered unintelligible.



In many cases users operating within the outer reaches of coverage can communicate only with difficulty. This usually requires message repeats and results in misunderstood message intention. Furthermore, analog systems provide little security from eavesdroppers. Anyone with an inexpensive scanner can easily intercept and monitor the traffic on an analog system. Analog voice scramblers are available however, they are expensive, offer poor voice quality and are cumbersome to implement.

Digital communications systems first arrived on the public safety communications scene in the late 1980's. These initial systems were characterized by poor range and highly distorted voice audio; however, they were highly secure. In the past two and a half decades digital mobile radio technology has advanced to the point that voice clarity in digital systems rivals the best analog audio. Radio coverage of a digital system is equivalent to or exceeds that of a similar analog system. Furthermore, the static and noise that is typical in analog systems is dramatically reduced.

Digital systems provide significantly more voice security than analog systems. Voice encryption on a digital system is easy to implement, provides excellent voice quality, and is virtually impossible to crack. Digital systems represent the future of public safety communications. As an example, the FCC has allocated a new section of spectrum in the 700 MHz band exclusively for public safety use, designed for digital systems only. Analog systems will not be permitted to utilize this new spectrum.

For some counties, the cost of a digital system is daunting. TUSA is prepared to propose a conceptual solution that includes a conventional system with digital capable equipment that can be software upgraded at a time in the future to grow with the county should the budget be the deciding factor in moving forward into a new system.

6.2 Proprietary Vs. Open Standard Systems

Today's VHF system provides basic call capacity for various county users. This does not necessarily provide sufficient coverage and capacity needed by the users. At the start of the digital transformation of public safety radio, older trunked systems utilized proprietary signaling protocols in their design. Some of these proprietary systems are still manufactured today but are less desirable. Examples of such systems are Motorola SmartNet/SmartZone, Motorola Solutions MotoTRBO DMR, L3Harris Technologies EDACS, and L3Harris Technologies OpenSky. While these proprietary protocols do significantly increase functional capabilities, they do so at the expense of intersystem interoperability and competition. In general, users with equipment from different vendors cannot directly communicate on the same digital system, and interoperability between them depends upon dispatcher relaying, console patches, or inter-system bridges. In terms of competition, if a system owner needs to expand or replace equipment in a proprietary system, the owner's procurement options are limited to one, or at most, two very limited number of vendors. Historically, this has resulted in a significant increase in the cost of a system over its lifetime.

All trunking systems initially developed and deployed for the public safety market, were proprietary. An agency that purchased a trunking system from one vendor would be stuck with that vendor for the life cycle of the system. That agency also was forced to buy user equipment (mobile and portable subscribers) from that same vendor at a cost that was not always very competitive. If a neighboring agency purchased a system from a different vendor, direct interoperability/roaming between the two was difficult at best. To address these and other issues, APCO, in concert with representatives of the Federal government and radio equipment manufacturers, have been working for more than two decades to develop a suite of open standards defining nearly all the technical specifications needed to build systems that can meet

the functional requirements of public safety communications yet not limit interoperability or competition. This suite of open standards is known collectively as Project 25 (P25).

While still evolving, sufficient progress has been made such that P25 compliant systems and user equipment are available today from multiple vendors. If adjacent jurisdictions or counties were to purchase P25 compliant systems from different vendors, user radios if properly programmed would be able to communicate directly with each other and on other P25 system infrastructure. In addition, each agency would be free to purchase radios from any vendor providing P25 compliant equipment, based on required features and budget.

Multiple vendors also now provide multiband radio user equipment. The multiband radio allows communication on multiple frequency bands (VHF, UHF, 7/800) and protocols (analog, digital, P25). This creates an environment of innovation at a cost competitive advantage to the county from these multiple vendors.

It should be noted that many of the Federal public safety communications grants available in the past few years, and expectedly in the future, either explicitly define P25 systems and equipment as a requirement, or heavily favor applications from agencies defining P25 in their requests. An agency applying for such a grant based on proprietary, non-P25 technology would be at a significant disadvantage in the competition for the available funds.

Vendors that provide P25 equipment as of today are:

Infrastructure	User Equipment
JVC Kenwood (EF Johnson)	BK Technologies (Relm)
L3Harris Technologies	Icom
Motorola Solutions	JVC Kenwood (EF Johnson)
Tait Communications	L3Harris Technologies
	Motorola Solutions
	Tait Communications
*Vendors are listed in alphabetical order	

Current P25 Radio System Vendors

7 Options for Covering Large Geographic Areas

Wide area systems fill the need when an agency's radio coverage requirement exceeds that which is capable of being met by a limited number of tower sites. Simply adding tower sites will increase radio coverage but adding sites alone will not result in a cohesive public safety communications system.

What is needed is the capability for users operating on one site to communicate with the users operating on the others along with seamless switching between zones/channels/talkgroups when traveling in the service area. That capability is provided by wide-area technology. The industry has developed several approaches to accomplishing this task, three of which have emerged as leading coverage enhancement options. Those three approaches are Multisite Networks, Simulcast, and Hybrid Simulcast/Multisite Networks. For those unfamiliar with wide area voice system technology, the following provides a general overview and describes the pros and cons of each approach. The following illustrations, while hypothetical cases in themselves, are representative of how such options are often configured.

7.1 Multisite Networks

A multi-site network is composed of radio sites spread throughout a geographic area, each having its own set of radio frequencies. The image shown is an example of such a configuration.



To allow communication between users operating in different tower site coverage areas, a means must be provided so that calls within the coverage area of one tower site are retransmitted on another tower site or combination of sites. Such wide area communication is accomplished through an intelligent central "switch" that monitors the site activity of every operational radio unit in the system and dynamically connects users together as needed. A call using a frequency on one site is connected to the appropriate, but different frequency on another. When a call is placed, the central switch determines which sites and frequencies are available to be assigned for that call and temporarily connects them all together via leased lines or microwave circuits.

The key characteristic of this type of network is that a separate set of radio frequencies (channels) is needed at each site. Because inter-site interference is not an issue, site placement

is much less critical for a multisite network, compared to a simulcast system. In addition, a multisite network is extremely robust from the standpoint of reliability. In the event of a failure of one or more of the inter-site links, a simulcast site must operate with reduced capacity. A multisite network can continue to operate at full capacity in the event of such a failure, although with reduced wide area coverage capability. The technical requirements for the communication links connecting the sites are also less critical than for simulcast systems, which can result in lower system implementation and operating cost.

While a primary strength in one regard, the requirement for separate frequency sets for each tower site is also a multisite network's primary weakness. The frequencies available for public safety use are extremely limited. The availability of frequencies can effectively block a multisite system's capability for future expansion, in terms of either coverage or capacity. If additional frequencies cannot be made available, additional sites cannot be added to an existing multisite network to increase its coverage.

Capacity expansion is further constrained by frequency availability as capacity expansion usually requires adding channels to multiple sites in the network. In order to prevent dropped or missed calls, the quantity of channels at each site must be high enough to handle all of the calls that the central switch may route to that site at any instant.

Another issue to consider is the effect of transitioning from one site to another when traveling throughout the service area. Site transitioning influences the apparent coverage performance of a multisite network. In order to ensure that coverage within the required service area is contiguous, the coverage from adjacent sites must overlap each other. As users travel in these overlapping coverage areas, the radio must determine which site provides the strongest signal at that specific location and transition to the stronger site's operating frequencies. This transition is not instantaneous. To prevent missed calls due to excessive transitioning between sites, the transition to the stronger site is delayed until the signal difference between the current site and the new site exceeds a specific signal difference threshold. The net result is that a user may not always be operating on the optimum site. From the user's perspective, system coverage can be sporadically less than expected.

7.2 Simulcast Technology

Like multisite, simulcast is a technology that increases coverage beyond that available from a single site by implementing multiple sites throughout the desired coverage area. Simulcast differs from a multisite configuration in that the same frequency set is used throughout a given system. With a simulcast system, a channel's associated transmitter at each site broadcasts the same information simultaneously on the same RF channel as the other sites, hence the name.

The primary advantage of a simulcast system over a multisite network is that simulcast increases coverage without increasing the number of channels necessary to support the system. Also, given the same site configuration, inbound coverage from subscriber units to the base stations is improved over multisite because of the diversity effect of multiple receiver sites monitoring the same inbound frequency, and outbound coverage is improved because there is no site transitioning effect to contend with. From the user's point of view a simulcast system operates exactly like a single site system. There are no zones or site transitions for the user to contend with.



However, because of multiple sites transmitting on the same frequency, each site's transmitted frequency, phase and timing must be precisely controlled to prevent destructive interference as signals transmitted from multiple sites overlap. This requirement to precisely control the output signals from each site to prevent destructive time delay interference (TDI) makes the implementation and long-term support of a simulcast system more complex and costly than for a multisite network. This disadvantage also places constraints on a simulcast system's site placement. With the Industry's adoption of linear-simulcast base station technology (vs. non-linear simulcast), the design of a simulcast is much easier to accomplish with its more relaxed TDI constraints.

A simulcast radio system also requires highly stable and reliable inter-site connectivity. If inter-site connectivity is lost in a simulcast system, the affected sites will operate as stand-alone sites with severely limited capacity. This requirement for reliability and stability can usually only be met by a dedicated microwave or fiber optic sub-system. Currently leased circuits, even leased fiber, are not recommended for simulcast, and some vendors will not support simulcast

systems utilizing them. From the standpoint of reliability, microwave networks have proven to be far more reliable and robust than leased circuits in the face of severe storms.

7.3 Hybrid Simulcast/Multi Site Configurations

The final wide area system configuration one might consider is a hybrid design using a combination of multisite and simulcast technologies. This system configuration consists of several simulcast sub-systems, or "cells" connected in a larger multisite network. From the standpoint of the multisite network, each simulcast cell looks like a single site, but each of these cells has significantly greater coverage than is possible from a single site. This design can provide a system solution when the geographic area is too large to be accommodated by a single simulcast system, and frequency constraints preclude a purely multisite network approach.



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8 Available Wireless Data System Configurations

The following section provides an overview of the various wireless data options currently available to field users.

8.1 Commercial Wireless Data

Current public safety wireless data requirements are being met almost entirely by commercial wireless carriers. The initial deployments of commercial wireless data provided only moderate data rates and spotty coverage which is still true in most areas. Within the past several years, however, commercial system data rates have dramatically improved. Commercial wireless carriers are currently implementing improvements to their systems to provide significantly increased data speeds compared to services available only a few years ago.

As an example, AT&T, Verizon, Sprint, and T-Mobile have constructed high-speed downlink packet access (HSDPA) sometimes known as 4G, with initial deployments providing peak rates in excess of 1 Mb/s and theoretical peak rates of 14 Mb/s. While performance is good and getting better, it is important to remember that these systems are still commercial networks. They are not hardened to withstand severe storms and long periods without commercial power. In addition, public safety users do not receive priority over private subscribers. Experience proves that these systems quickly overload and are rendered essentially useless during and immediately after a natural disaster such as a hurricane.

The bottom line is that a commercial wireless data solution cannot be counted on to provide reliable public safety/mission critical service in an emergency situation. While commercial systems can provide economical high-capacity mobile data connectivity on a routine basis, public safety agencies should have plans in place to deal with inevitable service outages.

8.2 Private Narrowband Wireless Data

A private narrowband data system provides data connectivity over narrow bandwidth RF channels that are primarily meant for voice service. These systems can provide good geographic coverage, but the narrow bandwidth limits data throughput. Such systems normally provide data throughput rates measured in thousands of bits per second instead of the hundreds of thousands of bits per second or more that a commercial data network can provide. The primary advantage of such a system is that it can be designed to public safety reliability standards. In addition, user access can be strictly controlled, reducing the possibility of system overload during emergency situations. In short, while the data throughput of a narrowband data system

cannot match that of a commercial system, it is far more likely to be available when needed most.

8.3 Private Broadband Wireless Data

Private broadband data systems operate on frequencies that have channel bandwidths measured in Megahertz. As such, they are capable of very high data throughput, but only over a very small area. Typically, these operate in the 900MHz, 2.4, 4.9, and 5GHz bands and utilize an access point model similar to Wi-Fi networks in their design. Because each access point only provides coverage over a small area, it would be extremely costly to cover an area the size of the service area with broadband wireless.

Instead, a more practical approach would be to provide access points at strategic locations throughout the service area to form high speed wireless "hotspots". This high-speed connectivity would then be available to users when they come within range of a hot spot, allowing them to access the central network and perform functions that require very high speed, such as updating local databases or uploading reports. Outside of the range of hotspots, users would have to rely on other means of data connectivity, either commercial or private narrowband.

A limiting factor in the deployment of a network of hotspots is the cost and availability of high-speed data connections that are necessary to connect each hotspot to the primary network.

8.4 Data On The Trunked Voice Network

Many trunked voice systems, including EDACS, OpenSky, and P25 have the capability of providing data communication using the voice network. This approach is called trunked data. It has the dual advantage of not requiring the implementation of a separate data infrastructure, and the data network inherits the same reliability as the voice network. The disadvantages are that a certain amount of voice capacity must be sacrificed in order to support trunked data, and that the maximum data rate that this technology can support is quite low (9.6kb/s).

Typically, trunked data rates are measured in hundreds of bits per second, instead of the kilobits or megabits per second offered by other options. This slow throughput of trunked data cannot support the requirements of modern public safety applications and most users that relied on this approach in the past have abandoned it for other options that provide the required higher data rates. The technology is still applicable in certain niche applications such as GPS location,

over-the-air reprogramming/rekeying of radios, status reporting and short text message delivery.

8.5 Hybrid Wireless Data

Each of the previous data options has advantages and disadvantages. Commercial data options have high throughput, good coverage, but poor reliability. Narrowband data has good coverage and reliability, but only moderate throughput. Trunked data has high reliability and low cost, but low throughput, whereas broadband data has excellent throughput, reasonable reliability, but poor coverage. A hybrid data solution is a mixture of the available options configured to provide an acceptable system solution when a single technology cannot. This hybrid approach does significantly increase cost and complexity.

Unlike with a voice multisite/simulcast hybrid approach where the subscriber equipment is essentially unaffected and the additional complexity is in the infrastructure, a data hybrid solution pushes the complexity out to the subscribers. In addition to multiple infrastructure subsystems, the mobile subscriber equipment must also be equipped with multiple radio platforms as well as additional software applications to permit selection of the appropriate data provider, depending upon the immediate circumstances.

8.6 FirstNet/Broadband data

Growing rapidly is FirstNet, a nationwide LTE broadband network to support First Responders. In 2012, Congress passed the Middle-Class Job Creations Act, which authorizes the creation of the First Responder Network Authority. This independent authority within NTIA is able to provide emergency responders with the first nationwide, high-speed, broadband network dedicated to public safety.

The construction of the new network requires each state to have a Radio Access Network (RAN), and each state can choose whether they will allow FirstNet to build the RAN, or each state can opt out and build their own RAN.

FirstNet released its initial state plans on June 19, and the state of Kentucky has chosen to opt-in and will accept the FirstNet deployment plans. The new network will be built by AT&T. Part of the plan is to leverage AT&T's existing cellular network and give public safety priority on the network. At the present time it is difficult to predict how FirstNet will play out. AT&T is now challenging the definitions of what public safety grade is for networks. To complicate this more, on August 15, 2017, Verizon announced they will build their own dedicated public safety LTE core network as a viable option to FirstNet.

Currently, FirstNet is available for users to register their phones. However, state-by-state operational usage varies. There have been small test cases (flooding, hurricanes, etc.) that have allowed FirstNet to be utilized for data applications. In March of 2020, FirstNet announced their first PTT services for voice use. However, widespread voice use is still lacking due to infrastructure missing from sites such as generators and redundant network links.

TUSA offers coverage mapping services for all cellular networks including FirstNet should the county be interested in learning more about coverage from these types of networks.

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9 Methods for Enhancing Coverage Reliability

A radio system's portable radio coverage reliability can be extended through the use of devices designed to receive and retransmit signals, much like a repeater. These options are typically reserved for worst case environments, such as mountainous areas, or for very dense structures such as hospitals that commonly have radio penetration issues.

9.1 Digital Vehicular Repeater System (DVRS)

A cost-effective solution to improve portable RF coverage reliability within a given radio system/network is accomplished using a Digital Vehicular Repeater System (DVRS). A DVRS provides repeater capability between portable radios (portable radios being the most susceptible to coverage problems) and the RF infrastructure system (tower sites). This dramatically improves coverage by leveraging the large mobile coverage of a radio system and extending it to portable radios which would otherwise have reduced coverage reliability in some buildings and remote areas.

A DVRS accomplishes this "repeating" function by using two radio devices integrated together with a hardware controlling device. One of the radios would be programmed onto the host trunked radio system with the appropriate talk groups. The second radio (usually supplied with the repeater device) operates outside of the frequency range of the trunked radio system. Because of this, a DVRS would require approval and licensing from the FCC via the state frequency coordinator.

A DVRS can also be implemented as a repeater to target coverage in a particular geographic area or used with a vehicle to extend the range of a portable radio.

There can be difficult engineering problems to overcome with these types of systems. Anytime there are two DVRS at the same physical location, a protocol must be established so a portable radio doesn't activate two or more DVRS simultaneously and potentially causes self-interference between multiple DVRS units. Technology has improved with these devices to help mitigate this issue. Using VHF portable to talk to a VHF mobile repeater is referred to as an in-band repeater. This requires extensive and costly filtering to work successfully. By using a dual band radio, the portable can talk back to the mobile on the UHF band and then the mobile can talk to the repeater on VHF. This is more cost effective than using the VHF filtering on the mobile device.

9.2 Bi-directional Amplifier (BDA)

The Bi-Directional Amplifier (BDA) amplifies and repeats the radio system frequencies from a donor antenna located in an area where host coverage is available. The amplified signal is then repeated in or toward an area experiencing degraded coverage. Likewise, the signal from a subscriber radio is repeated back to the donor antenna which directs it back to the host infrastructure site(s).

An important difference between BDA and Digital Vehicular Repeater System (DVRS) equipment is that BDAs do not change the frequency of the signal. This simplifies the operation of the BDA; however, results have a major drawback in this design. Because both uplink/downlink antennas operate on the same frequencies within a BDA configuration, they must be separated/isolated by some type of shielding mechanism. The more physical separation between the antennas, the better their performance will be. Water towers/water tanks offer the best type of structure for installing outdoor BDAs. Because of the metal used in these structures, these antennas can be separated in such a way as to offer the most advantageous isolation. Other types of structures appropriate for outdoor BDA configurations are building structures where antennas can be installed on opposite sides of the structure, thereby creating a shielding/decoupling effect.

In general, BDAs are more expensive in VHF than in 7/800 MHz, a factor that must be considered when designing and selecting a public safety radio system. However, BDAs are almost always lower cost than building a new tower site should an isolated building or area need specific coverage.

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10 Project 25 ISSI-Key to User Roaming

As cities and counties in Wisconsin move forward with their deployments of APCO Project 25 radio systems, the groundwork is being set for user radio roaming. First, of course, radios in a given region or area must be capable of operation on P25 equipped infrastructures. New radios should be fully compatible with Project 25's Phase-1 (12.5 KHz FDMA) and Phase-2 (12.5 KHz, two-slot TDMA) functional and operable requirements. By doing so, user radios newly purchased will be fully compatible with future Phase-1 and Phase-2 rollouts and will experience significantly longer service lives than those having only Phase-1 capabilities.

While equipping users with P25 compliant equipment will potentially allow a user to communicate while traveling outside of their home area, this step alone will not allow radio users to communicate directly with radio users located in another jurisdiction. Such interoperability and seamless roaming require the establishment of Memorandums of Understanding (MOUs), regional radio governance and technical committees, development of flexible Talkgroup profiles, and the instantaneous and continuous connectivity of radio system controllers (called switches) throughout the various regions.

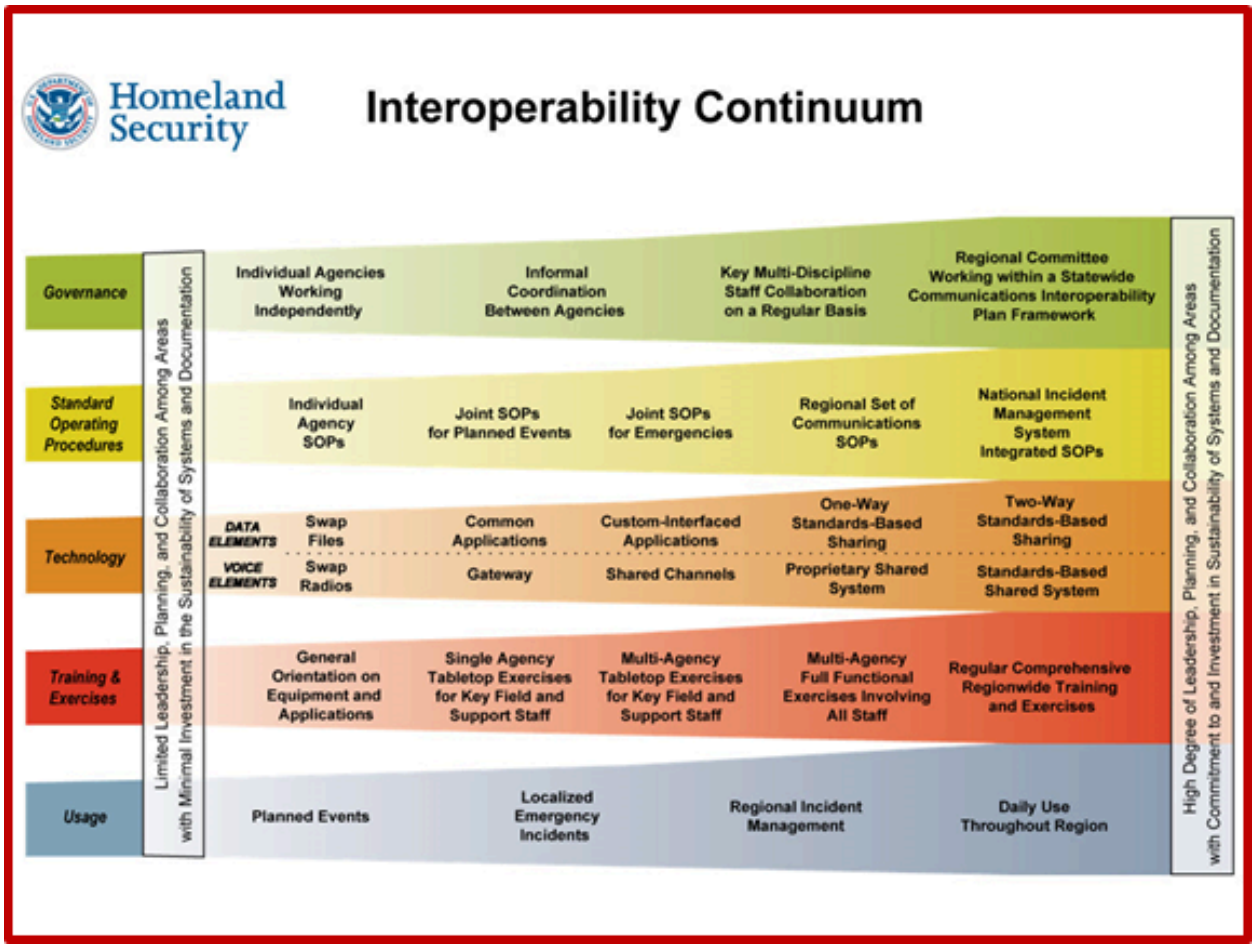
Prior to P25, connectivity standards between compliant radio systems did not exist. These standards exist today at a base level where user IDs, talk group and transaction audio can be instantaneously routed between radio systems. These new switch interoperability standards are termed: Inter RF Subsystem Interface (ISSI). Project 25 ISSI defines the types of functionality that can be supported between radio network/system switches. The ISSI P25 Standard is vendor neutral such that radio systems designed and deployed by competing radio vendors can support call interoperability and user roaming. This is an extremely important point as Project 25 would have otherwise failed its primary goal: open-architecture and elimination of proprietary solutions.

It is important to understand that ISSI is a functionality of the controllers/switches and gateways employed within the various deployed radio systems. All P25 cores/switches within a network that facilitates roaming must support ISSI or interoperability cannot occur via this method. Yet, nothing happens with respect to user roaming without a secure, reliable means for interconnecting the various radio system switches together and this is why an expanded microwave solution is so vitally important and bears consideration.

11 Interoperability/Roaming Considerations

Many states across the country, including Kansas, Ohio, Missouri, Louisiana, Mississippi, and other states have made great strides in improving public safety communications, interoperability, and user radio roaming.

Other interoperable solutions, of course, exist and those include swapping radios, gateways, shared channels, Nationwide mutual aid channels on VHF, UHF and 700/800MHz bands, and proprietary shared systems. The following illustrates the various recognized means for achieving interoperable communications:



Interoperability with the surrounding agencies can be done either by direct connection through ISSI equipment or by link radios for each channel that these groups operate on.

11.1 NPSPAC Mutual Aid System

Most public safety agencies in the State of Wisconsin who operate 800 MHz systems, or own subscriber units that operate on a participating Public Safety system, have access to the nationwide mutual aid channels generally referred to as the TAC (Tactical Communications) channels. These are five distinct 800MHz channel assignments that are designated for conventional analog communications in support of mutual aid operations and interoperable communications. These channels are generally set aside for 3 main categories:

- Day to Day Interoperability – Generally used during routine Public Safety operations such as accident scene response or other first response activity. Several area jurisdictions may respond to these types of calls. TAC channels are generally used so that Public Safety agencies may all use a designated common channel for communications during these routine events.
- Mutual Aid Disaster Response – Planned use of specified channels during joint response to major disasters that may exceed the resources of one specific agency. These events include possible terrorist activity, airplane crashes, bombings, large forest fires and other major events and acts of nature when the situation overwhelms local responses and outside support is requested.
- Task Force Interoperability involving state, local and/or federal agencies coming together for a period of time in response to major events such as sporting events, political rallies, or for investigations related to prolonged criminal activity.

The Association of Public-Safety Communication Officials (APCO) and the National Public Safety Telecommunication Council (NPSTC) have jointly developed a new ANSI (American National Standards Institute) Standard for Channel Naming for Public Safety Interoperability Channels. The standardization of mutual aid channels across the United States is important as it reduces confusion during mutual aid events and ensures uniformity.

NIFOG - National Interoperability Field Operations Guide link is available from a variety of public safety organizations.

12 Subscriber Radios

Public Safety users have stringent expectations for system reliability, radio coverage and audio quality. Interruptions in radio service availability and access are, in most cases, unacceptable. High-quality portable unit coverage is desired and necessary throughout the user-agency's geographic service area, both on-street and within buildings and automobiles. Delivered audio must be of the highest order of clarity with little background noise or radio static.

These requirements greatly exceed the needs of, for example, a commercial, radio-dispatched delivery service, but are essential to the mission of Public Safety departments. Unfortunately, increased performance leads to more complex and costly radio communication infrastructures.

Coverage reliability is enhanced through proper consideration of environmental losses, building losses and other user configuration factors. For example, it has been found that in-vehicle propagation losses may be 6 to 10 times higher than those encountered on-street. Portable radios operated at hip-level (by speaker/ microphones) are subjected to additional body losses which may be 8 to 10 times higher when compared to utilizing the same radio at head level. Building propagation losses vary widely due to location (densely packed structures are affected by shading losses) and construction materials, further aggravating portable radio operations.

The following illustrates the propagation losses at VHF that must be overcome by virtue of tower site placement and antenna configurations for typical geographic settings:

Environment	Category	Environment Loss dB
Water	Lakes	0
Snow & Ice	Snow Pack	0
Wetland	Non-forested	3
Open Land	Bare Land	5
Range Land	Herbaceous	3
Transportation	Roadways	3
Agricultural	Grassland	5
Residential	Suburban	10
Forest	Pine greater than 30 ft	15-21
Mixed Urban/Buildings	Apartments less than 4 stories	15
Commercial/Industrial	Commercial Services	19
High Density Urban	Skyscrapers	28

Environmental Propagation Losses for VHF

How users intend to operate radio communications systems and equipment likewise has a profound impact on infrastructure design configurations. Public Safety systems are optimized for the user group having the most stringent operational requirements, which automatically provides an enhanced performance margin to those groups having lesser needs.

To illustrate this point, consider that firemen utilize insulated “turn-out” gear due to the high heat and water encountered during fire-fighting incidents. Radios are usually placed within these coats and so the antenna is shielded or in contact with water-soaked fabric material. This naturally adds to signal loss. Police officers usually carry their radio in a belt holster. Thus, when inside an automotive vehicle, the radio is often jammed into the seat, with the antenna in contact with a fabric surface of some type and the radio is enveloped within the vehicle’s steel framework. So, in that instance, the additional propagation losses due to the vehicle’s local environment can be in the order of 8dB to upwards of 15dB in some cases.

For a radio system to meet an agency’s coverage expectations, these types of configurations and losses must be properly considered during the project’s design stage. A principal advantage of P25 technology is that radios are designed to an open standard, but what means is there to ensure where radios bought from multiple sources will, in fact, work on a host radio system?

Fortunately, this aspect as considered by EIA/TIA when developing the P25 standards and a means for compliance testing has been established. Multiple independent testing facilities have been certified by EIA/TIA as having the appropriate test equipment and expertise to accurately assess how closely vendor radios comply with P25 standards. Vendors routinely publish compliance testing statistics for manufactured radios whereby knowledgeable parties can determine if proposed products appropriately conform to P25 Industry standards.

Public Safety manufacturers are also providing mobile and portable radios with capabilities and convergence to use broadband LTE technology to supplement coverage outside the LMR restrictions of the FCC and a state’s RPC (Regional Planning Committee), as well as higher level of data requirements being realized by public safety agencies.

It is important to note that broadband networks are not built to the same standards as public safety LMR networks and cannot always be relied upon in catastrophic weather events for a multitude of reasons, such as backup power, connectivity, or the necessary capacity during a busy event.

13 Conceptual System Designs

This section focuses on providing conceptual design information aimed at addressing coverage and interoperability shortfalls along with expectations derived from interviews with county radio user agencies. TUSA considered the following when evaluating potential tower site placement solutions for next-generation conventional and trunked radio system configurations.

- The primary design goal was to achieve reliable on the street mobile radio coverage within the County.
- Balanced talk-out/talk-in coverage required, with a bias toward talk-in performance;
- Location of tower sites would focus on county-provided critical building/area locations;
- The minimally allowed delivered audio quality is TSB-88's defined DAQ 3.4 for a portable on the hip & DAQ 4.0 for mobile.;
- Construction of licensed microwave backhaul equipment.
- Reuse of existing County tower sites, if possible, to support a seamless parallel implementation.

TUSA developed coverage map overlays utilizing Google Earth. By doing so, Dodge County personnel can more readily evaluate and consider predicted coverage based on critical building locations and look through the County to identify any areas of concern.

13.1 Desired User Requirements

Throughout the interview sessions the same themes took root. The current system provides marginal portable coverage, minimal to no coverage in the buildings, and interoperability challenges both within and outside of the county. Any conceptual configuration design should thoroughly address coverage and interoperability concerns.

The following are the desired requirements that were defined by the users during the interview process. Based on the analysis completed to date, we identified the following features that a new system would need to support.

- Improved coverage
    - Improved county-wide coverage with portables
    - Improved coverage within the courthouse
    - Improved coverage within the jail, including the sally port and jail sergeant area

- More channels and system capacity, especially for specific events (event groups)
- Interoperability, especially during the transition period to any new system
    - Among agencies within Dodge County
    - Among agencies external to Dodge County
    - Compatibility with WISCOM
- Encryption
    - More encrypted channels, including for Fire/EMS
    - Change from current DES encryption to standard AES encryption
- Over the air rekeying
- Radio ID tags to identify users
- Backup / redundant equipment and radio towers
- Emergency button that works reliably
- GPS - valuable for dispatch, foot chases
- Resume Fire training program formerly sponsored by Dispatch
- CAD-to-CAD communications with county agencies
- MOUs for Mutual Aid / Support
- Ability to support increasing industrial base

13.2 Site Selection

The improvement approach used in developing the conceptual design was to identify candidate site locations, where needed, that would serve to improve each identified coverage-deficient area. These candidate sites were then compared to existing sites and determined which would best serve the needs of the county moving forward. In the iteration of coverage enhancements, identified improvement sites were added to yield the following configurations.

When defining candidate sites, TUSA kept in mind the various critical locations identified by the county, each of the sites depicted in the following maps provide for incremental increases in coverage reliability. Presumably, once a configuration has been decided upon, then TUSA would make available a composite using the final design, for a final concept configuration as part of an RFP specification for Dodge County.

13.3 Existing Equipment

After the visits to dispatch and the tower sites, it was revealed that parts of the county radio infrastructure are aging and well past end-of-life and the equipment has not been regularly maintained. Lack of regular preventive maintenance can lead to equipment not functioning optimally. End-of-life equipment can be difficult to repair and maintain, costing the county both time and money. A prevailing need for the county is to update/upgrade the aging technology to more modern, efficient, and better performing equipment.

13.4 Microwave Equipment Upgrade

TUSA reviewed the Cambium Networks PTP 820G microwave upgrade recently purchased by the county and has determined that it will support the modern P25 systems. This microwave operates in the 6GHz and 11GHz bands.

Currently the county microwave network is configured in a star configuration that has minimal redundancy. TUSA highly recommends a ring configuration that is much more tolerable to disruptions and increases resilience.

13.5 Presented Conceptual System Designs

The following conceptual system designs are presented in this report.

- Solution 1: Upgrade/refresh of the current VHF system
- Solution 2: Implement a stand alone 700/800 MHz radio system
- Solution 3: Partner with the WISCOM2 700/800 MHz Network
- Solution 4: Partner with the WiSPN 700/800 MHz Network

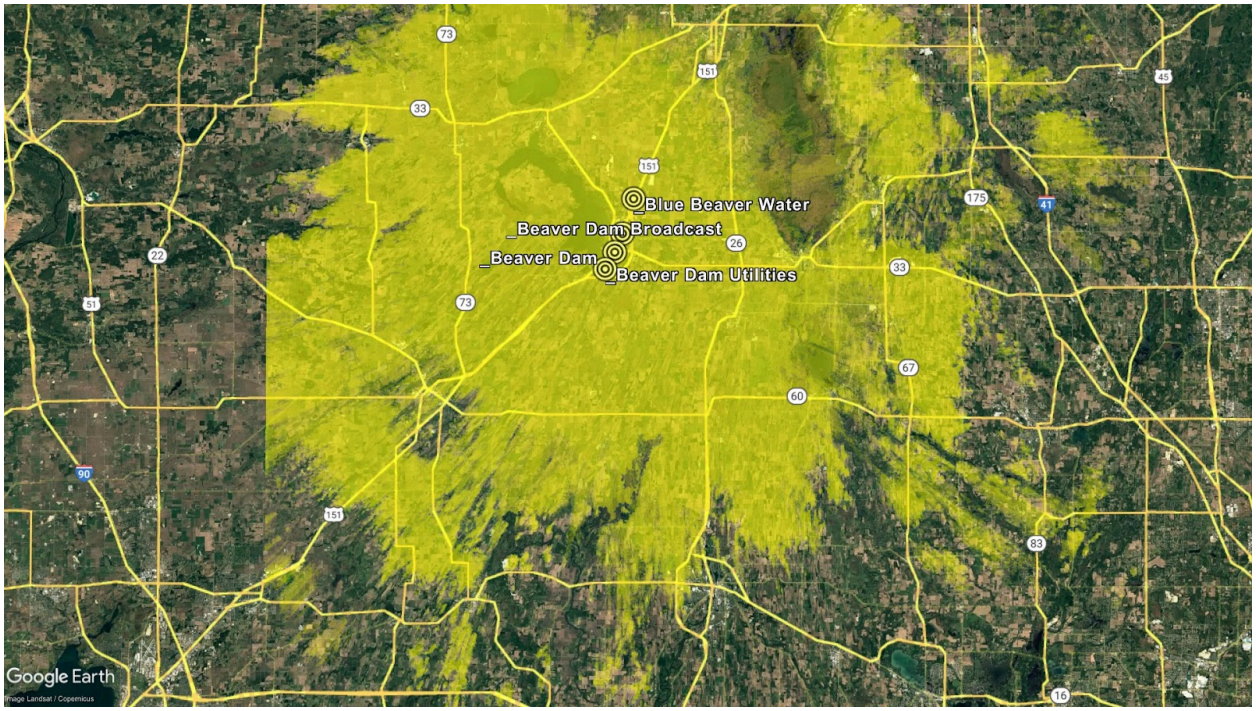
All of the proposed solutions include multiband radios to allow communications with agencies around Dodge County.

13.5.1 City of Beaver Dam, Horicon, and Mayville Coverage and Interoperability

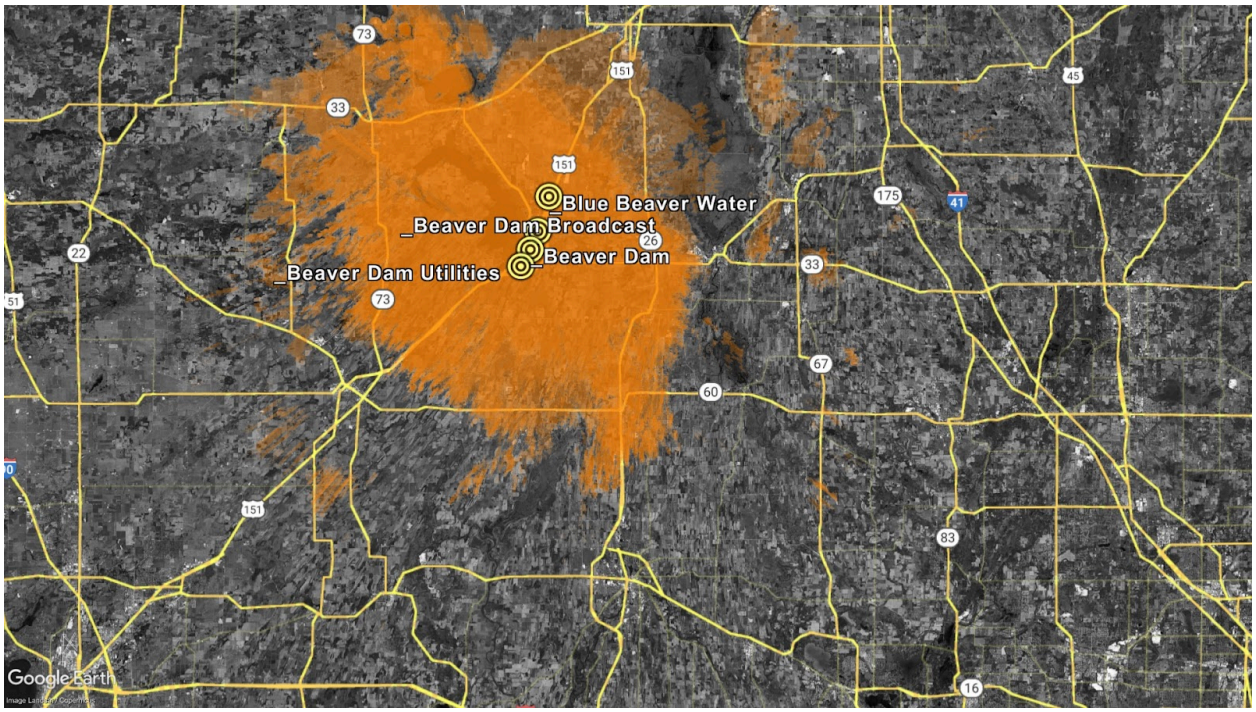
Consceptual designs two thru four incorporate a 700/800 Mhz system. This may create coverage concerns for Horicon, and Mayville based on challenges on the current system. Currently Horicon is using a UHF repeater to achieve coverage and there is a county VHF site in Mayville. These areas were considered as part of the 700/800 Mhz conceptual designs. This is reflected in the coverage maps shown in section 13.7.

The City of Beaver Dam is currently invested in a four site simulcast VHF infrastructure that will require interoperability with Dodge County. Interoperability between these two systems can be accomplished, but If the county chooses to proceed with a 700/800 Mhz system the City of Beaver Dam will only have coverage limited to the footprint of its VHF system. The city will no longer have the ability to rely on the current VHF footprint of the county wide system. This can be partly resolved by using multiband VHF/800MHz radios to allow communications on both systems. The following maps show the anticipated portable foot print of the Beaver Dam system. However, it's worth noting that all the issues described in the County infrastructure and VHF are most likely occurring with the Beaver Dam VHF radio system as well.

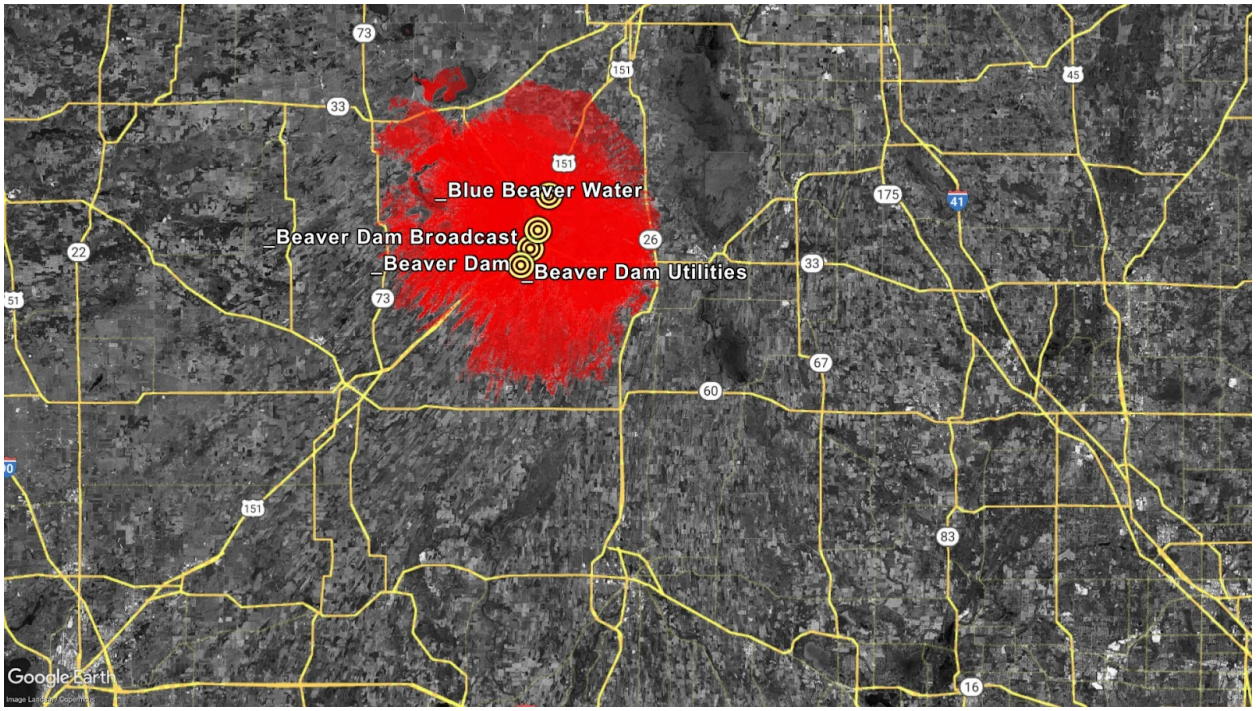
13.5.1.1 Beaver Dam – Anticipated Talk in Portables on-HIP/on-Street



13.5.2 Beaver Dam – Anticipated Talk in Portables Inside 10 dB Buildings



13.5.3 Beaver Dam – Talk in Portables Inside 200 dB Buildings



13.6 Solution 1: Upgrade and Rework of the Current VHF System

The intent of Solution 1 is to bring as much of the existing infrastructure up to date enhancing performance and capacity. It included upgrading the VHF channels at the tower sites to digital P25 conventional. The goal is to minimize the VHF noise by reducing the number of transmit sites and increasing receive only sites. There is still an abundance of VHF systems within and surrounding the county so the disadvantages of VHF will still be present. This solution would include the following.

- Reduce the number of transmit sites and increase the number of receive only sites. This should decrease both the VHF and simulcast noise.
- Upgrade all channels to digital P25 conventional to allow encryption and clearer communications.
- Add at least 2 additional channels to provide more user resources.
- Address the aging end-of-life equipment.
- Add shelters and commercial grade generators at the needed sites such as the water towers.
- Upgrading needed mobile and portables take advantage of the digital capabilities of P25.
- Add multiband trunked radios where needed to communicate with neighboring agencies.

The following identifies some of the pros and cons of solution 1.

Pros

- More channel capacity at each of the sites. This allows for improved communications during emergency events.
- Replace end of life equipment with current technology providing better system support and system reliability.
- P25 digital channels will help with portable coverage issues and allow for the use of AES encryption.
- Possible reuse of current VHF user equipment that supports P25 digital.

Cons

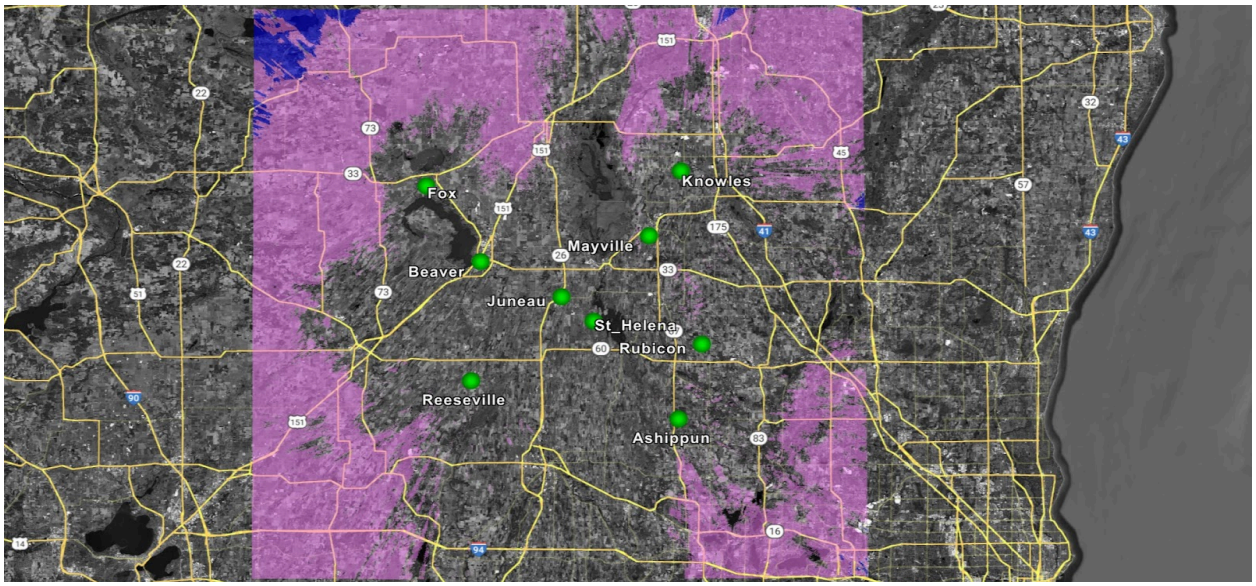
- Only replacing infrastructure and not significantly increasing coverage. This is due to the VHF noise and inability of a portable talking into the system.
- Removing transmit sites will help with VHF noise but the abundance of VHF used within and outside of the county will still contribute to the portable talk in issues.

- Not all user equipment is P25 digital and encryption capable and will have to be replaced.
- Operability issues will increase as neighboring counties move to 800/700 Mhz
- Multiband radios will have to be procured.

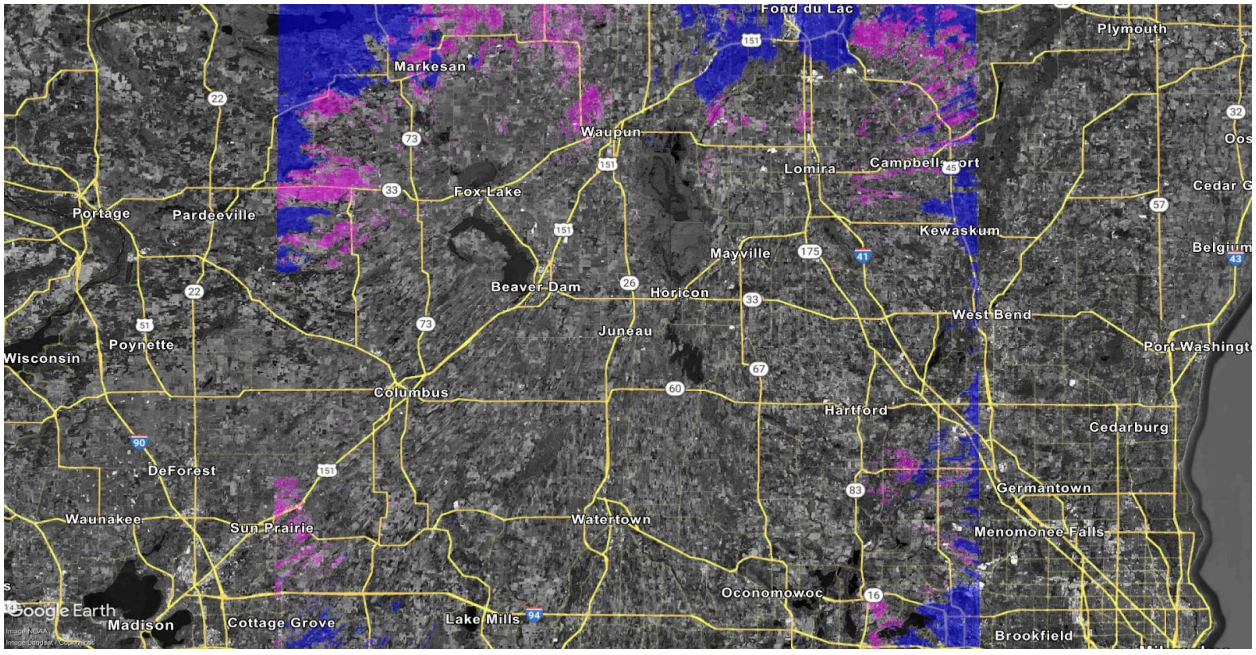
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13.6.1 Reduction of Self Induced Simulcast Noise (TDI)

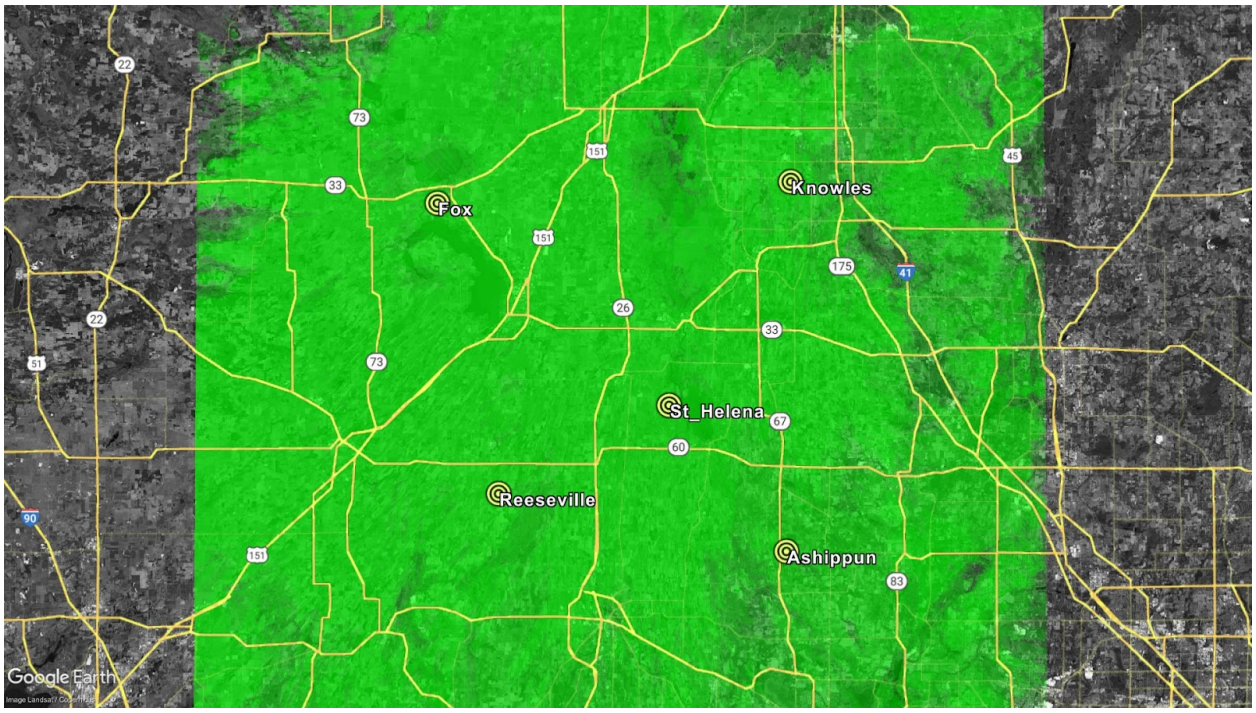
Reducing the number of transmit sites drastically decreases the level of self induced simulcast noise. The pink area on the following map shows the simulcast noise predicted from the current system configuration of 9 transmit sites.



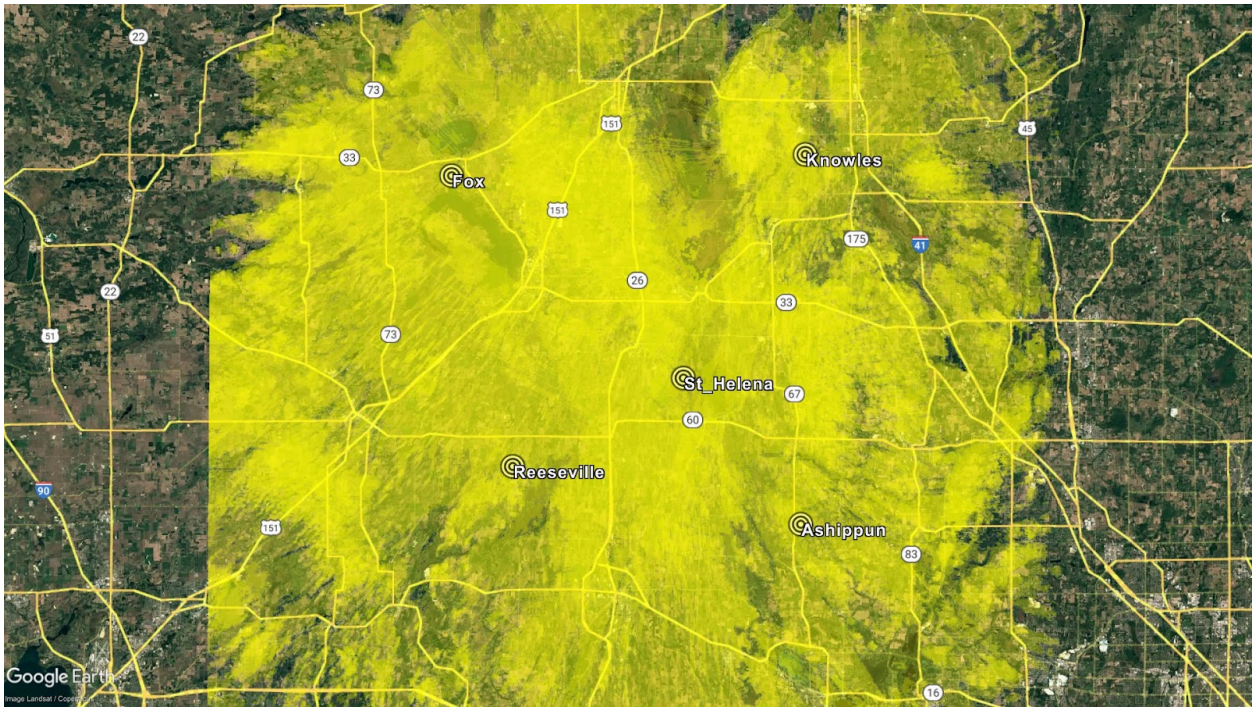
The next map shows the simulcast noise produced by decreasing the number of transmit sites to 5 and using the additional sites as receive only.



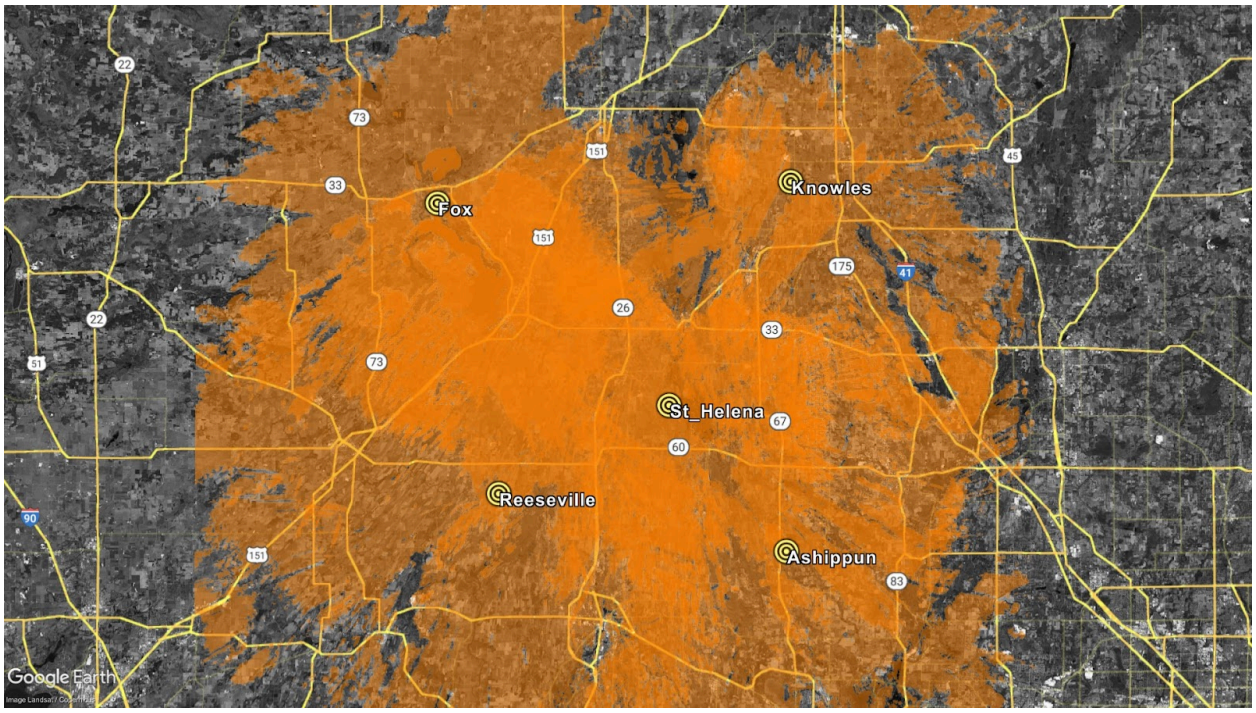
13.6.2 Coverage prediction – Talk in Mobiles



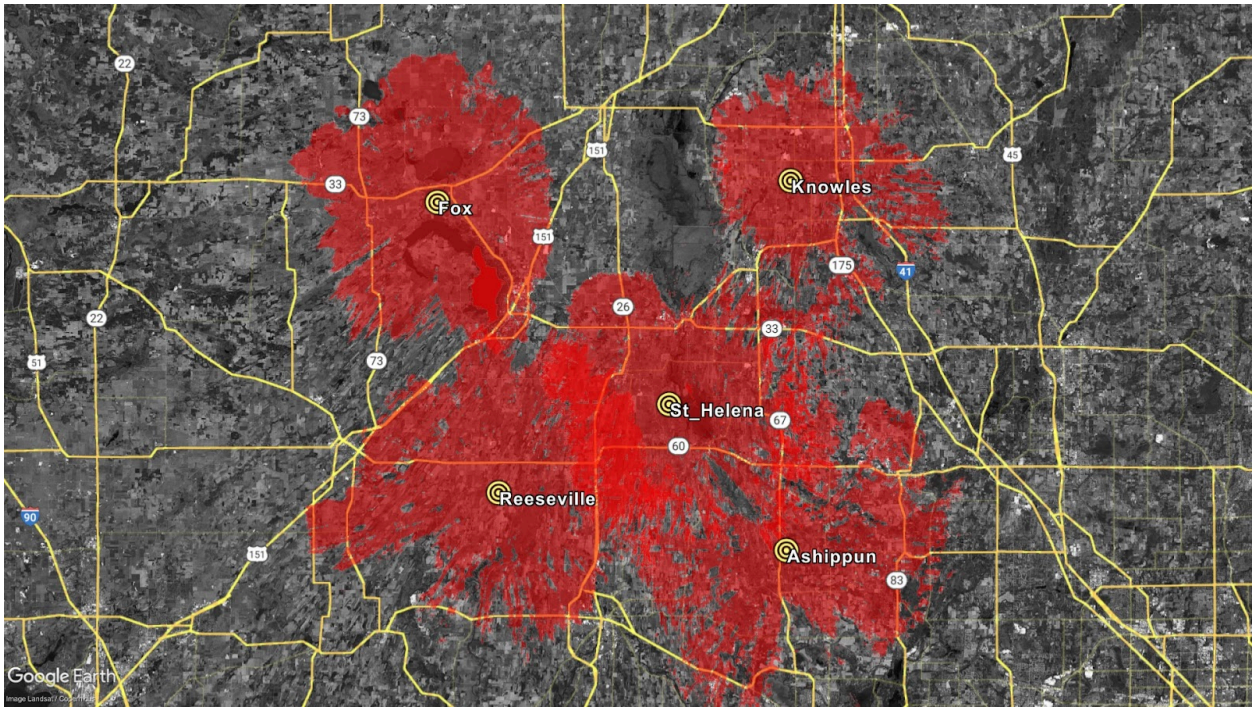
13.6.3 Coverage prediction – Talk in Portables on-HIP/on-Street



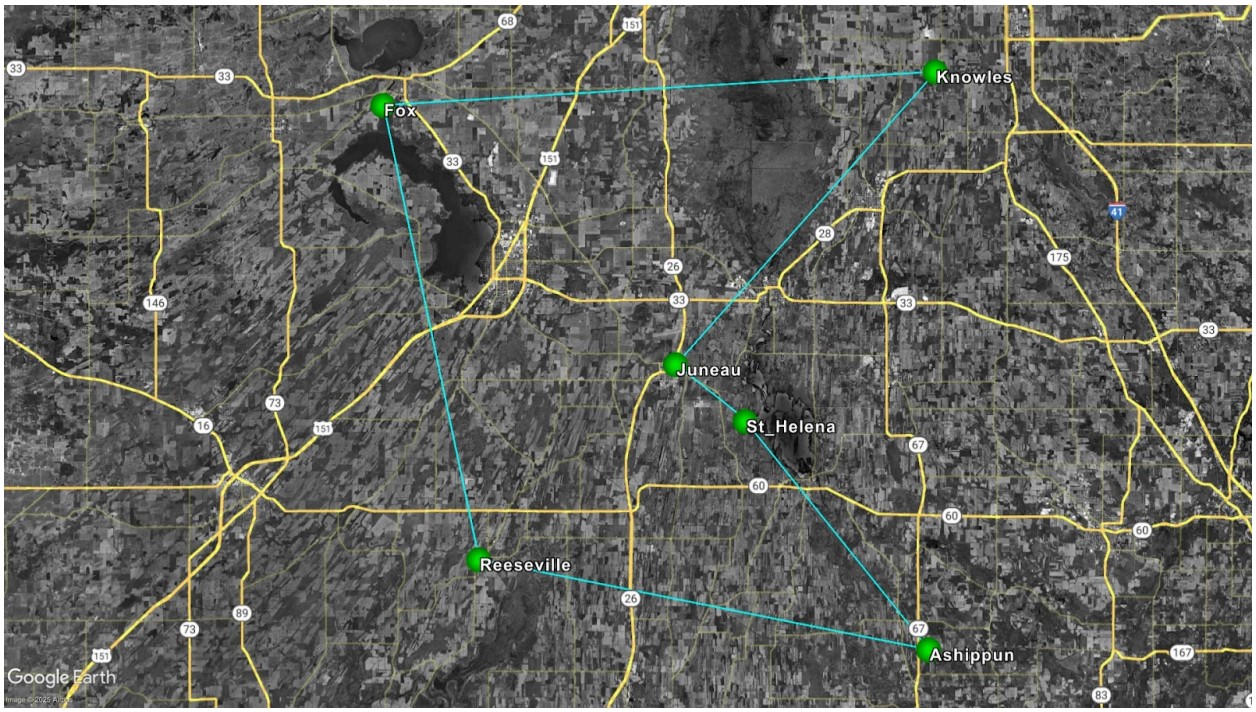
13.6.4 Coverage prediction – Talk in Portables Inside 10 dB Buildings



13.6.5 Coverage prediction – Talk in Portables Inside 20 dB Buildings



13.6.6 Conceptual Loop Microwave Network



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13.7 Solution 2: Implement a Stand Alone 700/800 MHz Radio System

Solution 2 is a modern stand alone 700/800MHz system. To achieve coverage in 10db buildings countywide 9 are needed. This is a much cleaner spectrum compared to VHF.

Pros

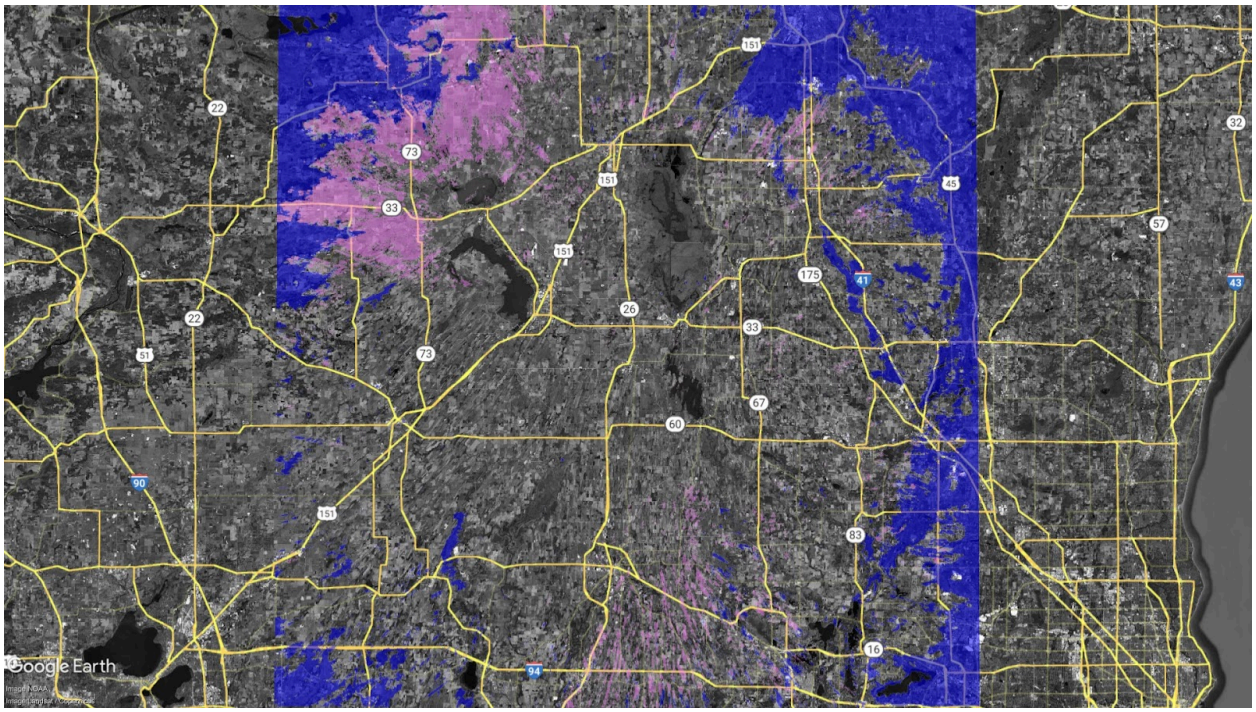
- The system is owned and operated by Dodge County.
- Reduce the number of sites to cover the county.
- Increased coverage inside of buildings.
- Better interoperability with neighboring 700/800MHz system
- Better interoperability with WISCOM and WiPSN

Cons

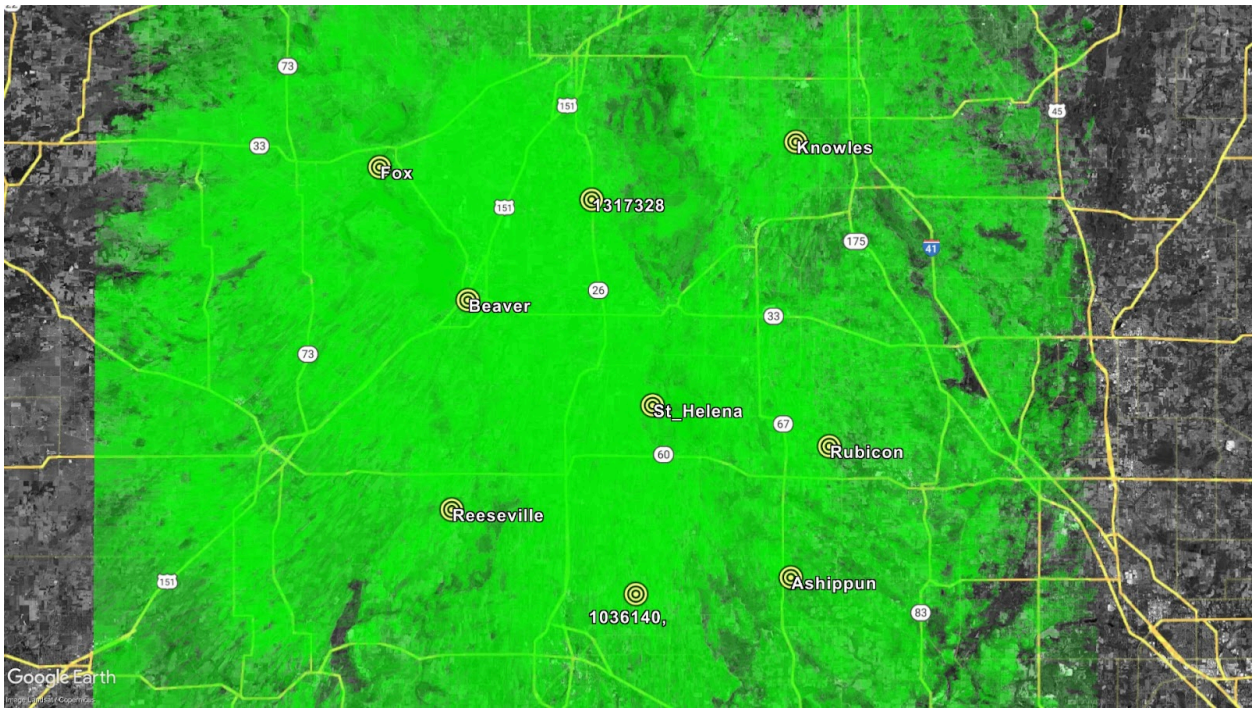
- Procurement of a new system is costly.
- All user equipment would have to be replaced.
- Will need multiband radios to communicate with surrounding agencies.
- May need to upgrade or build new towers.

13.7.1 Simulcast Time Delay Interference

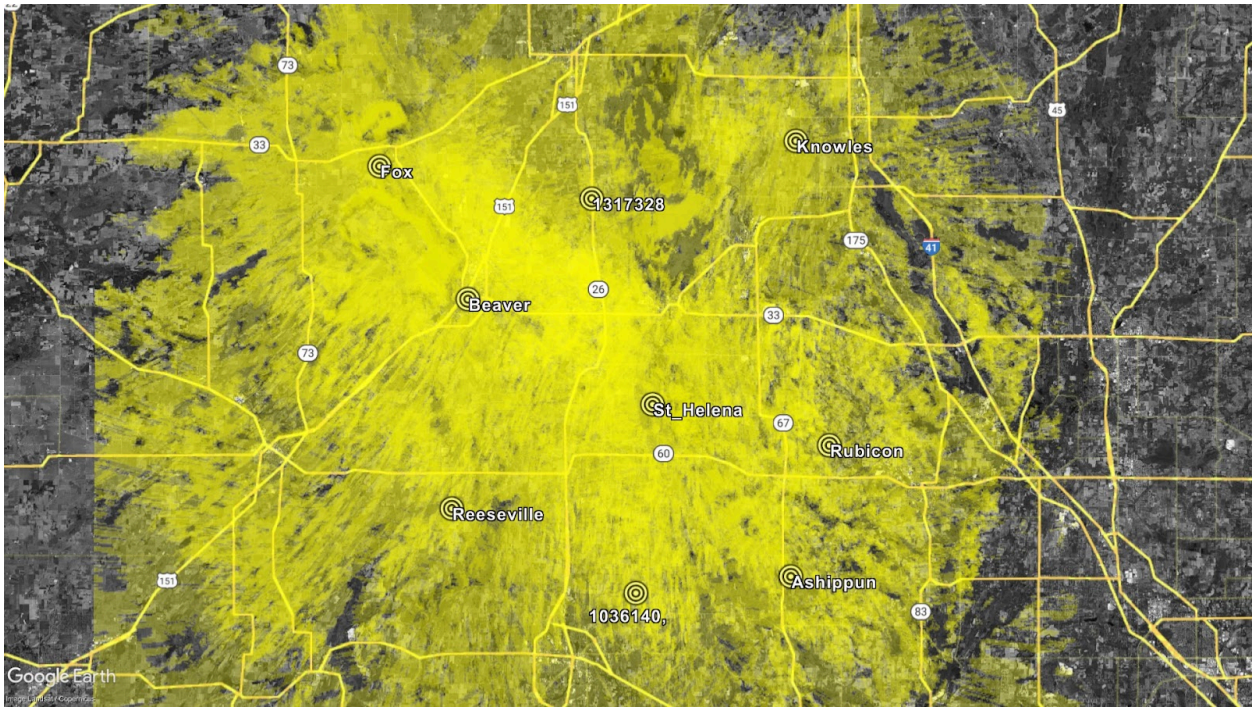
The simulcast interference for a 700/800 MHz solution is shown in pink.



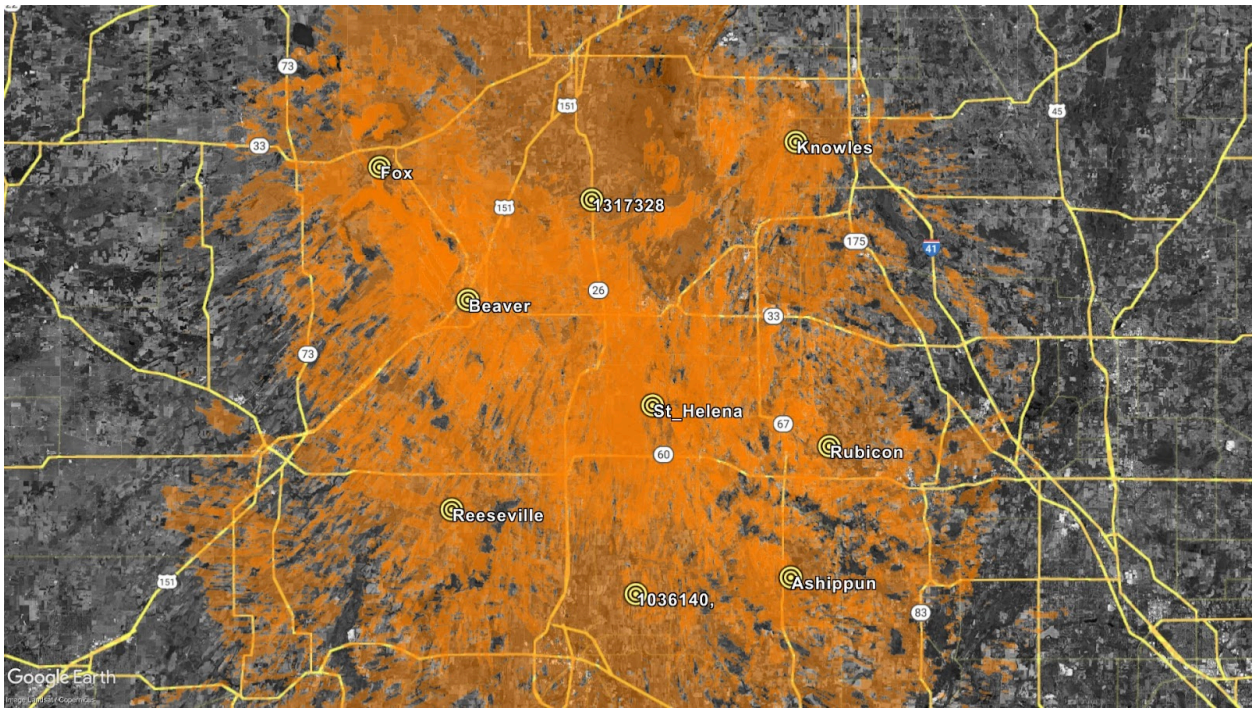
13.7.2 Coverage prediction – Talk in Mobiles



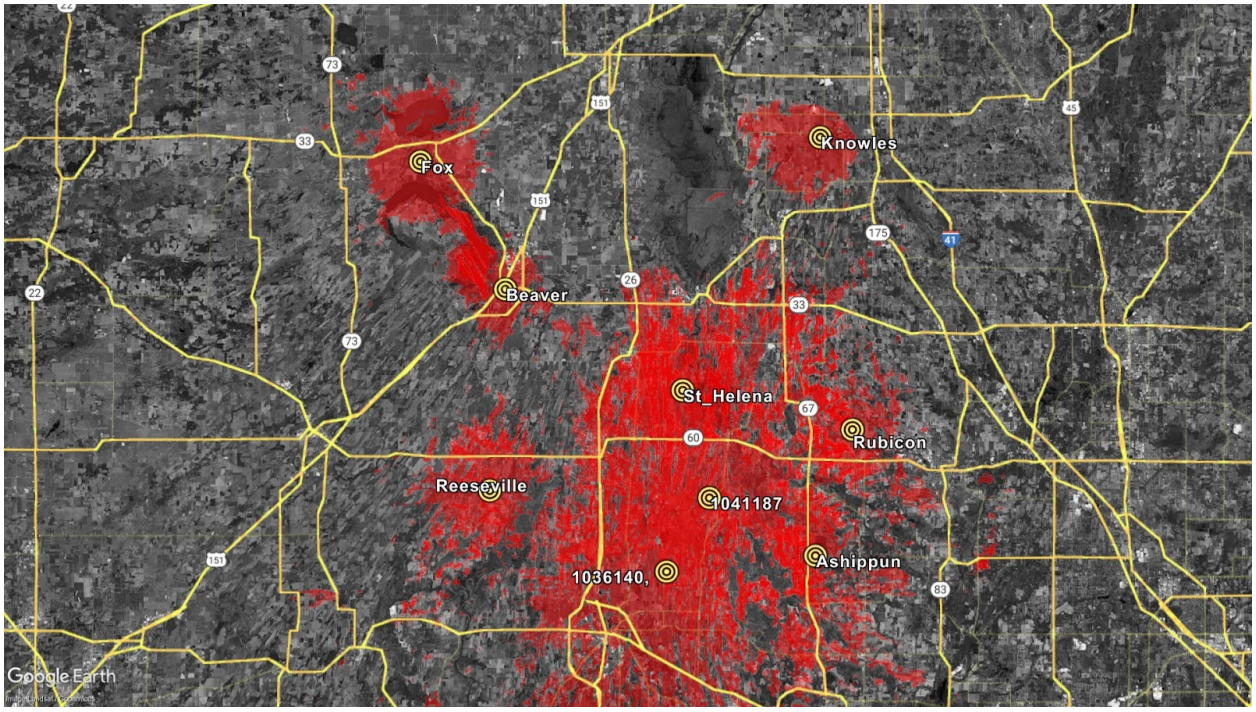
13.7.3 Coverage prediction – Talk in Portables on-HIP/on-Street



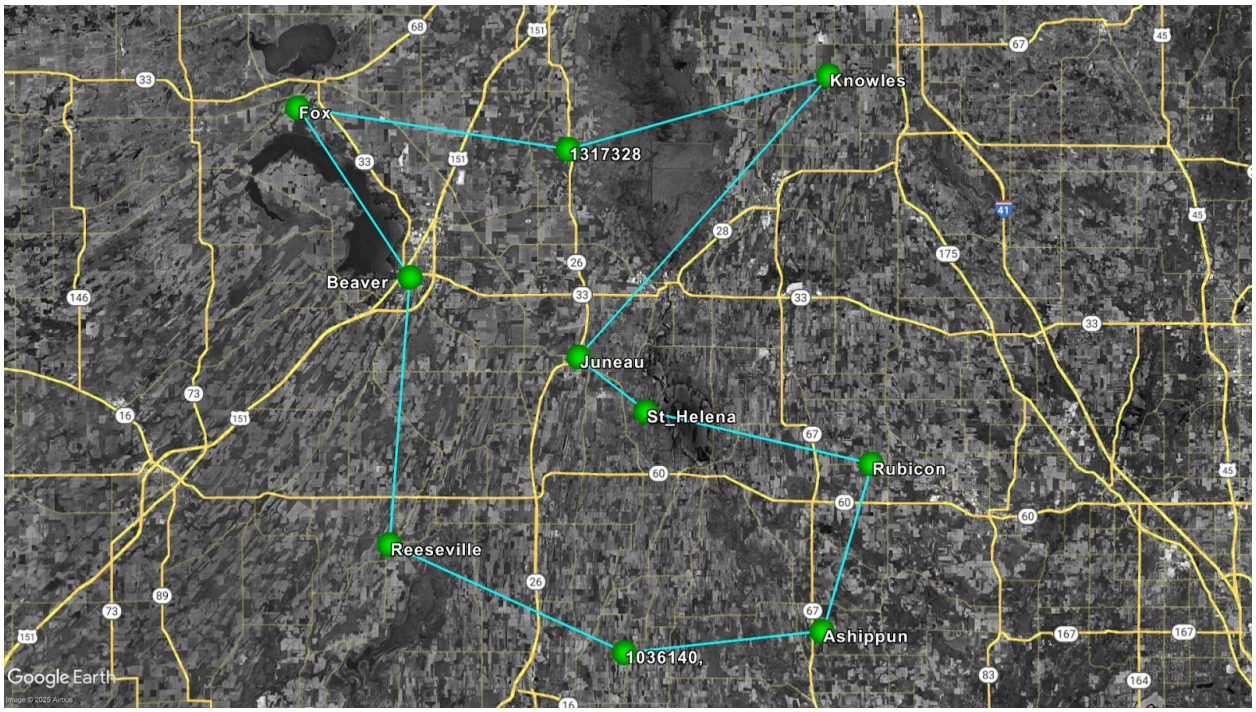
13.7.4 Coverage prediction – Talk in Portables Inside 10 dB Buildings



13.7.5 Coverage prediction – Talk in Portables Inside 20 dB Buildings



13.7.6 Conceptual Loop Microwave Network



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13.8 Solution 3: Partner with the WISCOM2 700/800 MHz Network

The Wisconsin Interoperable System for Communications (WISCOM2) is a statewide 700/800 MHz P25 system provided by L3HARRIS. This system will consist of 12 cores over 6 Regions. The County can leverage the cores of the WISCOM Network and take advantage of a statewide footprint. Sites, towers, and infrastructure will have to be built out to ensure portable coverage throughout the county. For coverage refer to the maps provided in Solution 2.

Pros

- The cost of purchasing and maintaining the core would be shared with the WISCOM system.
- Multiple cores throughout the state provide additional redundancy.
- There are state grants available for WISCOM upgrades.
- Coverage foot print can be extended statewide.
- Reduce the number of sites to cover the county.
- Increased coverage inside of buildings.
- Better interoperability with neighboring 700/800MHz system
- Better interoperability with WISCOM and WiSPN

Cons

- There will be a degree of control given to WISCOM.
- Procurement of a new system is costly.
- Console and backbone equipment will have to be replaced.
- All user equipment would have to be replaced.
- Will need multiband radios to communicate with surrounding agencies.

13.9 Solution 4: Partner with the WiSPN 700/800 MHz Network

The Wisconsin Public Safety Network (WiPSN) is a public-private Partnership operated by Motorola Solutions. It is a statewide 700/800 MHz P25 network. As with WISCOM the county can take advantage of shared cores and resources. Sites, towers, and infrastructure will have to be built out to ensure portable coverage throughout the county. Joining the WiSPN system is the current recommendation that has been proposed to the county by Baycom. For coverage refer to the maps provided in Solution 2.

Pros

- The cost of purchasing and maintaining the core would be shared with the WiPSN system.
- Coverage foot print can be extended to the WiPSN footprint.
- Reduce the number of sites to cover the county.
- Increased coverage inside of buildings.
- Better interoperability with neighboring 700/800MHz system
- Better interoperability with WISCOM2 and WiSPN
- May be able to reuse some console and backbone equipment.
- Not all user equipment would have to be replaced.

Cons

- There will be a degree of control given to WiPSN.
- Procurement of a new system is costly.
- Will need multiband radios to communicate with surrounding agencies.

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14 Conceptual Design Budgets

The following budgetary estimates are based on actual prices that TUSA has seen in recent RFPs with other clients. It takes into consideration cost results seen by other recent procurements throughout the country.

The budgetary estimates also look at the total cost of ownership over a 20-year anticipated lifecycle period. Often, a proposing vendor will discount the system on the front end, only to make up for it on the back end. TUSA looks at the entire life cycle of the system as proposed by responsive vendors, including maintenance and upkeep as part of the RFP specification process. This gives the county a 20 year total cost of ownership (TCO) or their radio communications system.

There are multiple options in today's procurement environment that the county can consider. These options typically are:

- Capital Outlay (CAPX): The county pays for the system and then budgets yearly for maintenance throughout the system life cycle.
- Leased Option (OPX): The County pays for the system over a defined period to include maintenance throughout the system life cycle.
- Service Option: The Vendor builds the network, and the county pays a monthly service fee over the lifecycle.
- State Plan: **WISCOM UPGRADES** *Governor: Provide $10,000,000 in 2025-26 for grants to local governments for public safety interoperable communication system upgrades. Under 2023 Act 19, an annual GPR appropriation was created under DMA to provide grants for public safety interoperable communication system upgrades, and $2,000,000 was placed in the Joint Committee on Finance's supplemental GPR appropriation in 2024-25. As of February, 2025, DMA has not requested the release of these funds. The Department indicates that it intends to do so before the end of 2024-25. The grant program was created to support the purchase of 7/800 MHz subscriber radios needed by local users to transition to the new public safety interoperable communication system currently under development (WISCOM 800). According to DMA, the total need for equipment replacement to facilitate the transition to WISCOM 800 is approximately $46,000,000*

14.1 Conceptual Budget Solution 1: Upgrade/Refresh Of The Current VHF System

The following conceptual budget shows the anticipated procurement for solution 1 in section 13.2. It also includes 20 years and maintenance and total cost of ownership (TCO) for 20 years.

The following should be noted.

- The VHF GTR repeater reaches end of life in 2034.
- Current MW being replaced but will require additional links for ring configuration.
- The MCC7500 Console reaches the end of Life in 2030.

14.1.1 Conceptual Budget Solution 1 – Budget summary

Pricing Summary - Conceptual Solution #1 - VHF Conventional P25	
Infrastructure Site Budget	
Description	**Total**
Voice Infrastructure	$4,442,500
Systems Integration	$1,377,175
Voice Infrastructure Total	**$5,819,675**
Site Construction	$2,225,000
Site Construction Contingency	$333,750
Site Construction Total	**$2,558,750**
Microwave	$2,430,000
Microwave System Integration	$753,300
Microwave Contingency	$243,000
Microwave Total	**$3,426,300**
Customer Dispatch Centers	$1,157,729
Dispatch Center Total	**$1,157,729**
Customer Subscribers	**$15,470,064**
Customer Grand Total	**$28,432,518**
Competitive Procurement Process	
Infrastructure	$8,853,544
Dispatch	$868,297
Subscribers	$12,376,051
Competitive Process Grand Total	**$22,097,892**

Maintenance Budget	
Description	**Total**
Competitive Process Grand Total	**$22,097,892**
Maintenance Services (2-5 yr plan)/Estimated	
Corrective Maintenance and Software/Hardware Maintenance	$763,628
Preventative Maintenance	$100,000
Subscriber Depot & Return	$300,960
Subscription Costs (ISSI & Broadband)	$300,000
Microwave Maintenance	incl
HVAC	$36,000
Generators	$43,200
Battery Plants & UPS	$36,000
Logging Recorder	$25,000
Year 2-5 Maintenance Services Plan Total	**$1,604,788**
Average Yearly Total	**$401,197**
Maintenance Services (6-10 yr plan)/Estimated	
Corrective Maintenance and Software/Hardware Maintenance	$1,015,625
Preventative Maintenance	$115,000
Subscriber Depot & Return	$508,800
Subscription Costs (ISSI & Broadband)	$431,250
Microwave Maintenance	incl
HVAC	$41,400
Generators	$49,680
Battery Plants & UPS	$41,400
Logging Recorder	$28,750
Year 6-10 Maintenance Services Plan Total	**$2,231,905**
Average Yearly Total	**$446,381**

Maintenance Services (11-15 yr plan)/Estimated		
Corrective Maintenance and Software/Hardware Maintenance		$1,167,969
Preventative Maintenance		$132,250
Subscriber Depot & Return		$636,000
Subscription Costs (ISSI & Broadband)		$495,938
Microwave Maintenance		incl
HVAC		$62,100
Generators		$74,520
Battery Plants & UPS		$47,610
Logging Recorder		$33,063
Year 11-15 Maintenance Services Plan Total		**$2,649,449**
	Average Yearly Total	**$529,890**
Maintenance Services (15-20 yr plan)/Estimated		
Corrective Maintenance and Software/Hardware Maintenance		$1,343,164
Preventative Maintenance		$152,088
Subscriber Depot & Return		$763,200
Subscription Costs (ISSI & Broadband)		$570,328
Microwave Maintenance		incl
HVAC		$93,150
Generators		$111,780
Battery Plants & UPS		$54,752
Logging Recorder		$38,022
Year 15-20 Maintenance Services Plan Total		**$3,126,484**
	Average Yearly Total	**$625,297**
Total Cost of Ownership 20 Years		**$31,710,517**

14.1.2 Conceptual Budget Solution 1 – Infrastructure Budget

Infrastructure Site Budget							
	Fox	**Knowles**	**St Helena**	**Reeseville**	**Ashippun**	**Juneau**	**Total**
5 site/7 channel P25 Conventional Simulcast						MW Only	
P25 Base Station	$385,000	$385,000	$385,000	$385,000	$385,000	$0	$1,925,000
P25 System Core	$750,000	$0	$0	$0	$0	$0	$750,000
P25 Georedundant Core	$0	$0	$0	$0	$0	$0	$0
Simulcast Control Point Eq.	$0		$385,000	$0	$0		$385,000
Rx Antenna System(antenna, multicoupler, T	$30,000	$30,000	$30,000	$30,000	$30,000		$150,000
Tx Antenna System (antenna, combiner)	$50,000	$50,000	$50,000	$50,000	$50,000		$250,000
Mutual Aid System	$0	$0	$0	$0	$0	$150,000	$150,000
Administrator Training	$0	$0	$0	$0	$0	$50,000	$50,000
Installation Services	$125,000	$125,000	$125,000	$125,000	$125,000	$100,000	$725,000
ISSI (one gateway) - WISCOM2		$0	$0	$0	$0	$0	$0
Broadband Gateway (100 user license)	$50,000	$0	$0	$0	$0	$7,500	$57,500
Voice Infrastructure Total	**$1,390,000**	**$590,000**	**$975,000**	**$590,000**	**$590,000**	**$307,500**	**$4,442,500**
Systems Integration							**$1,377,175**
Voice Infrastructure Grand Total							**$5,819,675**
Site Construction							
Shelter - Foundation	$0	$0	$0	$650,000	$0	$0	$650,000
Tower - Foundation	$0	$0	$0	$750,000	$0	$0	$750,000
Generator Subsystem	$0	$20,000	$20,000	$20,000	$20,000	$0	$80,000
DC Power System	$48,000	$48,000	$48,000	$48,000	$48,000	$25,000	$265,000
Site Development	$50,000	$50,000	$50,000	$20,000	$50,000	$20,000	$240,000
Site Upgrades / Water Tower Upgrades	$50,000	$50,000	$50,000	$20,000	$50,000	$20,000	$240,000
Site Construction Total	**$148,000**	**$168,000**	**$168,000**	**$1,508,000**	**$168,000**	**$65,000**	**$2,225,000**
Site Construction Contingency							**$333,750**
Site Construction Grand Total							**$2,558,750**
Microwave Backhaul							
Microwave Radio Equipment	$250,000	$250,000	$250,000	$250,000	$250,000	$250,000	$1,500,000
LAN/WAN Equipment	$35,000	$35,000	$35,000	$35,000	$35,000	$35,000	$210,000
DC Power System	$35,000	$35,000	$35,000	$35,000	$35,000	$35,000	$210,000
Antenna Systems	$45,000	$45,000	$45,000	$45,000	$45,000	$45,000	$270,000
Path Surveys	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$30,000
Installation Services	$35,000	$35,000	$35,000	$35,000	$35,000	$35,000	$210,000
Microwave Total	**$405,000**	**$405,000**	**$405,000**	**$405,000**	**$405,000**	**$405,000**	**$2,430,000**
Microwave Systems Integration							**$753,300**
Microwave Contingency							**$243,000**
Microwave Grand Total							**$3,426,300**
Site Infrastructure Grand Total							**$11,804,725**

14.1.3 Conceptual Budget Solution 1 - Dispatch Budget

Solution 1 - VHF Dispatch Budget		
	Dispatch	**Jail**
Dispatch Positions	6	1
Desktop	$480,000	$80,000
Microphone	$1,950	$325
Headset	$7,680	$1,280
Auxiliary Speaker (Qty. 4)	$4,200	$700
Backup Control Stations	$44,123	$7,354
Interoperability Control Stations (Multiband Qty.10)*	$44,118	
LAN/WAN	$35,000	
Radio Network Manager	$30,000	
Logging Recorder	$75,000	
Alarm Monitoring/Network Management	$100,000	
Installation Services	$168,000	$28,000
Training	$50,000	
Dispatch Equipment Total		**$1,157,729**

14.1.4 Conceptual Budget Solution 1 - Subscriber Budget

The subscriber budget is in section 14.5 Note: these budgets are based on documentation provided by the county.

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14.2 Conceptual Budget Solution 2: Implement a Stand Alone 700/800 MHz Radio System

The following conceptual budget shows the anticipated procurement for solution 2 in section 13.2. It also includes 20 years and maintenance and total cost of ownership (TCO) for 20 years.

14.2.1 Conceptual Budget Solution 2 – Budget Summary

Dodge County Conceptual Solution #2 - P25 System 7/800 MHz – Stand Alone P25 System	
Pricing Summary	
Description	**Total**
Voice Infrastructure	$12,175,390
Systems Integration	$3,774,371
Voice Infrastructure Total	**$15,949,761**
Site Construction	$6,957,000
Site Construction Contingency	$1,043,550
Site Construction Total	**$8,000,550**
Microwave	$4,080,000
Microwave System Integration	$1,264,800
Microwave Contingency	$408,000
Microwave Total	**$5,752,800**
Customer Dispatch Centers	$1,157,729
Dispatch Center Total	**$1,157,729**
Customer Subscribers	**$15,470,064**
Customer Grand Total	**$46,330,904**
Competitive Procurement Process	
Infrastructure	$22,277,333
Dispatch	$868,297
Subscribers	$12,376,051
Competitive Process Grand Total	**$35,521,681**

Dodge County Conceptual Solution #2 - P25 System 7/800 MHz – Stand Alone P25 System	
Maintenance Budget	
Description	**Total**
Competitive Process Grand Total	**$35,521,681**
Maintenance Services (2-5 yr plan)/Estimated	
Corrective Maintenance and Software/Hardware Maintenance	$1,889,574
Preventative Maintenance	$100,000
Subscription Costs (ISSI & Broadband)	$300,000
Subscriber Depot & Return	$305,280
Microwave Maintenance	incl
HVAC	$36,000
Generators	$43,200
Battery Plants & UPS	$36,000
Logging Recorder	$25,000
Year 2-5 Maintenance Services Plan Total	**$2,735,054**
Average Yearly Total	**$683,764**
Maintenance Services (6-10 yr plan)/Estimated	
Corrective Maintenance and Software/Hardware Maintenance	$2,173,010
Preventative Maintenance	$133,000
Subscription Costs (ISSI & Broadband)	$431,250
Subscriber Depot & Return	$508,800
Microwave Maintenance	incl
HVAC	$41,400
Generators	$49,680
Battery Plants & UPS	$41,400
Logging Recorder	$28,750
Year 6-10 Maintenance Services Plan Total	**$3,407,290**
Average Yearly Total	**$681,458**

Maintenance Services (11-15 yr plan)/Estimated		
Corrective Maintenance and Software/Hardware Maintenance		$2,498,962
Preventative Maintenance		$152,950
Subscriber Depot & Return		$636,000
Subscription Costs (ISSI & Broadband)		$495,938
Microwave Maintenance		incl
HVAC		$62,100
Generators		$74,520
Battery Plants & UPS		$47,610
Logging Recorder		$33,063
Year 11-15 Maintenance Services Plan Total		**$4,001,142**
	Average Yearly Total	**$800,228**
Maintenance Services (15-20 yr plan)/Estimated		
Corrective Maintenance and Software/Hardware Maintenance		$2,873,806
Preventative Maintenance		$175,893
Subscriber Depot & Return		$763,200
Subscription Costs (ISSI & Broadband)		$570,328
Microwave Maintenance		incl
HVAC		$93,150
Generators		$111,780
Battery Plants & UPS		$54,752
Logging Recorder		$38,022
Year 15-20 Maintenance Services Plan Total		**$4,680,931**
	Average Yearly Total	**$936,186**
Total Cost of Ownership 20 Years		**$50,346,097**

14.2.2 Conceptual Budget Solution 2 – Infrastructure Budget

Dodge County Conceptual Solution #2 - P25 System 7/800 MHz – Stand Alone P25 System											
Infrastructure Site Budget											
	Fox	**1317328**	**Knowles**	**Beaver**	**St Helena**	**Rubicon**	**Reeseville**	**1036140**	**Ashippun**	**Junea**	**Total**
9 Site P25 Simulcast, 6 Channels eeach										MW only	
P25 Base Station	$750,000	$750,000	$750,000	$750,000	$750,000	$750,000	$750,000	$750,000	$750,000		$6,750,000
P25 System Core		$0	$0	$0	$1,200,000	$0	$0	$0	$0	$0	$1,200,000
P25 Georedundant Core	$0	0	$0	$0	$0	$520,000	$0	$0	$0	$0	$520,000
Simulcast Control Point Eq.	$0	0	0	$0	$368,945	$368,945	$0	$0	$0	$0	$737,890
Rx Antenna System(antenna, multicoupler, TTA)	$40,000	$40,000	$40,000	$40,000	$40,000	$40,000	$40,000	$40,000	$40,000	$0	$360,000
Tx Antenna System (antenna, combiner)	$25,000	$25,000	$25,000	$25,000	$25,000	$25,000	$25,000	$25,000	$25,000	$0	$225,000
Mutual Aid System	$0	$0	$0	$0	$0	$0	$0	$0	$0	$150,000	$150,000
Administrator Training	$0	$0	$0	$0	$0	$0	$0	$0	$0	$50,000	$50,000
Installation Services	$150,000	$150,000	$150,000	$150,000	$150,000	$150,000	$150,000	$150,000	$150,000	$100,000	$1,450,000
ISSI (one gateway) - WISCOM2/requires subscription services	$0	$0	$0	$0		$325,000	$0	$0	$0	$0	$325,000
Broadband Gateway (100 user license)/requires subscription services	$0	$0	$0	$0	$0	$0	$0	$0	$0	$7,500	$7,500
Critical Building BDA Solutions (estimatd Qty 8)	$0	$0	$0	$0	$0	$0	$0	$0	$0	$400,000	$400,000
Voice Infrastructure Total	**$965,000**	**$965,000**	**$965,000**	**$965,000**	**$2,533,945**	**$2,178,945**	**$965,000**	**$965,000**	**$965,000**	**$707,500**	**$12,175,390**
Systems Integration											**$3,774,371**
Voice Infrastructure Grand Total											**$15,949,761**
Site Construction											
Shelter - Foundation	$0	$650,000	$0	$650,000	$0	$0	$650,000	$650,000	$0	$0	$2,600,000
Tower - Foundation	$0	$750,000	$0	$750,000	$0	$0	$750,000	$750,000	$0	$0	$3,000,000
Generator Subsystem	$0	$20,000	$20,000	$20,000	$20,000	$0	$20,000	$20,000	$20,000	$0	$140,000
DC Power System	$48,000	$48,000	$48,000	$48,000	$48,000	$48,000	$48,000	$48,000	$48,000	$25,000	$457,000
Site Development	$50,000	$20,000	$50,000	$20,000	$50,000	$50,000	$20,000	$20,000	$50,000	$50,000	$380,000
Site Upgrades / Water Tower Upgrades	$50,000	$20,000	$50,000	$20,000	$50,000	$50,000	$20,000	$20,000	$50,000	$50,000	$380,000
Site Construction Total	**$148,000**	**$1,508,000**	**$168,000**	**$1,508,000**	**$168,000**	**$148,000**	**$1,508,000**	**$1,508,000**	**$168,000**	**$125,000**	**$6,957,000**
Site Construction Contingency											**$1,043,550**
Site Construction Grand Total											**$8,000,550**
Microwave Backhaul											
Microwave Radio Equipment	$250,000	$250,000	$250,000	$250,000	$250,000	$250,000	$250,000	$250,000	$250,000	$250,000	$2,500,000
LAN/WAN Equipment	$35,000	$35,000	$35,000	$35,000	$50,000	$50,000	$35,000	$35,000	$35,000	$35,000	$380,000
DC Power System	$35,000	$35,000	$35,000	$35,000	$35,000	$35,000	$35,000	$35,000	$35,000	$35,000	$350,000
Antenna Systems	$45,000	$45,000	$45,000	$45,000	$45,000	$45,000	$45,000	$45,000	$45,000	$45,000	$450,000
Path Surveys	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$50,000
Installation Services	$35,000	$35,000	$35,000	$35,000	$35,000	$35,000	$35,000	$35,000	$35,000	$35,000	$350,000
Microwave Total	**$405,000**	**$405,000**	**$405,000**	**$405,000**	**$420,000**	**$420,000**	**$405,000**	**$405,000**	**$405,000**	**$405,000**	**$4,080,000**
Microwave Systems Integration											**$1,264,800**
Microwave Contingency											**$408,000**
Microwave Grand Total											**$5,752,800**
Site Infrastructure Grand Total											**$29,703,111**

14.2.3 Conceptual Budget Solution 2 - Dispatch Budget

Dodge County Conceptual Solution #2 - P25 System 7/800 MHz – Stand Alone P25 System		
Dispatch		
	Dispatch	**Jail**
Dispatch Positions	6	1
Desktop	$480,000	$80,000
Microphone	$1,950	$325
Headset	$7,680	$1,280
Auxiliary Speaker (Qty. 4)	$4,200	$700
Backup Control Stations	$44,123	$7,354
Interoperability Control Stations (Multiband Qty.10)*	$44,118	
LAN/WAN	$35,000	
Radio Network Manager	$30,000	
Logging Recorder	$75,000	
Alarm Monitoring/Network Management	$100,000	
Installation Services	$168,000	$28,000
Training	$50,000	
Dispatch Equipment Total		**$1,157,729**

14.2.4 Conceptual Budget Solution 1 - Subscriber Budget

The subscriber budget is in section 14.5 Note: these budgets are based on documentation provided by the county.

14.3 Conceptual Budget Solution 3: Partner with the WISCOM 700/800 MHz Network

The following conceptual budget shows the anticipated procurement for solution 3 in section 13.2. It also includes 20 years and maintenance and total cost of ownership (TCO) for 20 years.

It should be noted that,

- It is unknown what costs will be covered by WISCOM2 grants.

14.3.1 Conceptual Budget Solution 3 – Budget Summary

Dodge County Conceptual Solution #3 - P25 System 7/800 MHz – WISCOM2	
Pricing Summary	
Description	**Total**
Voice Infrastructure	$11,330,390
Systems Integration	$3,512,421
Voice Infrastructure Total	**$14,842,811**
Site Construction	$6,957,000
Site Construction Contingency	$1,043,550
Site Construction Total	**$8,000,550**
Microwave	$4,080,000
Microwave System Integration	$1,264,800
Microwave Contingency	$408,000
Microwave Total	**$5,752,800**
Customer Dispatch Centers	$1,157,729
Dispatch Center Total	**$1,157,729**
Customer Subscribers	**$15,470,064**
Customer Grand Total	**$45,223,954**
Competitive Procurement Process	
Infrastructure	$21,447,121
Dispatch	$868,297
Subscribers	$12,376,051
Competitive Process Grand Total	**$34,691,469**

Dodge County Conceptual Solution #3 - P25 System 7/800 MHz – WISCOM2	
Maintenance Budget	
Description	**Total**
Competitive Process Grand Total	**$34,691,469**
Maintenance Services (2-5 yr plan)/Estimated	
Corrective Maintenance and Software/Hardware Maintenance	$1,788,174
Preventative Maintenance	$100,000
Subscription Costs (Core & Broadband)	$35,000
Subscriber Depot & Return	$421,056
Microwave Maintenance	incl
HVAC	$36,000
Generators	$43,200
Battery Plants & UPS	$36,000
Logging Recorder	$25,000
Year 2-5 Maintenance Services Plan Total	**$2,484,430**
Average Yearly Total	**$621,108**
Maintenance Services (6-10 yr plan)/Estimated	
Corrective Maintenance and Software/Hardware Maintenance	$2,056,400
Preventative Maintenance	$133,000
Subscription Costs (Core & Broadband)	$40,250
Subscriber Depot & Return	$701,760
Microwave Maintenance	incl
HVAC	$41,400
Generators	$49,680
Battery Plants & UPS	$41,400
Logging Recorder	$28,750
Year 6-10 Maintenance Services Plan Total	**$3,092,640**
Average Yearly Total	**$618,528**

Maintenance Services (11-15 yr plan)/Estimated		
Corrective Maintenance and Softw are/Hardw are Maintenance		$2,364,860
Preventative Maintenance		$152,950
Subscriber Depot & Return		$877,200
Subscription Costs (Core & Broadband)		$46,288
Microw ave Maintenance		incl
HVAC		$62,100
Generators		$74,520
Battery Plants & UPS		$47,610
Logging Recorder		$33,063
Year 11-15 Maintenance Services Plan Total		**$3,658,590**
	Average Yearly Total	**$731,718**
Maintenance Services (15-20 yr plan)/Estimated		
Corrective Maintenance and Softw are/Hardw are Maintenance		$2,719,589
Preventative Maintenance		$175,893
Subscriber Depot & Return		$1,052,640
Subscription Costs (Core & Broadband)		$53,231
Microw ave Maintenance		incl
HVAC		$93,150
Generators		$111,780
Battery Plants & UPS		$54,752
Logging Recorder		$38,022
Year 15-20 Maintenance Services Plan Total		**$4,299,056**
	Average Yearly Total	**$859,811**
Total Cost of Ownership 20 Years		**$48,226,185**

14.3.2 Conceptual Budget Solution 3 – Infrastructure Budget

Dodge County Conceptual Solution #3 - P25 System 7/800 MHz – WISCOM2											
Infrastructure Site Budget											
	Fox	1317328	Knowles	Beaver	St Helena	Rubicon	Reeseville	1036140	Ashippun	Junea MW Only	Total
9 Site P25 Simulcast, 6 Channels ea.											
P25 Base Station	$750,000	$750,000	$750,000	$750,000	$750,000	$750,000	$750,000	$750,000	$750,000		$6,750,000
P25 System Connect Core		$0	$0	$0	$750,000	$0	$0	$0	$0	$0	$750,000
P25 Georedundant Connect Core	$0	0	$0	$0	$0	$450,000	$0	$0	$0	$0	$450,000
Simulcast Control Point Eq.	$0	0	0	$0	$368,945	$368,945	$0	$0	$0	$0	$737,890
Rx Antenna System(antenna, multicoupler, TTA)	$40,000	$40,000	$40,000	$40,000	$40,000	$40,000	$40,000	$40,000	$40,000	$0	$360,000
Tx Antenna System(antenna, combiner)	$25,000	$25,000	$25,000	$25,000	$25,000	$25,000	$25,000	$25,000	$25,000	$0	$225,000
Mutual Aid System	$0	$0	$0	$0	$0	$0	$0	$0	$0	$150,000	$150,000
Administrator Training	$0	$0	$0	$0	$0	$0	$0	$0	$0	$50,000	$50,000
Installation Services	$150,000	$150,000	$150,000	$150,000	$150,000	$150,000	$150,000	$150,000	$150,000	$100,000	$1,450,000
Broadband Gateway (100 user license)/requires subscription services	$0	$0	$0	$0	$0	$0	$0	$0	$0	$7,500	$7,500
Critical Building BDA Solutions (estimatd Qty 8)	$0	$0	$0	$0	$0	$0	$0	$0	$0	$400,000	$400,000
Voice Infrastructure Total	**$965,000**	**$965,000**	**$965,000**	**$965,000**	**$2,083,945**	**$1,783,945**	**$965,000**	**$965,000**	**$965,000**	**$707,500**	**$11,330,390**
Systems Integration											**$3,512,421**
Voice Infrastructure Grand Total											**$14,842,811**
Site Construction											
Shelter - Foundation	$0	$650,000	$0	$650,000	$0	$0	$650,000	$650,000	$0	$0	$2,600,000
Tower - Foundation	$0	$750,000	$0	$750,000	$0	$0	$750,000	$750,000	$0	$0	$3,000,000
Generator Subsystem	$0	$20,000	$20,000	$20,000	$20,000	$0	$20,000	$20,000	$20,000	$0	$140,000
DC Power System	$48,000	$48,000	$48,000	$48,000	$48,000	$48,000	$48,000	$48,000	$48,000	$25,000	$457,000
Site Development	$50,000	$20,000	$50,000	$20,000	$50,000	$50,000	$20,000	$20,000	$50,000	$50,000	$380,000
Site Upgrades / Water Tower Upgrades	$50,000	$20,000	$50,000	$20,000	$50,000	$50,000	$20,000	$20,000	$50,000	$50,000	$380,000
Site Construction Total	**$148,000**	**$1,508,000**	**$168,000**	**$1,508,000**	**$168,000**	**$148,000**	**$1,508,000**	**$1,508,000**	**$168,000**	**$125,000**	**$6,957,000**
Site Construction Contingency											**$1,043,550**
Site Construction Grand Total											**$8,000,550**
Microwave Backhaul											
Microwave Radio Equipment	$250,000	$250,000	$250,000	$250,000	$250,000	$250,000	$250,000	$250,000	$250,000	$250,000	$2,500,000
LAN/WAN Equipment	$35,000	$35,000	$35,000	$35,000	$50,000	$50,000	$35,000	$35,000	$35,000	$35,000	$380,000
DC Power System	$35,000	$35,000	$35,000	$35,000	$35,000	$35,000	$35,000	$35,000	$35,000	$35,000	$350,000
Antenna Systems	$45,000	$45,000	$45,000	$45,000	$45,000	$45,000	$45,000	$45,000	$45,000	$45,000	$450,000
Path Surveys	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$50,000
Installation Services	$35,000	$35,000	$35,000	$35,000	$35,000	$35,000	$35,000	$35,000	$35,000	$35,000	$350,000
Microwave Total	**$405,000**	**$405,000**	**$405,000**	**$405,000**	**$420,000**	**$420,000**	**$405,000**	**$405,000**	**$405,000**	**$405,000**	**$4,080,000**
Microwave Systems Integration											**$1,264,800**
Microwave Contingency											**$408,000**
Microwave Grand Total											**$5,752,800**
Site Infrastructure Grand Total											**$28,596,161**

14.3.3 Conceptual Budget Solution 3 - Dispatch Budget

Dodge County Conceptual Solution #3 - P25 System 7/800 MHz – WISCOM2		
Dispatch		
	Dispatch	Jail
Dispatch Positions	6	1
Desktop	$480,000	$80,000
Microphone	$1,950	$325
Headset	$7,680	$1,280
Auxiliary Speaker (Qty. 4)	$4,200	$700
Backup Control Stations	$44,123	$7,354
Interoperability Control Stations (Multiband Qty.10)*	$44,118	
LAN/WAN	$35,000	
Radio Network Manager	$30,000	
Logging Recorder	$75,000	
Alarm Monitoring/Network Management	$100,000	
Installation Services	$168,000	$28,000
Training	$50,000	
Dispatch Equipment Total		**$1,157,729**

14.3.4 Conceptual Budget Solution 3 - Subscriber Budget

The subscriber budget is in section 14.5 Note: these budgets are based on documentation provided by the county.

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14.4 Conceptual Budget Solution 4: Partner with the WiSPN 700/800 MHz Network

The following conceptual budget shows the anticipated procurement for solution 4 in section 13.2. It also includes 20 years and maintenance and total cost of ownership (TCO) for 20 years.

14.4.1 Conceptual Budget Solution 4 – Budget Summary

Dodge County Conceptual Solution #4 - P25 System 7/800 MHz – WiPSN	
Pricing Summary	
Description	**Total**
Voice Infrastructure	$10,280,390
Systems Integration	$3,186,921
Voice Infrastructure Total	**$13,467,311**
Site Construction	$6,957,000
Site Construction Contingency	$1,043,550
Site Construction Total	**$8,000,550**
Microwave	$4,080,000
Microwave System Integration	$1,264,800
Microwave Contingency	$408,000
Microwave Total	**$5,752,800**
Customer Dispatch Centers	$1,157,729
Dispatch Center Total	**$1,157,729**
Customer Subscribers	**$15,470,064**
Customer Grand Total	**$43,848,454**
Competitive Procurement Process	
Infrastructure	$20,415,496
Dispatch	$868,297
Subscribers	$12,376,051
Competitive Process Grand Total	**$33,659,844**

Dodge County Conceptual Solution #4 - P25 System 7/800 MHz – WiPSN	
Maintenance Budget	
Description	**Total**
Competitive Process Grand Total	**$33,659,844**
Maintenance Services (2-5 yr plan)/Estimated	
Corrective Maintenance and Software/Hardware Maintenance	$1,351,812
Preventative Maintenance	$100,000
Subscription Costs (Core & Broadband)	$35,000
Subscriber Depot & Return	$421,056
Microwave Maintenance	incl
HVAC	$36,000
Generators	$43,200
Battery Plants & UPS	$36,000
Logging Recorder	$25,000
Year 2-5 Maintenance Services Plan Total	**$2,048,068**
Average Yearly Total	**$512,017**
Maintenance Services (6-10 yr plan)/Estimated	
Corrective Maintenance and Software/Hardware Maintenance	$1,554,584
Preventative Maintenance	$133,000
Subscription Costs (Core & Broadband)	$40,250
Subscriber Depot & Return	$701,760
Microwave Maintenance	incl
HVAC	$41,400
Generators	$49,680
Battery Plants & UPS	$41,400
Logging Recorder	$28,750
Year 6-10 Maintenance Services Plan Total	**$2,590,824**
Average Yearly Total	**$518,165**

Maintenance Services (11-15 yr plan)/Estimated		
Corrective Maintenance and Softw are/Hardw are Maintenance		$1,787,772
Preventative Maintenance		$152,950
Subscriber Depot & Return		$877,200
Subscription Costs (Core & Broadband)		$46,288
Microw ave Maintenance		incl
HVAC		$62,100
Generators		$74,520
Battery Plants & UPS		$47,610
Logging Recorder		$33,063
Year 11-15 Maintenance Services Plan Total		**$3,081,502**
	Average Yearly Total	**$616,300**
Maintenance Services (15-20 yr plan)/Estimated		
Corrective Maintenance and Softw are/Hardw are Maintenance		$2,055,938
Preventative Maintenance		$175,893
Subscriber Depot & Return		$1,052,640
Subscription Costs (Core & Broadband)		$53,231
Microw ave Maintenance		incl
HVAC		$93,150
Generators		$111,780
Battery Plants & UPS		$54,752
Logging Recorder		$38,022
Year 15-20 Maintenance Services Plan Total		**$3,635,405**
	Average Yearly Total	**$727,081**
Total Cost of Ownership 20 Years		**$45,015,643**

14.4.2 Conceptual Budget Solution 4 – Infrastructure Budget

Dodge County Conceptual Solution #4 - P25 System 7/800 MHz – WiPSN											
Infrastructure Site Budget											
	Fox	1317328	Knowles	Beaver	St Helena	Rubicon	Reeseville	1036140	Ashippun	Junea MW Only	Total
9 Site P25 Simulcast, 6 Channels ea.											
P25 Base Station	$750,000	$750,000	$750,000	$750,000	$750,000	$750,000	$750,000	$750,000	$750,000		$6,750,000
P25 System Virtual Core		$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
P25 Georedundant Edge Controller	$0	0	$0	$0	$150,000	$0	$0	$0	$0	$0	$150,000
Simulcast Control Point Eq.	$0	0	0	$0	$368,945	$368,945	$0	$0	$0	$0	$737,890
Rx Antenna System(antenna, multicoupler, TTA)	$40,000	$40,000	$40,000	$40,000	$40,000	$40,000	$40,000	$40,000	$40,000	$0	$360,000
Tx Antenna System(antenna, combiner)	$25,000	$25,000	$25,000	$25,000	$25,000	$25,000	$25,000	$25,000	$25,000	$0	$225,000
Mutual Aid System	$0	$0	$0	$0	$0	$0	$0	$0	$0	$150,000	$150,000
Administrator Training	$0	$0	$0	$0	$0	$0	$0	$0	$0	$50,000	$50,000
Installation Services	$150,000	$150,000	$150,000	$150,000	$150,000	$150,000	$150,000	$150,000	$150,000	$100,000	$1,450,000
Broadband Gateway (100 user license)/requires subscription services	$0	$0	$0	$0	$0	$0	$0	$0	$0	$7,500	$7,500
Critical Building BDA Solutions (estimatd Qty 8)	$0	$0	$0	$0	$0	$0	$0	$0	$0	$400,000	$400,000
Voice Infrastructure Total	**$965,000**	**$965,000**	**$965,000**	**$965,000**	**$1,483,945**	**$1,333,945**	**$965,000**	**$965,000**	**$965,000**	**$707,500**	**$10,280,390**
Systems Integration											**$3,186,921**
Voice Infrastructure Grand Total											**$13,467,311**
Site Construction											
Shelter - Foundation	$0	$650,000	$0	$650,000	$0	$0	$650,000	$650,000	$0	$0	$2,600,000
Tower - Foundation	$0	$750,000	$0	$750,000	$0	$0	$750,000	$750,000	$0	$0	$3,000,000
Generator Subsystem	$0	$20,000	$20,000	$20,000	$20,000	$0	$20,000	$20,000	$20,000	$0	$140,000
DC Power System	$48,000	$48,000	$48,000	$48,000	$48,000	$48,000	$48,000	$48,000	$48,000	$25,000	$457,000
Site Development	$50,000	$20,000	$50,000	$20,000	$50,000	$50,000	$20,000	$20,000	$50,000	$50,000	$380,000
Site Upgrades / Water Tower Upgrades	$50,000	$20,000	$50,000	$20,000	$50,000	$50,000	$20,000	$20,000	$50,000	$50,000	$380,000
Site Construction Total	**$148,000**	**$1,508,000**	**$168,000**	**$1,508,000**	**$168,000**	**$148,000**	**$1,508,000**	**$1,508,000**	**$168,000**	**$125,000**	**$6,957,000**
Site Construction Contingency											**$1,043,550**
Site Construction Grand Total											**$8,000,550**
Microwave Backhaul											
Microwave Radio Equipment	$250,000	$250,000	$250,000	$250,000	$250,000	$250,000	$250,000	$250,000	$250,000	$250,000	$2,500,000
LAN/WAN Equipment	$35,000	$35,000	$35,000	$35,000	$50,000	$50,000	$35,000	$35,000	$35,000	$35,000	$380,000
DC Power System	$35,000	$35,000	$35,000	$35,000	$35,000	$35,000	$35,000	$35,000	$35,000	$35,000	$350,000
Antenna Systems	$45,000	$45,000	$45,000	$45,000	$45,000	$45,000	$45,000	$45,000	$45,000	$45,000	$450,000
Path Surveys	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$50,000
Installation Services	$35,000	$35,000	$35,000	$35,000	$35,000	$35,000	$35,000	$35,000	$35,000	$35,000	$350,000
Microwave Total	**$405,000**	**$405,000**	**$405,000**	**$405,000**	**$420,000**	**$420,000**	**$405,000**	**$405,000**	**$405,000**	**$405,000**	**$4,080,000**
Microwave Systems Integration											**$1,264,800**
Microwave Contingency											**$408,000**
Microwave Grand Total											**$5,752,800**
Site Infrastructure Grand Total											**$27,220,661**

14.4.3 Conceptual Budget Solution 4 - Dispatch Budget

Dodge County Conceptual Solution #4 - P25 System 7/800 MHz – WiPSN		
Dispatch		
	Dispatch	Jail
Dispatch Positions	6	1
Desktop	$480,000	$80,000
Microphone	$1,950	$325
Headset	$7,680	$1,280
Auxiliary Speaker (Qty. 4)	$4,200	$700
Backup Control Stations	$44,123	$7,354
Interoperability Control Stations (Multiband Qty.10)*	$44,118	
LAN/WAN	$35,000	
Radio Network Manager	$30,000	
Logging Recorder	$75,000	
Alarm Monitoring/Network Management	$100,000	
Installation Services	$168,000	$28,000
Training	$50,000	
Dispatch Equipment Total		**$1,157,729**

14.4.4 Conceptual Budget Solution 4 - Subscriber Budget

The subscriber budget is in section 14.5 Note: these budgets are based on documentation provided by the county.

14.5 Subscriber Budget

			Subscriber Budget																								
		Total	Each	Waupun FD	Waupun PD	Dodge County SO	DPW	Juneau FD & EMS	Juneau PD	DPW	Mayville EMS	Neosho FD	Neosho PD	Theresa PD	Hustisford Utilities	Hustisford PD	Watertown FD	Watertown PD	Lomira FD	Lomira DPW	Randolf FD	Knowles VFD	Beaver Dam PD	Columbus FD	Horicon FD	Lifestar EMS
Mobile																											
Mid-tier Remote Mount P25 Single Band	Qty.	12																									
	Total	**$77,940**	$6,495	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Mid-tier Dash Mount P25 Single Band	Qty.	0																									
	Total	**$0**	$5,995	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Low-tier Dash Mount P25	Qty.	0																									
	Total	**$0**	$4,658	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
High-tier Dash Mount P25 Multiband	Qty.	0																									
	Total	**$0**	$9,500	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
High-tier Remote Mount P25 Multiband	Qty.	430		13	12	58	20	11	4	20	7	7	2	2	6	2	18	17	40	5	13	7	23	17		3
	Total	**$4,515,000**	$10,500	$136,500	$126,000	$609,000	$210,000	$115,500	$42,000	$210,000	$73,500	$73,500	$21,000	$21,000	$63,000	$21,000	$189,000	$178,500	$420,000	$52,500	$136,500	$73,500	$241,500	$178,500	$0	$31,500
Installation & Programming	Total	**$243,100**	$550	$7,150	$6,600	$31,900	$11,000	$6,050	$2,200	$11,000	$3,850	$3,850	$1,100	$1,100	$3,300	$1,100	$9,900	$9,350	$22,000	$2,750	$7,150	$3,850	$12,650	$9,350	$0	$1,650
Removal Old Equipment	Total	**$33,150**	$75	$975	$900	$4,350	$1,500	$825	$300	$1,500	$525	$525	$150	$150	$450	$150	$1,350	$1,275	$3,000	$375	$975	$525	$1,725	$1,275	$0	$225
		$4,869,190																									
Portable																											
	Qty.	0																									
Mid-tier Portable P25 Police/EMS	Total	**$0**	$8,823	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
	Qty.	0																									
Mid-tier Portable P25 Fire	Total	**$0**	$9,575	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
	Qty.	191																									
Low-tier P25	Total	**$0**	$6,264	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
	Qty.	829		52	30	64	6	40	8	6	12	22	4	5	2	8	43	51	33		37	26	41	40	2	4
High-tier Portable P25 Multiband	Total	**$2,289,000**	$10,500	$546,000	$315,000	$672,000	$63,000	$420,000	$84,000	$63,000	$126,000	$231,000	$42,000	$52,500	$21,000	$84,000	$451,500	$535,500	$346,500	$0	$388,500	$273,000	$430,500	$420,000	$21,00	$42,000
Programming	Total	**$49,268**	$226	$11,752	$6,780	$14,464	$1,356	$9,040	$1,808	$1,356	$2,712	$4,972	$904	$1,130	$452	$1,808	$9,718	$11,526	$7,458	$0	$8,362	$5,876	$9,266	$9,040	$452	$904
	Qty.	829		52	30	64	6	40	8	6	12	22	4	5	2	8	43	51	33		37	26	41	40	2	4
Carrying Case/Belt Clip	Total	**$13,952**	$64	$3,328	$1,920	$4,096	$384	$2,560	$512	$384	$768	$1,408	$256	$320	$128	$512	$2,752	$3,264	$2,112	$0	$2,368	$1,664	$2,624	$2,560	$128	$256
	Qty.	1020		52	30	64	6	40	8	6	12	22	4	5	2	8	43	51	33		37	26	41	40	2	4
Desk Charger	Total	**$112,200**	$110	$5,720	$3,300	$7,040	$660	$4,400	$880	$660	$1,320	$2,420	$440	$550	$220	$880	$4,730	$5,610	$3,630	$0	$4,070	$2,860	$4,510	$4,400	$220	$440
	Qty.	20		2				2				1					2	2	1		1	1				
Multi-Unit Charger	Total	**$12,000**	$600	$1,200	$0	$0	$0	$1,200	$0	$0	$0	$600	$0	$0	$0	$0	$1,200	$1,200	$600	$0	$600	$600	$0	$0	$0	$0
	Qty.	1012		52	30	64	6	40	8	6	12	22	4	5	2	8	43	51	33		37	26	41	40	2	4
Speaker Mic	Total	**$126,500**	$125	$6,500	$3,750	$8,000	$750	$5,000	$1,000	$750	$1,500	$2,750	$500	$625	$250	$1,000	$5,375	$6,375	$4,125	$0	$4,625	$3,250	$5,125	$5,000	$250	$500
		$2,602,920																									
Control Station (non-dispatch)																											
	Qty.	13		1				1		1		1			1		1	1	1	1	1					
Control Station	Total	**$90,350**	$6,950	$6,950	$0	$0	$0	$6,950	$0	$6,950	$0	$6,950	$0	$0	$6,950	$0	$6,950	$6,950	$6,950	$6,950	$6,950	$0	$0	$0	$0	$0
	Qty.	13		1				1		1		1			1		1	1	1	1	1					
Antenna System	Total	**$10,725**	$825	$825	$0	$0	$0	$825	$0	$825	$0	$825	$0	$0	$825	$0	$825	$825	$825	$825	$825	$0	$0	$0	$0	$0
Installation & Programming	Total	**$14,599**	$1,123	$1,123	$0	$0	$0	$1,123	$0	$1,123	$0	$1,123	$0	$0	$1,123	$0	$1,123	$1,123	$1,123	$1,123	$1,123	$0	$0	$0	$0	$0
	Qty.	0																									
Unication Pager	Total	**$0**	$660	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Training		**$50,000**																									
Subscriber Total		**$15,470,064**		$728,023	$464,250	$1,350,850	$288,650	$573,473	$132,700	$297,548	$210,175	$329,923	$66,350	$77,375	$97,698	$110,450	$684,423	$761,498	$818,323	$64,523	$562,048	$365,125	$707,900	$630,125	$22,0	$77,475

		Total	Fox Lake Correctional	Fox Lake PD	Allenton FD	Emmet PD	Emmet DPW	Hartford PD	WI DNR	Columbus FD	Lebanon FD	HFD	Other
Mobile													
Mid-tier Remote Mount P25 Single Band	Qty.	12	12										
	Total	**$77,940**	$77,940	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Mid-tier Dash Mount P25 Single Band	Qty.	0											
	Total	**$0**	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Low-tier Dash Mount P25	Qty.	0											
	Total	**$0**	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
High-tier Dash Mount P25 Multiband	Qty.	0											
	Total	**$0**	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
High-tier Remote Mount P25 Multiband	Qty.	430		2	13	1	6	13	4	14	12	11	47
	Total	**$4,515,000**	$0	$21,000	$136,500	$10,500	$63,000	$136,500	$42,000	$147,000	$126,000	$115,500	$493,500
Installation & Programming	Total	**$243,100**	$6,600	$1,100	$7,150	$550	$3,300	$7,150	$2,200	$7,700	$6,600	$6,050	$25,850
Removal Old Equipment	Total	**$33,150**	$900	$150	$975	$75	$450	$975	$300	$1,050	$900	$825	$3,525
		$4,869,190											
Portable													
Mid-tier Portable P25 Police/EMS	Qty.	0											
	Total	**$0**	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Mid-tier Portable P25 Fire	Qty.	0											
	Total	**$0**	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Low-tier P25	Qty.	191	191										
	Total	**$0**	$1,196,424	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
High-tier Portable P25 Multiband	Qty.	829		2	28	4		34	3	34	34	36	118
	Total	**$2,289,000**	$0	$21,000	$294,000	$42,000	$0	$357,000	$31,500	$357,000	$357,000	$378,000	$1,239,000
Programming	Total	**$49,268**	$43,166	$452	$6,328	$904	$0	$7,684	$678	$7,684	$7,684	$8,136	$26,668
Carrying Case/Belt Clip	Qty.	829		2	28	4		34	3	34	34	36	118
	Total	**$13,952**	$0	$128	$1,792	$256	$0	$2,176	$192	$2,176	$2,176	$2,304	$7,552
Desk Charger	Qty.	1020	191	2	28	4		34	3	34	34	36	118
	Total	**$112,200**	$21,010	$220	$3,080	$440	$0	$3,740	$330	$3,740	$3,740	$3,960	$12,980
Multi-Unit Charger	Qty.	20	4		1					1	1	1	
	Total	**$12,000**	$2,400	$0	$600	$0	$0	$0	$0	$600	$600	$600	$0
Speaker Mic	Qty.	1012	191	4	28	4		34	3	34	34	26	118
	Total	**$126,500**	$23,875	$500	$3,500	$500	$0	$4,250	$375	$4,250	$4,250	$3,250	$14,750
		$2,602,920											
Control Station (non-dispatch)													
Control Station	Qty.	13			1		1				1		
	Total	**$90,350**	$0	$0	$6,950	$0	$6,950	$0	$0	$0	$6,950	$0	$0
Antenna System	Qty.	13			1		1				1		
	Total	**$10,725**	$0	$0	$825	$0	$825	$0	$0	$0	$825	$0	$0
Installation & Programming	Total	**$14,599**	$0	$0	$1,123	$0	$1,123	$0	$0	$0	$1,123	$0	$0
Unication Pager	Qty.	0											
	Total	**$0**	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Training		**$50,000**											
Subscriber Total		**$15,470,064**	$1,372,315	$44,550	$462,823	$55,225	$75,648	$519,475	$77,575	$531,200	$517,848	$518,625	$1,823,82

14.6 Budget Summary

The following Table is a budget summary of each of the conceptual solutions.

Solution	Description	Build Out Cost	20 Years TCO
1	Upgrade/refresh of the current VHF system	$22,097,892	$31,710,517
2	Implement a stand alone 700/800 MHz radio system	$35,521,681	$50,346,097
3	Partner with the WISCOM2 700/800 MHz Network	$34,691,469	$48,226,185
4	Partner with the WiSPN 700/800 MHz Network	$33,659,844	$45,015,643

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15 Executive Summary and Recommendations

The current VHF system has inadequate portable radio coverage with "dead zones" in rural areas and within buildings. Substantial radio performance degradation has been observed due to high in-band VHF noise and time delay interference (TDI) inherent in simulcast technology. The existing VHF conventional channels can be overwhelmed, as observed during a recent tornado event in Dodge County. Aging infrastructure, including old AC units, corroded grounding, and end-of-life equipment like Intraplex mux units, can contribute to poor overall system reliability.

In contrast, 700/800 MHz systems offer advantages. The FCC has exclusively allocated this band for public safety digital systems. This provides improved interoperability as surrounding agencies are already on or transitioning to 700/800 MHz based on the P25 open standard, fostering competition among vendors for equipment and potentially reducing costs.

A 700/800 MHz P25 trunking system offers several key advantages for Dodge County:

- Improved Interoperability: Many surrounding counties and state agencies (like the Wisconsin State Patrol with its new WISCOM2 P25 System) are already using or transitioning to 700/800 MHz systems. This significantly enhances communication capabilities and mutual aid with these entities, addressing current interoperability challenges.

- Dedicated Public Safety Spectrum: The FCC has allocated a new section of the 700 MHz band exclusively for public safety digital systems, ensuring clear and dedicated channels for emergency services.

- P25 Open Standard Benefits: Being a P25 compliant system, it promotes competition among multiple vendors for both infrastructure and user equipment. This allows Dodge County to acquire radios and system components from various manufacturers, potentially leading to better pricing and more innovative solutions.

- Enhanced Grant Eligibility: Federal public safety communications grants frequently require or heavily favor P25 systems and equipment, increasing Dodge County's chances of securing funding for system upgrades.

- Multiband Radio Compatibility: The availability of multiband radios allows users to communicate across different frequency bands (VHF, UHF, 700/800 MHz) and protocols (analog, digital, P25), simplifying equipment management for personnel who currently need to carry multiple radios.
- Addressing Current VHF Limitations: Transitioning to 700/800 MHz inherently addresses issues faced by the current VHF system, such as high in-band noise, time delay interference (TDI) from simulcast technology, and channel limitations, leading to better overall coverage and audio quality.

Recommendations

Given the pervasive disadvantages of the current VHF system and the clear advantages of 700/800 MHz P25 trunking systems in terms of interoperability, coverage, long-term sustainability, and grant eligibility, it is recommended that Dodge County transition to a 700/800 MHz P25 trunking system. This system recommendation can be any of the following configurations.

- A stand alone 700/800 MHz radio system with a county owned core
- A 700/800 MHz radio system with a WISCOM2 core
- A 700/800 MHz radio system with a WiPSN core

(End of report)