APPENDIX D

Telecommunication Studies

ONE ENERGY
WIND FOR INDUSTRY®

MICROWAVE BEAM PATH STUDY

10/04/2021

One Energy commissioned Spectrum Center to perform a "Proposed Wind Turbine to Existing Microwave Link Analysis" for all five turbines. The studies were completed on April 26, 2021 and are attached. Spectrum reviewed the updated turbine locations for WTG01 and WTG02 on August 24, 2021 and the results of the review are attached. Using the attached studies, One Energy has determined that this project will not have an impact on any existing microwave beam paths.

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24 August, 2021

Mr. Ben Mallernee
One Energy
12385 Township Road 215
Findlay, OH 45840

RE: New site coordinates for WTG01 and WTG02 (Stark County, ND)

Dear Mr. Mallernee:

The proposed wind turbine to existing microwave link analysis reports for WTG01 and WTG02 (both dated 23 April 2021) used the specifications provided in Table 1.

Table 1: Specifications for WTG01 and WTG02

	WTG01	WTG02
Latitude (decimal degrees)	46.859224	46.859974
Longitude (decimal degrees)	-102.913278	-102.909412
Hub height (m)	80.0	80.0
Rotor diameter (m)	103.0	103.0
Overall height (m)	131.5	131.5

For both WTG01 and WTG02, the closest existing microwave links at the time of the study are provided in Table 2.

Table 2: Nearby microwave link(s)

Call sign	Licensee	Freq. (MHz)	Site A	Site B
WQML740	TOTALLY AMPED LLC	945.00	Dickinson	Tower
KVY58	BNSF Railway Co.	6635.00	Dickinson	Fryburg
KVY60	BNSF Railway Co	6795.00	Fryburg	Dickinson

The results of the analyses are provided in Table 3 (for WTG01) and Table 4 (for WTG02).

Table 3: Separation distances and azimuths for WTG01

Call sign	Min. separation distance (m)	Incursion Azi (°)	Azi_1 (°)	Azi_2 (°)
KVY58	2422.1	356.1	-	-

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Table 4: Separation distances and azimuths for WTG02

Call sign	Min. separation distance (m)	Incursion Azi. (°)	Azi_1 (°)	Azi_2 (°)
KVY58	2359.0	356.1	-	-

It is understood that the site coordinates for WTG01 and WTG02 have been changed to those in Table 5. The hub height and rotor diameter remain the same.

Table 5: New site coordinates

Site	Latitude (decimal deg.)	Longitude (decimal deg.)
WTG01	46.859654	-102.913217
WTG02	46.860222	-102.909532

Based on the version of the FCC ULS database available at the time of the previous analysis, we believe that the minimum separation distances found in Table 3 and Table 4 will change due to the new site coordinates, but interference to the microwave link (call sign KVY58) is not expected. It is also possible that WTG01, WTG02, or both may be closer to the second Fresnel zone of a different microwave link. Without considering the most current microwave link records from the FCC database, the new locations for WTGO1 and WTG02 seem unlikely to interfere with or obstruct the other microwave links found in Table 2 since the closest distance was 2359.0 meters at the time of the 23 April 2021 analysis.

Best regards,

Clara Yang

Proposed Wind Turbine to Existing Microwave Link Analysis

WTG01
Stark County, ND

Prepared 23 April 2021 on behalf of One Energy

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1 Introduction

1.1 Background

Due to their unique physical characteristics, wind turbines are potential interferers for wireless systems, such as communications links, air traffic control radars, and navigational aids. The nature and severity of the wind turbine interference depend on various factors, including

- The location of the wind turbine between receiver and transmitter;
- Characteristics of the rotor blades;
- Characteristics of receiver;
- Signal frequency; and
- The radio wave propagation in the local atmosphere.

Wireless communications systems include terrestrial microwave links. Two main types of terrestrial microwave links are those that communicate with satellites and those that communicate with each other in a point-to-point (PTP) fashion. Wind turbines are unlikely to affect satellite communications links because of the high angle of inclination of the earth station antenna. Wind turbines, however, may affect terrestrial PTP microwave links since the antenna heights at each end of a link are typically the minimum heights required to achieve line-of-sight.

PTP microwave transmission is the transmission of digital or analog signals in the microwave band, i.e., 1 to 30 gigahertz (GHz). Long-distance telephone calls, television programs, computer data, and cellular network backhaul are common microwave transmissions. Referring to Figure 1, in a fixed PTP microwave link, radio signals are transmitted between two locations with directional antennas. There must be line-of-sight between the two antennas because any structures or vegetation that partially or fully block the electromagnetic energy of the transmitted signal will lower the quality and reliability of transmission.

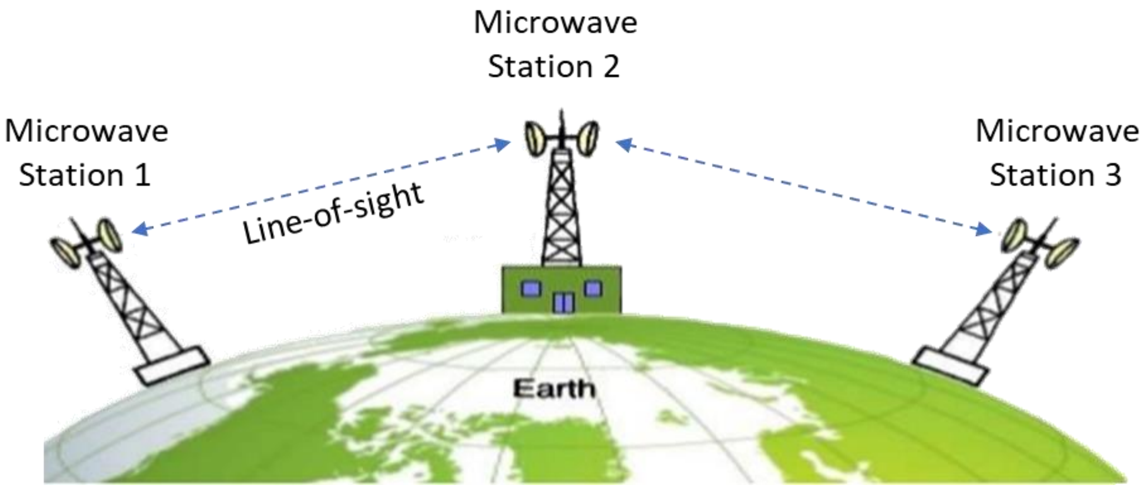

Figure 1: PTP microwave transmission (typical path length of approximately 40 – 60 km for frequencies below 11 GHz)

PTP microwave paths mainly consist of links licensed by the Federal Communications Commission (FCC) and are granted a certain level of protection from interference. For unlicensed transmission, a certain amount of degradation of service must be tolerated, as long as the object responsible for the degradation does not emit electromagnetic waves of too much power within the unlicensed frequency range.

1.2 Potential wind turbine effects on PTP microwave links

A wind turbine in close proximity to a single microwave link can degrade the link via three possible mechanisms:

- Near-field effects, which can occur when the wind turbine is within the near-field of a microwave antenna, thereby rendering prediction of the impact on the microwave link to be extremely complex since inductive as well as radiated fields have to be considered;
- Diffraction from the wind turbine's physical structure, which can detrimentally alter the advancing wavefront of a radio signal by obstructing the wave's path of travel; and
- Reflection/scattering from the rotating blades, which can receive a primary transmitted signal and produce and transmit a scattered signal that causes electromagnetic interference.

Various studies indicate that the main mechanisms by which a wind turbine may degrade radio link performance were those of diffraction in the Fresnel zone as well as reflection and scattering from the turbine structure and blades. Diffraction effects can be avoided if obstructions are kept outside the Fresnel zone of a microwave link. In regards to avoiding reflection and scattering effects, a method for determining the minimum distance between a wind turbine and a radio link has yet to be developed because there is insufficient information on radar cross section (RCS) values of wind turbines. RCS values quantify the extent to which an object will reflect or scatter radio waves. There is little detailed information on wind turbine RCS values because wind turbines have variable geometry. For example, in addition to the blades rotating, the horizontal axis of blade rotation varies in azimuth according to wind direction, and the pitch angle of the blades varies according to wind speed and electrical load. Consequently, only diffraction effects will be addressed in this analysis.

1.3 Fresnel zone clearance

As mentioned in the previous section, diffraction effects can be avoided if obstructions are kept outside the Fresnel zone of a microwave link. A Fresnel zone is an elliptical volume around a direct radio path that contains a certain amount of electromagnetic energy. Microwave operators use the concept of Fresnel zone clearance to prevent interference by obstacles near the direct radio path. When designing a fixed PTP microwave link, the operators usually try to clear at least 60% of the first Fresnel zone from large static obstructions, e.g., terrain or buildings.

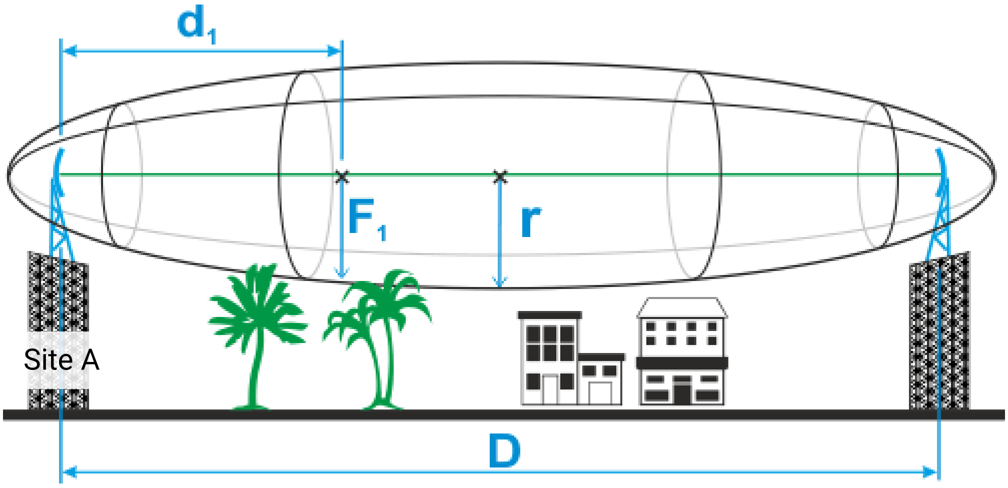

Figure 2: The first Fresnel zone (F_1) where D is the distance of the radio path, and r is the radius of the first Fresnel zone at a point along the path that is d_1 away from Site A

Using a more conservative criterion than 60% of the first Fresnel Zone is preferable for a wind turbine due to its varying geometry. It is an industry-accepted standard to define a wind turbine exclusion zone equal to the complete second Fresnel zone of a PTP microwave link to avoid any harmful effects caused by the energy contained in that volume, as shown below in Figure 3.

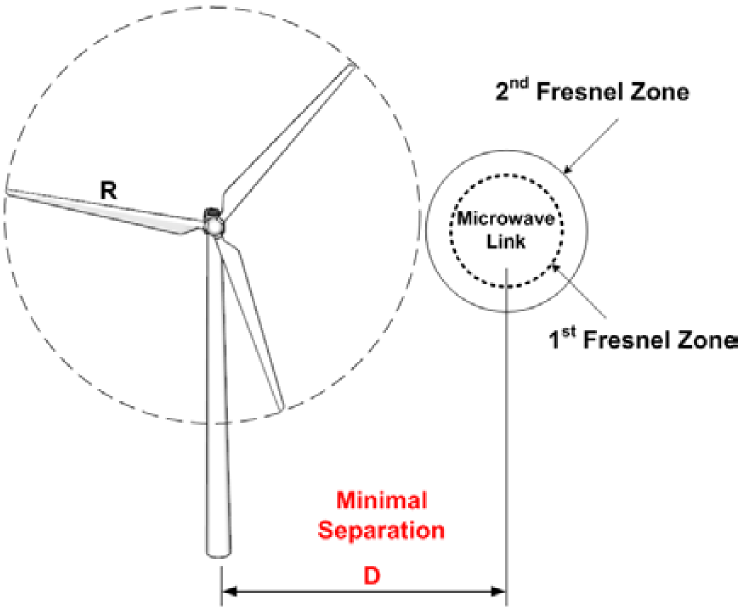

Figure 3: Cross-section view of minimum separation objective

2 Objective

The objective of this report is to utilize the cartographic data in Spectrum Center's radio frequency (RF) planning software (i.e., Spectrum-E™) to calculate separation distances between the three-dimensional rotor volume of a proposed wind turbine and the second Fresnel zone of existing microwave links.

3 Proposed wind turbine specifications

The specifications for the proposed wind turbine are provided below:

Table 1: Wind turbine specifications

Wind Turbine: WTG01, Stark County, ND	
Latitude (decimal degrees)	46.859224
Longitude (decimal degrees)	-102.913278
Hub height (m)	80.0
Rotor diameter (m)	103.0
Overall height (m)	131.5

The proposed location of the wind turbine is Stark County, ND. Its location is shown in a satellite image as well as a map in Figure 4. The maximum possible extent of the rotor swept volume is represented by a circle:

Figure 4: Proposed wind turbine location

4 Methodology for calculating the second Fresnel zone

A second Fresnel zone clearance method is applied to determine the protected volume of the fixed PTP microwave paths.

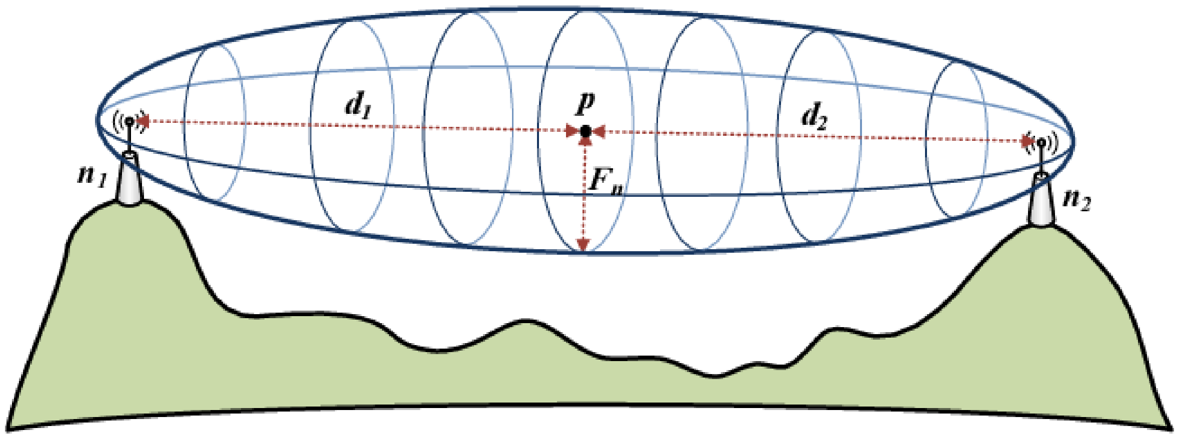

Figure 5: nth Fresnel zone calculation

Reffering to Figure 5, the Fresnel zone size depends on the frequency and distance from the microwave stations and is given by the generic formula

$$F_n = \sqrt{\frac{n\lambda d_1 d_2}{d_1 + d_2}}$$

where F_n is the radius of the nth Fresnel zone in meters;
n is the Fresnel zone number;
λ is the wavelength of the microwave signal in meters; and
d_1 and d_2 are the distances to n_1 and n_2, respectively, from the point p in question.

The second Fresnel zone is the largest at the midpoint between the two antennas where $d_1 = d_2$. Its radius is defined by:

$$r_{WCFZ_2} = 12.243\sqrt{\frac{D}{f}}$$

where r_{WCFZ2} is the radius of the second Fresnel zone in meters;
f is the frequency in gigahertz; and
D is the total link distance in kilometers.

This radius is commonly called the worst-case second Fresnel zone. When applied to a microwave link, it should provide enough clearance for the link to continue functioning without a significant drop in quality or reliability of transmission.

5 Analysis

5.1 Data retrieval

To ensure that the proposed wind turbine clears the second Fresnel zones of existing microwave paths in the area, records of licensed microwave links within a 25 km^2 square area around the proposed wind turbine are retrieved from the FCC Universal Licensing System (ULS). If there are none, the analysis is complete, and further analysis is unnecessary. The analysis uses the information available from the daily download dated 04/23/2021.

Figure 6 is a map of the proposed wind turbine and the retrieved licensed microwave links (in red) in active or pending status that are partially or completely within the search area, which is represented by the green box.

Figure 6: Proximity of wind turbine to existing microwave links

Information on the retrieved links is provided in the table below:

Table 2: Nearby microwave link(s)

Call sign	Licensee	Freq. (MHz)	Site A	Site B
WQML740	TOTALLY AMPED LLC	945.00	Dickinson	Tower
KVY58	BNSF Railway Co.	6635.00	Dickinson	Fryburg
KVY60	BNSF Railway Co	6795.00	Fryburg	Dickinson

5.2 Second Fresnel zone clearance results

Using the retrieved FCC ULS records and referring to Table 3, Spectrum-E™ calculates the following for each licensed microwave link:

- Either (1) the minimum separation distance (in meters) between the proposed wind turbine rotor blade and the worst-case second Fresnel zone of the microwave link or (2) the worst-case second Fresnel zone incursion, which is indicated by a negative value;
- The azimuth Azi (in degrees) of the wind turbine blade when it is closest to the worst-case second Fresnel zone or causing the worst-case incursion; and

- The azimuths Azi_1 and Azi_2 (in degrees) of the wind turbine blade before incursion.

The results of the Spectrum-E calculations are in Table 3

Table 3: Separation distances and azimuths

Call sign	Min. separation distance (m)	Azi (°)	Azi_1 (°)	Azi_2 (°)
KVY58	2422.1	356.1	-	-

6 Conclusion

Point-to-point microwave links are communications systems that transmit their signals via beams of radio waves. Although 60% clearance of the first Fresnel zone is usually sufficient to guarantee undisturbed performance of a microwave link, in the case of wind turbines, the recommendation is to keep the second Fresnel zone 100% clear since wind turbines are not static obstacles.

The second Fresnel zone volumes of existing microwave links obtained from the FCC ULS were compared to the rotor volume of the proposed wind turbine. The nearest that the potential 3-dimensional rotor swept volume of the wind turbine approaches the second Fresnel zone of an existing microwave link is 2422.1 meters; therefore, interference to the microwave link is not expected.

Proposed Wind Turbine to Existing Microwave Link Analysis

WTG02
Stark County, ND

Prepared 23 April 2021 on behalf of One Energy

SPECTRUM CENTER

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1 Introduction

1.1 Background

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- The location of the wind turbine between receiver and transmitter;
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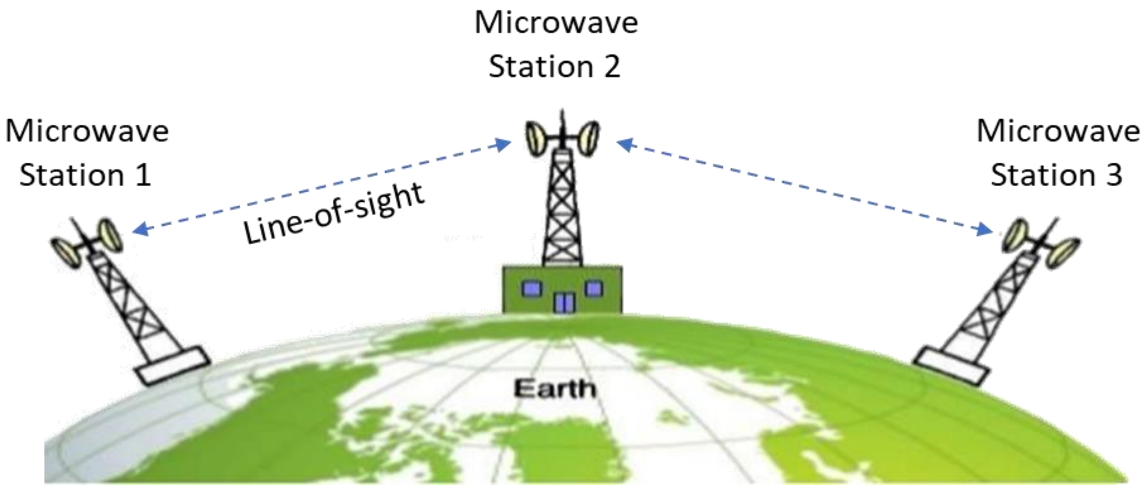
PTP microwave transmission is the transmission of digital or analog signals in the microwave band, i.e., 1 to 30 gigahertz (GHz). Long-distance telephone calls, television programs, computer data, and cellular network backhaul are common microwave transmissions. Referring to Figure 1, in a fixed PTP microwave link, radio signals are transmitted between two locations with directional antennas. There must be line-of-sight between the two antennas because any structures or vegetation that partially or fully block the electromagnetic energy of the transmitted signal will lower the quality and reliability of transmission.



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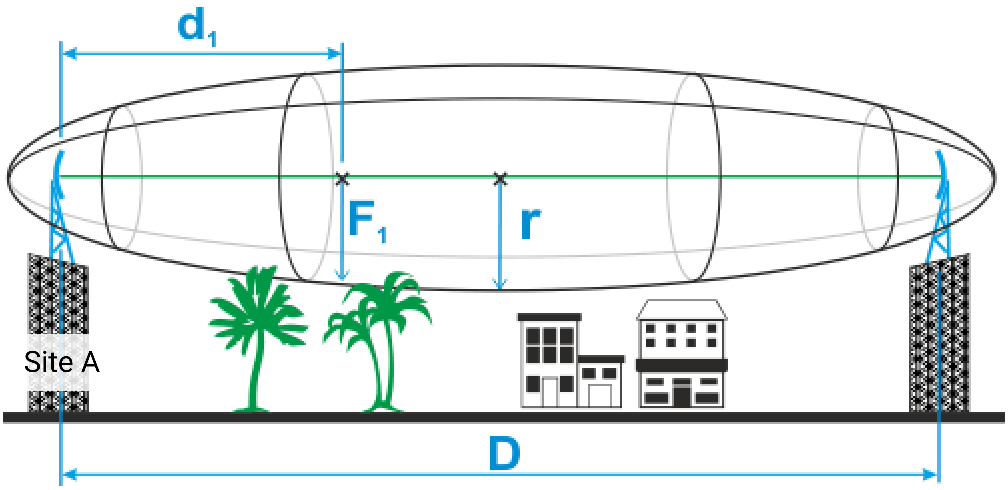

Figure 2: The first Fresnel zone (F_1) where D is the distance of the radio path, and r is the radius of the first Fresnel zone at a point along the path that is d_1 away from Site A

Using a more conservative criterion than 60% of the first Fresnel Zone is preferable for a wind turbine due to its varying geometry. It is an industry-accepted standard to define a wind turbine exclusion zone equal to the complete second Fresnel zone of a PTP microwave link to avoid any harmful effects caused by the energy contained in that volume, as shown below in Figure 3.

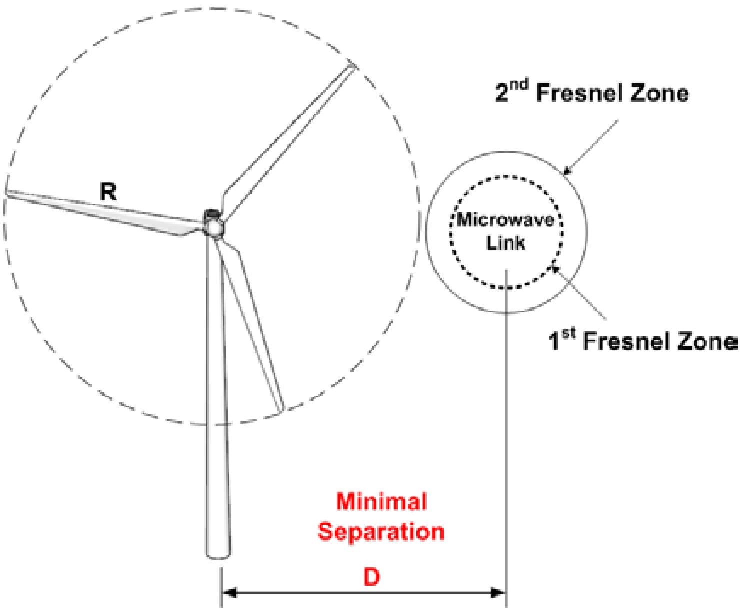

Figure 3: Cross-section view of minimum separation objective

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3 Proposed wind turbine specifications

The specifications for the proposed wind turbine are provided below:

Table 1: Wind turbine specifications

Wind Turbine: WTG02, Stark County, ND	
Latitude (decimal degrees)	46.859974
Longitude (decimal degrees)	-102.909412
Hub height (m)	80.0
Rotor diameter (m)	103.0
Overall height (m)	131.5

The proposed location of the wind turbine is Stark County, ND. Its location is shown in a satellite image as well as a map in Figure 4. The maximum possible extent of the rotor swept volume is represented by a circle:

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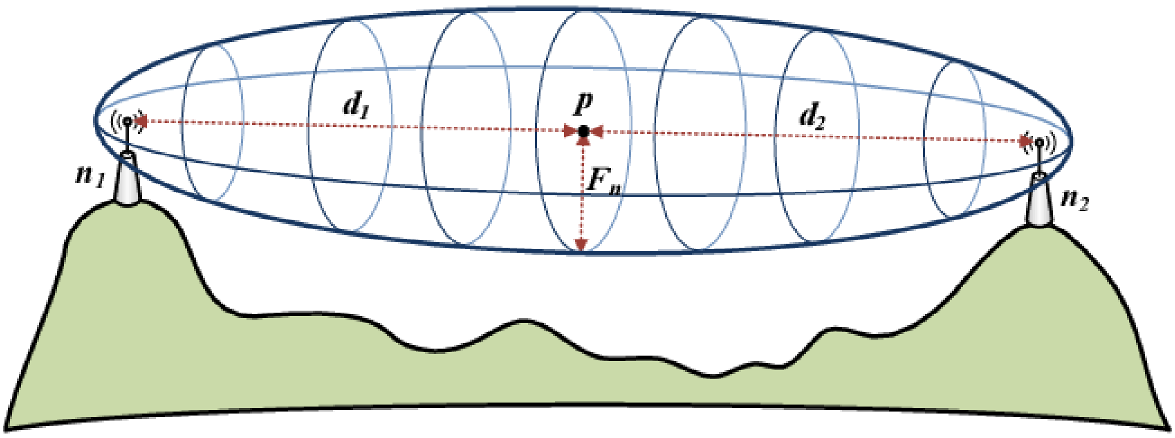

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where F_n is the radius of the nth Fresnel zone in meters;
n is the Fresnel zone number;
λ is the wavelength of the microwave signal in meters; and
d_1 and d_2 are the distances to n_1 and n_2, respectively, from the point p in question.

The second Fresnel zone is the largest at the midpoint between the two antennas where $d_1 = d_2$. Its radius is defined by:

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The results of the Spectrum-E calculations are in Table 3.

Table 3: Separation distances

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6 Conclusion

Point-to-point microwave links are communications systems that transmit their signals via beams of radio waves. Although 60% clearance of the first Fresnel zone is usually sufficient to guarantee undisturbed performance of a microwave link, in the case of wind turbines, the recommendation is to keep the second Fresnel zone 100% clear since wind turbines are not static obstacles.

The second Fresnel zone volumes of existing microwave links obtained from the FCC ULS were compared to the rotor volume of the proposed wind turbine. The nearest that the potential 3-dimensional rotor swept volume of the wind turbine approaches the second Fresnel zone of an existing microwave link is 2359.0 meters; therefore, interference to the microwave link is not expected.

Proposed Wind Turbine to Existing Microwave Link Analysis

WTG03
Stark County, ND

Prepared 26 April 2021 on behalf of One Energy

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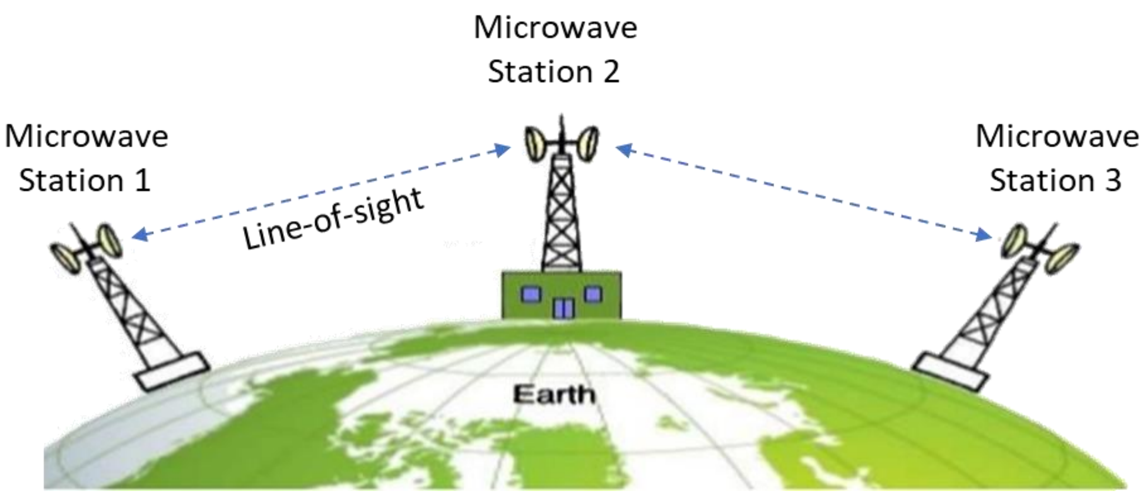

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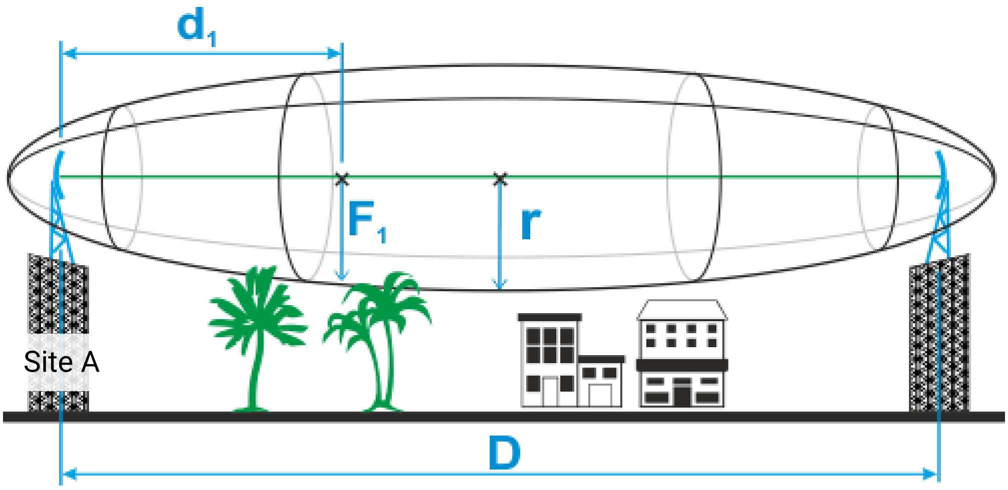

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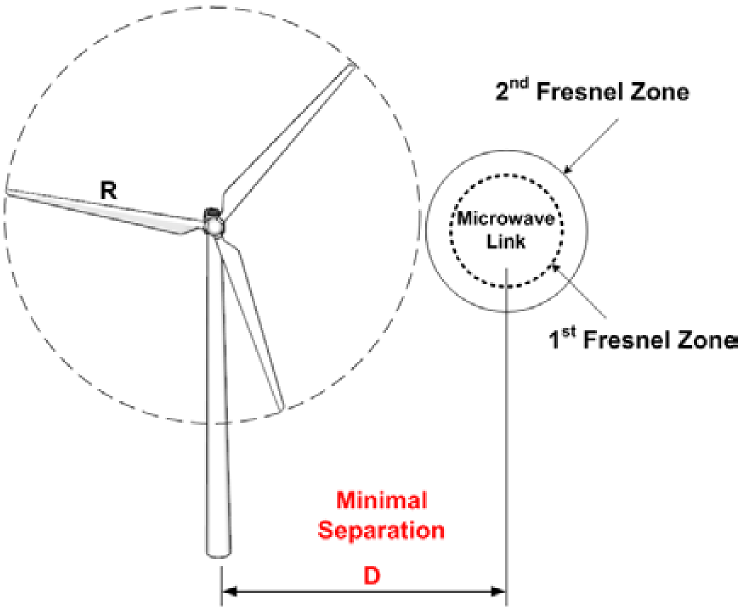

Figure 3: Cross-section view of minimum separation objective

2 Objective

The objective of this report is to utilize the cartographic data in Spectrum Center's radio frequency (RF) planning software (i.e., Spectrum-E™) to calculate separation distances between the three-dimensional rotor volume of a proposed wind turbine and the second Fresnel zone of existing microwave links.

3 Proposed wind turbine specifications

The specifications for the proposed wind turbine are provided below:

Table 1: Wind turbine specifications

Wind Turbine: WTG03, Stark County, ND	
Latitude (decimal degrees)	46.854388
Longitude (decimal degrees)	-102.903689
Hub height (m)	80.0
Rotor diameter (m)	103.0
Overall height (m)	131.5

The proposed location of the wind turbine is Stark County, ND. Its location is shown in a satellite image as well as a map in Figure 4. The maximum possible extent of the rotor swept volume is represented by a circle:

Figure 4: Proposed wind turbine location

4 Methodology for calculating the second Fresnel zone

A second Fresnel zone clearance method is applied to determine the protected volume of the fixed PTP microwave paths.

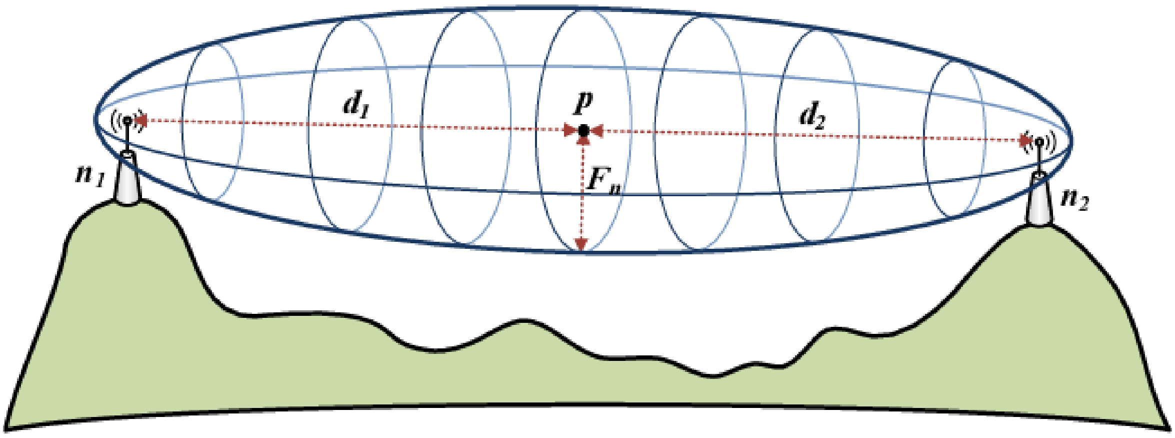

Figure 5: nth Fresnel zone calculation

Reffering to Figure 5, the Fresnel zone size depends on the frequency and distance from the microwave stations and is given by the generic formula

$$F_n = \sqrt{\frac{n\lambda d_1 d_2}{d_1 + d_2}}$$

where F_n is the radius of the nth Fresnel zone in meters;
n is the Fresnel zone number;
λ is the wavelength of the microwave signal in meters; and
d_1 and d_2 are the distances to n_1 and n_2, respectively, from the point p in question.

The second Fresnel zone is the largest at the midpoint between the two antennas where $d_1 = d_2$. Its radius is defined by:

$$r_{WCFZ_2} = 12.243\sqrt{\frac{D}{f}}$$

where r_{WCFZ2} is the radius of the second Fresnel zone in meters;
f is the frequency in gigahertz; and
D is the total link distance in kilometers.

This radius is commonly called the worst-case second Fresnel zone. When applied to a microwave link, it should provide enough clearance for the link to continue functioning without a significant drop in quality or reliability of transmission.

5 Analysis

5.1 Data retrieval

To ensure that the proposed wind turbine clears the second Fresnel zones of existing microwave paths in the area, records of licensed microwave links within a 25 km^2 square area around the proposed wind turbine are retrieved from the FCC Universal Licensing System (ULS). If there are none, the analysis is complete, and further analysis is unnecessary. The analysis uses the information available from the daily download dated 04/26/2021.

Figure 6 is a map of the proposed wind turbine and the retrieved licensed microwave links (in red) in active or pending status that are partially or completely within the search area, which is represented by the green box.

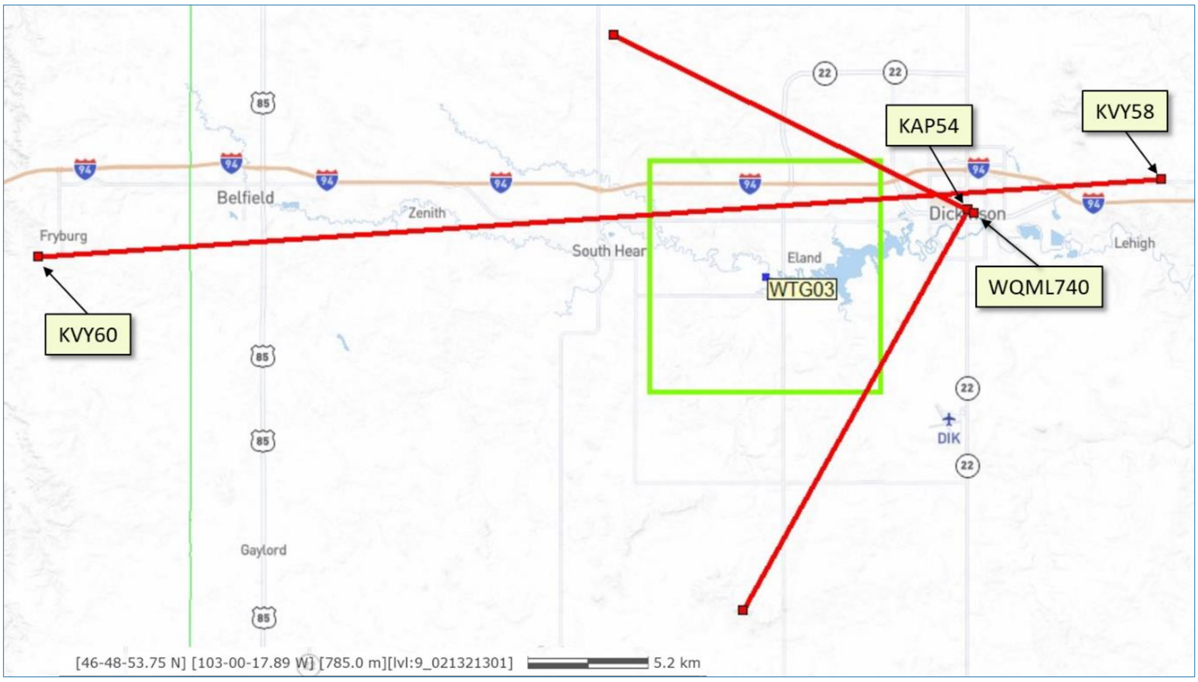

Figure 6: Proximity of wind turbine to existing microwave links

Information on the retrieved links is provided in the table below:

Table 2: Nearby microwave link(s)

Call sign	Licensee	Freq. (MHz)	Site A	Site B
WQML740	TOTALLY AMPED LLC	945.00	Dickinson	Tower
KVY58	BNSF Railway Co.	6635.00	Dickinson	Fryburg
KVY60	BNSF Railway Co	6795.00	Fryburg	Dickinson
KAP54	NEXSTAR INC.	6925.00-6950.00	Dickinson	-

5.2 Second Fresnel zone clearance results

Using the retrieved FCC ULS records and referring to Table 3, Spectrum-E™ calculates the following for each licensed microwave link:

- Either (1) the minimum separation distance (in meters) between the proposed wind turbine rotor blade and the worst-case second Fresnel zone of the microwave link or (2) the worst-case second Fresnel zone incursion, which is indicated by a negative value;
- The azimuth Azi (in degrees) of the wind turbine blade when it is closest to the worst-case second Fresnel zone or causing the worst-case incursion; and
- The azimuths Azi_1 and Azi_2 (in degrees) of the wind turbine blade before incursion.

The results of the Spectrum-E calculations are in Table 3

Table 3: Separation distances and azimuths

Call sign	Min. separation distance (m)	Azi (°)	Azi_1 (°)	Azi_2 (°)
KVY58	3008.3	356.1	-	-
KAP54	6107.3	119.4	-	-

6 Conclusion

Point-to-point microwave links are communications systems that transmit their signals via beams of radio waves. Although 60% clearance of the first Fresnel zone is usually sufficient to guarantee undisturbed performance of a microwave link, in the case of wind turbines, the recommendation is to keep the second Fresnel zone 100% clear since wind turbines are not static obstacles.

The second Fresnel zone volumes of existing microwave links obtained from the FCC ULS were compared to the rotor volume of the proposed wind turbine. The nearest that the potential 3-dimensional rotor swept volume of the wind turbine approaches the second Fresnel zone of an existing microwave link is 3008.3 meters; therefore, interference to the microwave link is not expected.

Proposed Wind Turbine to Existing Microwave Link Analysis

WTG04
Stark County, ND

Prepared 26 April 2021 on behalf of One Energy

1451 Dolley Madison Blvd | Suite 320 | McLean, VA 22101 | www.spectrum.center

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1 Introduction

1.1 Background

Due to their unique physical characteristics, wind turbines are potential interferers for wireless systems, such as communications links, air traffic control radars, and navigational aids. The nature and severity of the wind turbine interference depend on various factors, including

- The location of the wind turbine between receiver and transmitter;
- Characteristics of the rotor blades;
- Characteristics of receiver;
- Signal frequency; and
- The radio wave propagation in the local atmosphere.

Wireless communications systems include terrestrial microwave links. Two main types of terrestrial microwave links are those that communicate with satellites and those that communicate with each other in a point-to-point (PTP) fashion. Wind turbines are unlikely to affect satellite communications links because of the high angle of inclination of the earth station antenna. Wind turbines, however, may affect terrestrial PTP microwave links since the antenna heights at each end of a link are typically the minimum heights required to achieve line-of-sight.

PTP microwave transmission is the transmission of digital or analog signals in the microwave band, i.e., 1 to 30 gigahertz (GHz). Long-distance telephone calls, television programs, computer data, and cellular network backhaul are common microwave transmissions. Referring to Figure 1, in a fixed PTP microwave link, radio signals are transmitted between two locations with directional antennas. There must be line-of-sight between the two antennas because any structures or vegetation that partially or fully block the electromagnetic energy of the transmitted signal will lower the quality and reliability of transmission.

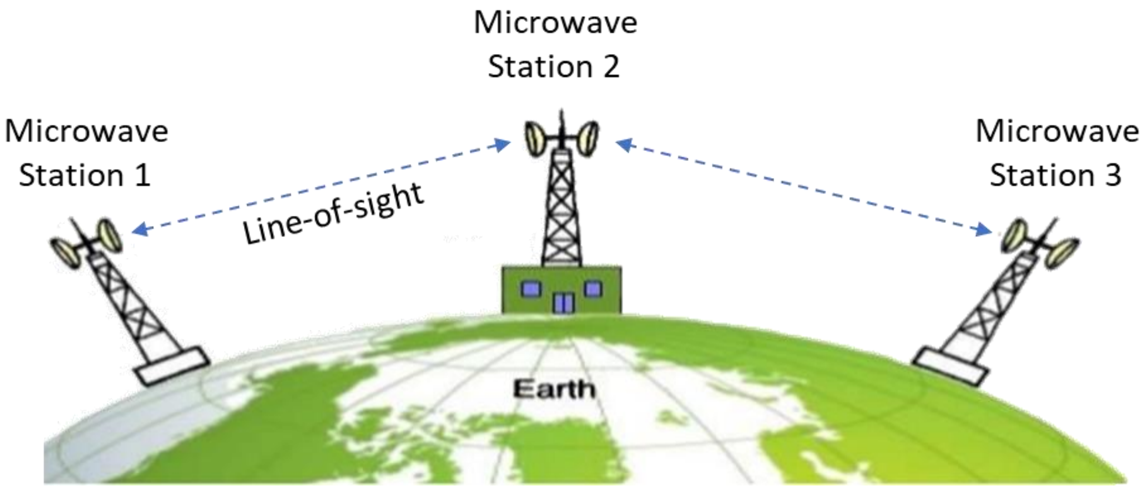

Figure 1: PTP microwave transmission (typical path length of approximately 40 – 60 km for frequencies below 11 GHz)

PTP microwave paths mainly consist of links licensed by the Federal Communications Commission (FCC) and are granted a certain level of protection from interference. For unlicensed transmission, a certain amount of degradation of service must be tolerated, as long as the object responsible for the degradation does not emit electromagnetic waves of too much power within the unlicensed frequency range.

1.2 Potential wind turbine effects on PTP microwave links

A wind turbine in close proximity to a single microwave link can degrade the link via three possible mechanisms:

- Near-field effects, which can occur when the wind turbine is within the near-field of a microwave antenna, thereby rendering prediction of the impact on the microwave link to be extremely complex since inductive as well as radiated fields have to be considered;
- Diffraction from the wind turbine's physical structure, which can detrimentally alter the advancing wavefront of a radio signal by obstructing the wave's path of travel; and
- Reflection/scattering from the rotating blades, which can receive a primary transmitted signal and produce and transmit a scattered signal that causes electromagnetic interference.

Various studies indicate that the main mechanisms by which a wind turbine may degrade radio link performance were those of diffraction in the Fresnel zone as well as reflection and scattering from the turbine structure and blades. Diffraction effects can be avoided if obstructions are kept outside the Fresnel zone of a microwave link. In regards to avoiding reflection and scattering effects, a method for determining the minimum distance between a wind turbine and a radio link has yet to be developed because there is insufficient information on radar cross section (RCS) values of wind turbines. RCS values quantify the extent to which an object will reflect or scatter radio waves. There is little detailed information on wind turbine RCS values because wind turbines have variable geometry. For example, in addition to the blades rotating, the horizontal axis of blade rotation varies in azimuth according to wind direction, and the pitch angle of the blades varies according to wind speed and electrical load. Consequently, only diffraction effects will be addressed in this analysis.

1.3 Fresnel zone clearance

As mentioned in the previous section, diffraction effects can be avoided if obstructions are kept outside the Fresnel zone of a microwave link. A Fresnel zone is an elliptical volume around a direct radio path that contains a certain amount of electromagnetic energy. Microwave operators use the concept of Fresnel zone clearance to prevent interference by obstacles near the direct radio path. When designing a fixed PTP microwave link, the operators usually try to clear at least 60% of the first Fresnel zone from large static obstructions, e.g., terrain or buildings.

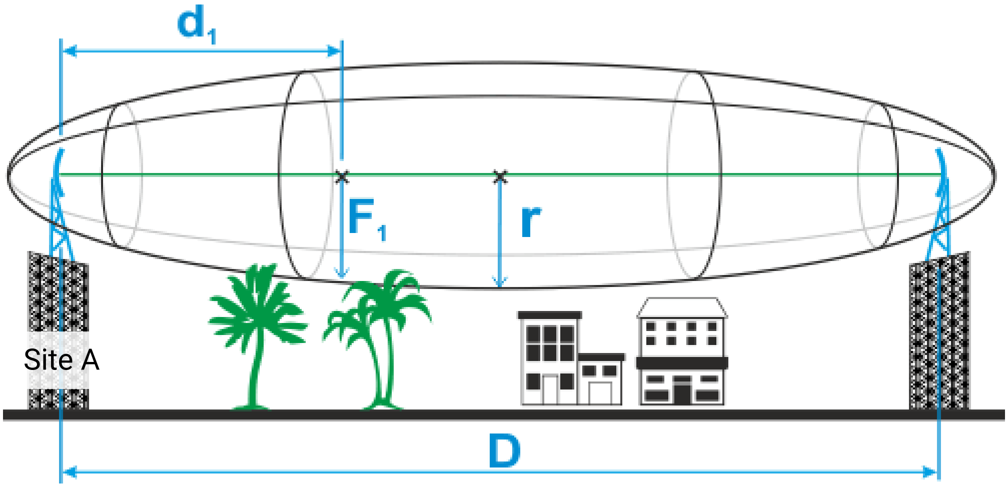

Figure 2: The first Fresnel zone (F_1) where D is the distance of the radio path, and r is the radius of the first Fresnel zone at a point along the path that is d_1 away from Site A

Using a more conservative criterion than 60% of the first Fresnel Zone is preferable for a wind turbine due to its varying geometry. It is an industry-accepted standard to define a wind turbine exclusion zone equal to the complete second Fresnel zone of a PTP microwave link to avoid any harmful effects caused by the energy contained in that volume, as shown below in Figure 3.

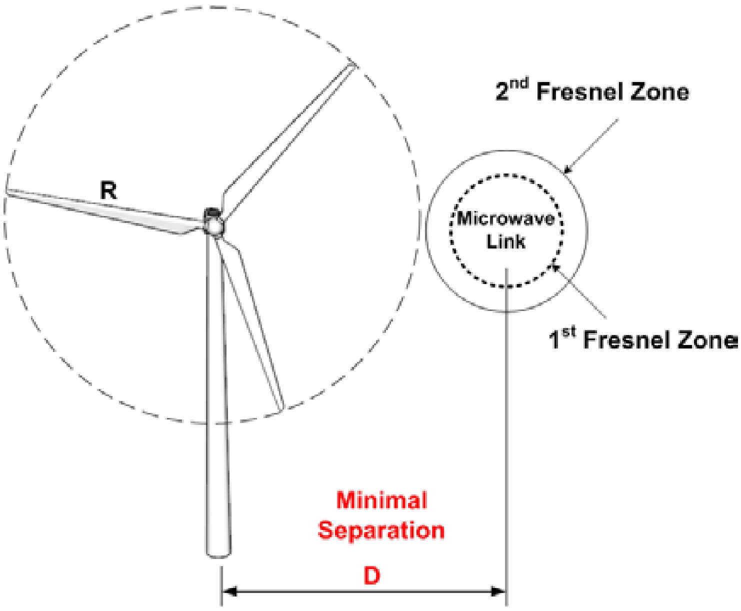

Figure 3: Cross-section view of minimum separation objective

2 Objective

The objective of this report is to utilize the cartographic data in Spectrum Center's radio frequency (RF) planning software (i.e., Spectrum-E™) to calculate separation distances between the three-dimensional rotor volume of a proposed wind turbine and the second Fresnel zone of existing microwave links.

3 Proposed wind turbine specifications

The specifications for the proposed wind turbine are provided below:

Table 1: Wind turbine specifications

Wind Turbine: WTG04, Stark County, ND	
Latitude (decimal degrees)	46.854733
Longitude (decimal degrees)	-102.900790
Hub height (m)	80.0
Rotor diameter (m)	103.0
Overall height (m)	131.5

The proposed location of the wind turbine is Stark County, ND. Its location is shown in a satellite image as well as a map in Figure 4. The maximum possible extent of the rotor swept volume is represented by a circle:

Figure 4: Proposed wind turbine location

4 Methodology for calculating the second Fresnel zone

A second Fresnel zone clearance method is applied to determine the protected volume of the fixed PTP microwave paths.

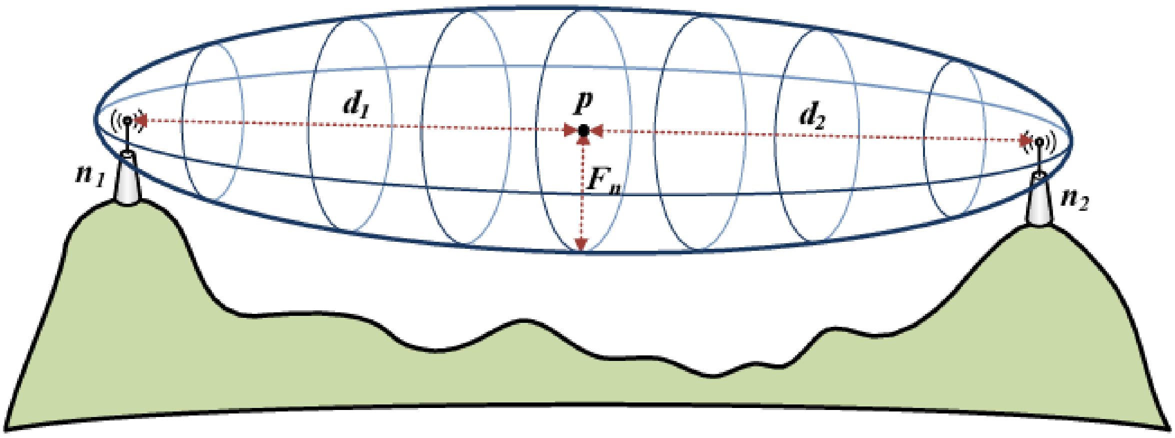

Figure 5: nth Fresnel zone calculation

Reffering to Figure 5, the Fresnel zone size depends on the frequency and distance from the microwave stations and is given by the generic formula

$$F_n = \sqrt{\frac{n\lambda d_1 d_2}{d_1 + d_2}}$$

where F_n is the radius of the nth Fresnel zone in meters;
n is the Fresnel zone number;
λ is the wavelength of the microwave signal in meters; and
d_1 and d_2 are the distances to n_1 and n_2, respectively, from the point p in question.

The second Fresnel zone is the largest at the midpoint between the two antennas where $d_1 = d_2$. Its radius is defined by:

$$r_{WCFZ_2} = 12.243\sqrt{\frac{D}{f}}$$

where r_{WCFZ2} is the radius of the second Fresnel zone in meters;
f is the frequency in gigahertz; and
D is the total link distance in kilometers.

This radius is commonly called the worst-case second Fresnel zone. When applied to a microwave link, it should provide enough clearance for the link to continue functioning without a significant drop in quality or reliability of transmission.

5 Analysis

5.1 Data retrieval

To ensure that the proposed wind turbine clears the second Fresnel zones of existing microwave paths in the area, records of licensed microwave links within a 25 km^2 square area around the proposed wind turbine are retrieved from the FCC Universal Licensing System (ULS). If there are none, the analysis is complete, and further analysis is unnecessary. The analysis uses the information available from the daily download dated 04/26/2021.

Figure 6 is a map of the proposed wind turbine and the retrieved licensed microwave links (in red) in active or pending status that are partially or completely within the search area, which is represented by the green box.

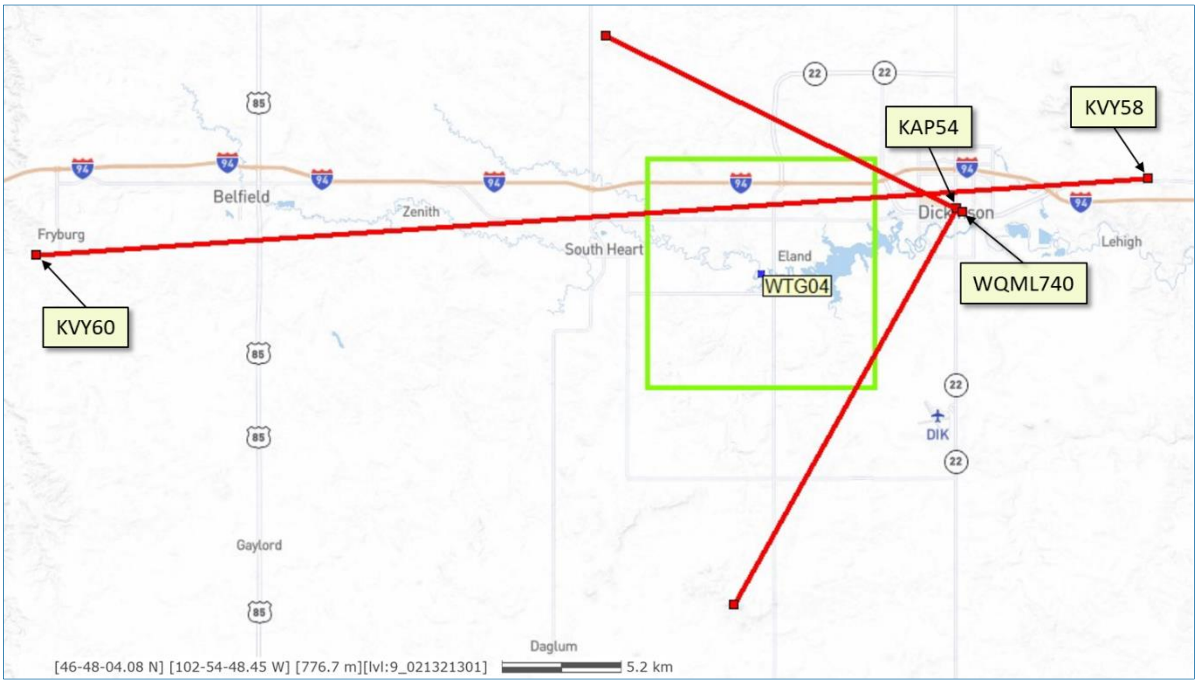

Figure 6: Proximity of wind turbine to existing microwave links

Information on the retrieved links is provided in the table below:

Table 2: Nearby microwave link(s)

Call sign	Licensee	Freq. (MHz)	Site A	Site B
WQML740	TOTALLY AMPED LLC	945.00	Dickinson	Tower
KVY58	BNSF Railway Co.	6635.00	Dickinson	Fryburg
KVY60	BNSF Railway Co	6795.00	Fryburg	Dickinson
KAP54	NEXSTAR INC.	6925.00-6950.00	Dickinson	-

5.2 Second Fresnel zone clearance results

Using the retrieved FCC ULS records and referring to Table 3, Spectrum-E™ calculates the following for each licensed microwave link:

- Either (1) the minimum separation distance (in meters) between the proposed wind turbine rotor blade and the worst-case second Fresnel zone of the microwave link or (2) the worst-case second Fresnel zone incursion, which is indicated by a negative value;
- The azimuth Azi (in degrees) of the wind turbine blade when it is closest to the worst-case second Fresnel zone or causing the worst-case incursion; and
- The azimuths Azi_1 and Azi_2 (in degrees) of the wind turbine blade before incursion.

The results of the Spectrum-E calculations are in Table 3

Table 3: Separation distances and azimuths

Call sign	Min. separation distance (m)	Azi (°)	Azi_1 (°)	Azi_2 (°)
KVY58	2985.1	356.1	-	-
KAP54	5933.4	119.4	-	-

6 Conclusion

Point-to-point microwave links are communications systems that transmit their signals via beams of radio waves. Although 60% clearance of the first Fresnel zone is usually sufficient to guarantee undisturbed performance of a microwave link, in the case of wind turbines, the recommendation is to keep the second Fresnel zone 100% clear since wind turbines are not static obstacles.

The second Fresnel zone volumes of existing microwave links obtained from the FCC ULS were compared to the rotor volume of the proposed wind turbine. The nearest that the potential 3-dimensional rotor swept volume of the wind turbine approaches the second Fresnel zone of an existing microwave link is 2985.1 meters; therefore, interference to the microwave link is not expected.

Proposed Wind Turbine to Existing Microwave Link Analysis

WTG05
Stark County, ND

Prepared 26 April 2021 on behalf of One Energy

SPECTRUM CENTER

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1 Introduction

1.1 Background

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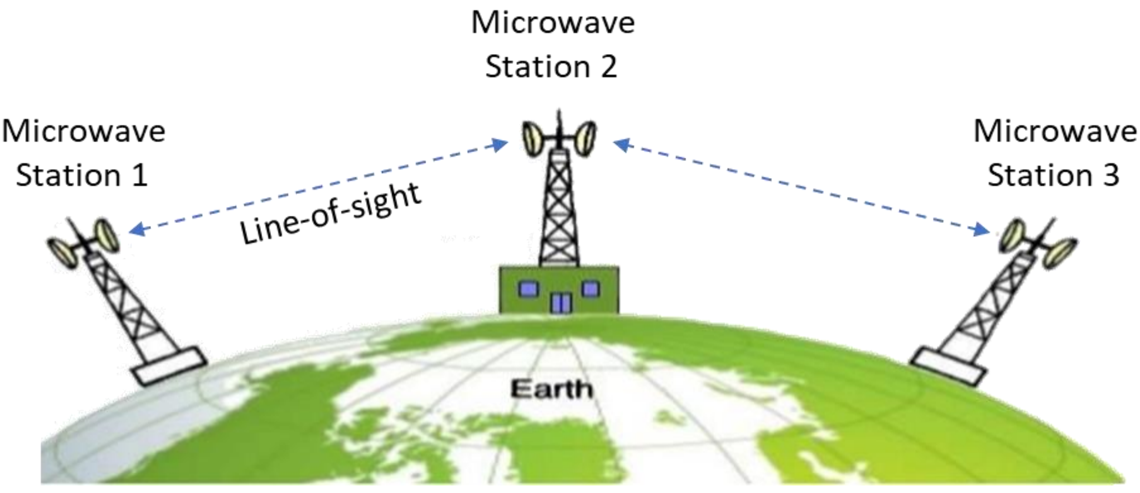

Figure 1: PTP microwave transmission (typical path length of approximately 40 – 60 km for frequencies below 11 GHz)

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Various studies indicate that the main mechanisms by which a wind turbine may degrade radio link performance were those of diffraction in the Fresnel zone as well as reflection and scattering from the turbine structure and blades. Diffraction effects can be avoided if obstructions are kept outside the Fresnel zone of a microwave link. In regards to avoiding reflection and scattering effects, a method for determining the minimum distance between a wind turbine and a radio link has yet to be developed because there is insufficient information on radar cross section (RCS) values of wind turbines. RCS values quantify the extent to which an object will reflect or scatter radio waves. There is little detailed information on wind turbine RCS values because wind turbines have variable geometry. For example, in addition to the blades rotating, the horizontal axis of blade rotation varies in azimuth according to wind direction, and the pitch angle of the blades varies according to wind speed and electrical load. Consequently, only diffraction effects will be addressed in this analysis.

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As mentioned in the previous section, diffraction effects can be avoided if obstructions are kept outside the Fresnel zone of a microwave link. A Fresnel zone is an elliptical volume around a direct radio path that contains a certain amount of electromagnetic energy. Microwave operators use the concept of Fresnel zone clearance to prevent interference by obstacles near the direct radio path. When designing a fixed PTP microwave link, the operators usually try to clear at least 60% of the first Fresnel zone from large static obstructions, e.g., terrain or buildings.

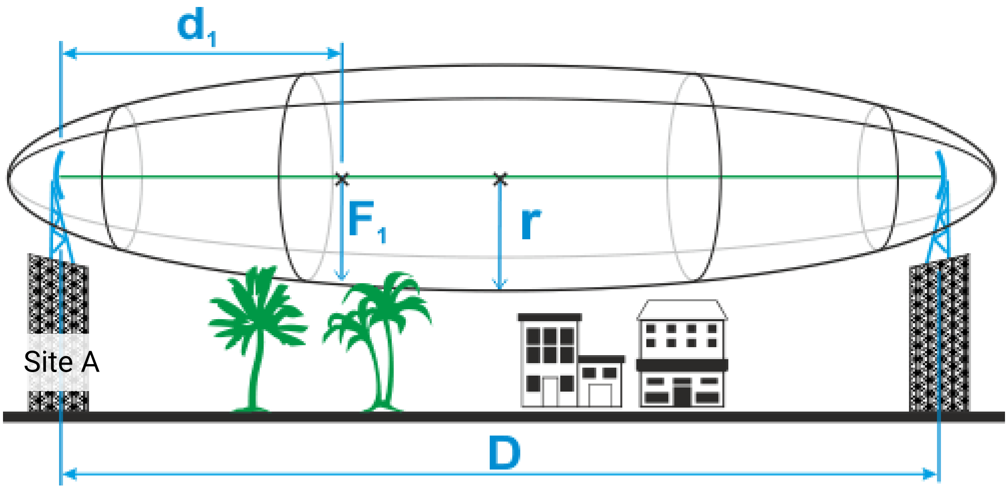


Figure 2: The first Fresnel zone (F_1) where D is the distance of the radio path, and r is the radius of the first Fresnel zone at a point along the path that is d_1 away from Site A

Using a more conservative criterion than 60% of the first Fresnel Zone is preferable for a wind turbine due to its varying geometry. It is an industry-accepted standard to define a wind turbine exclusion zone equal to the complete second Fresnel zone of a PTP microwave link to avoid any harmful effects caused by the energy contained in that volume, as shown below in Figure 3.

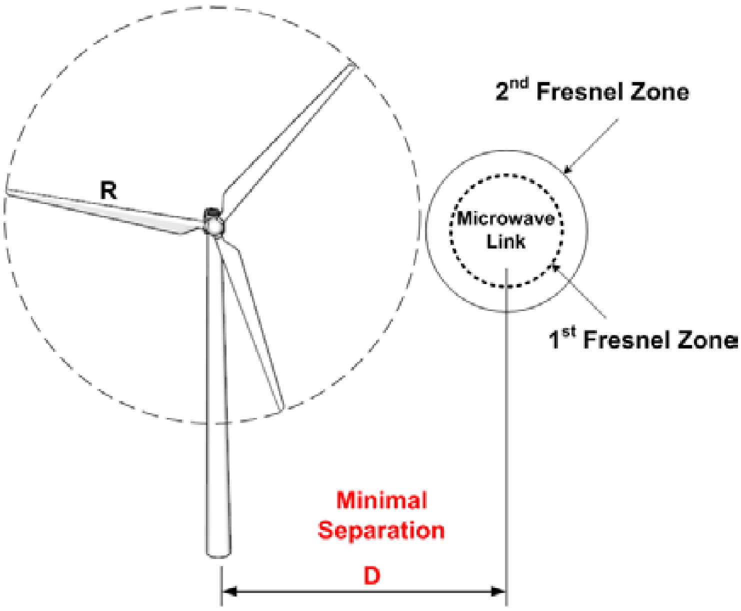


Figure 3: Cross-section view of minimum separation objective

2 Objective

The objective of this report is to utilize the cartographic data in Spectrum Center's radio frequency (RF) planning software (i.e., Spectrum-E™) to calculate separation distances between the three-dimensional rotor volume of a proposed wind turbine and the second Fresnel zone of existing microwave links.

3 Proposed wind turbine specifications

The specifications for the proposed wind turbine are provided below:

Table 1: Wind turbine specifications

Wind Turbine: WTG05, Stark County, ND	
Latitude (decimal degrees)	46.855505
Longitude (decimal degrees)	-102.898077
Hub height (m)	80.0
Rotor diameter (m)	103.0
Overall height (m)	131.5

The proposed location of the wind turbine is Stark County, ND. Its location is shown in a satellite image as well as a map in Figure 4. The maximum possible extent of the rotor swept volume is represented by a circle:

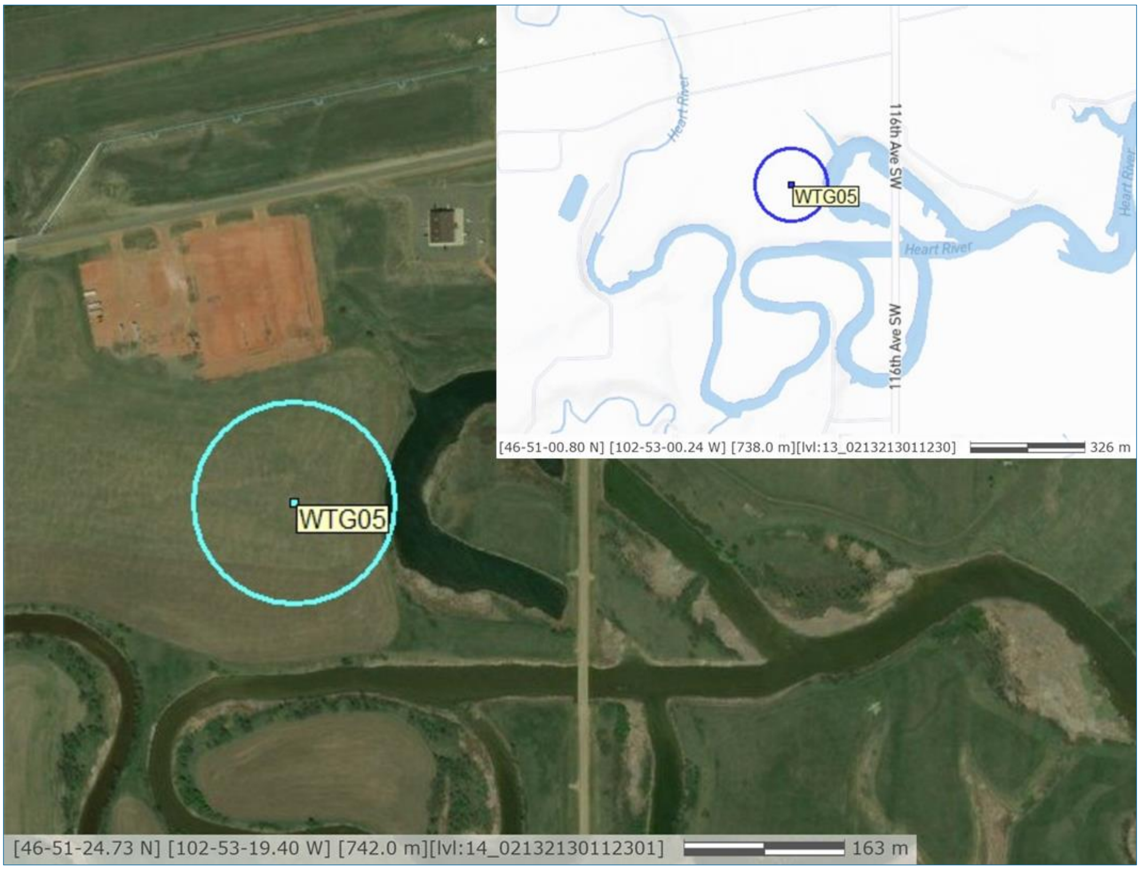
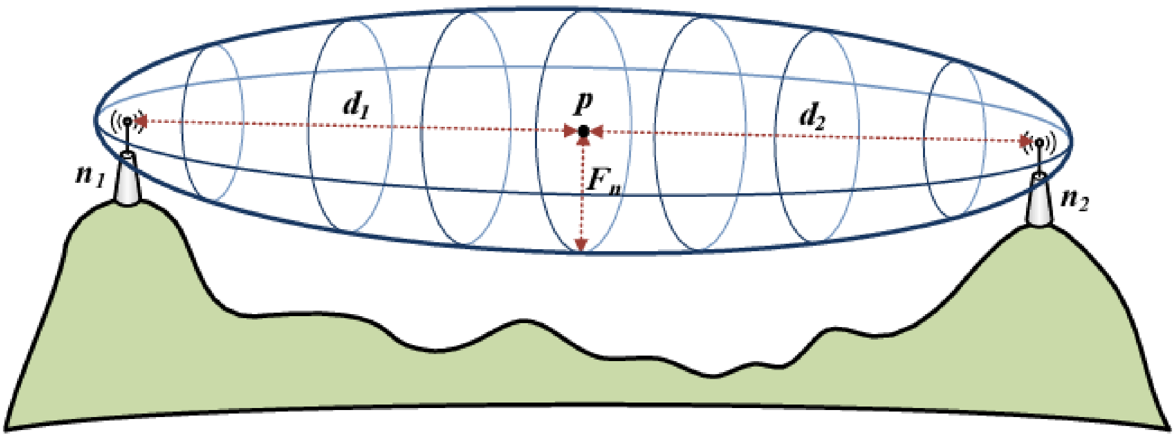


Figure 4: Proposed wind turbine location

4 Methodology for calculating the second Fresnel zone

A second Fresnel zone clearance method is applied to determine the protected volume of the fixed PTP microwave paths.



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where F_n is the radius of the nth Fresnel zone in meters;
n is the Fresnel zone number;
λ is the wavelength of the microwave signal in meters; and
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where r_{WCFZ2} is the radius of the second Fresnel zone in meters;
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This radius is commonly called the worst-case second Fresnel zone. When applied to a microwave link, it should provide enough clearance for the link to continue functioning without a significant drop in quality or reliability of transmission.

5 Analysis

5.1 Data retrieval

To ensure that the proposed wind turbine clears the second Fresnel zones of existing microwave paths in the area, records of licensed microwave links within a 25 km^2 square area around the proposed wind turbine are retrieved from the FCC Universal Licensing System (ULS). If there are none, the analysis is complete, and further analysis is unnecessary. The analysis uses the information available from the daily download dated 04/26/2021.

Figure 6 is a map of the proposed wind turbine and the retrieved licensed microwave links (in red) in active or pending status that are partially or completely within the search area, which is represented by the green box.

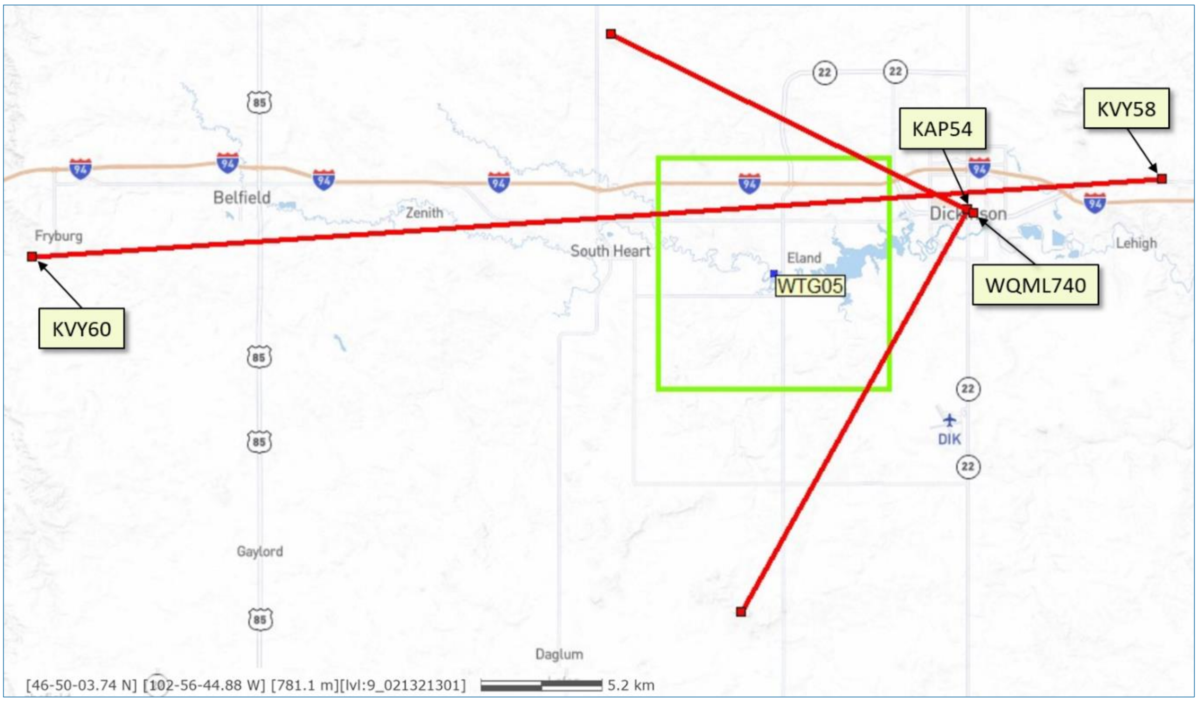

Figure 6: Proximity of wind turbine to existing microwave links

Information on the retrieved links is provided in the table below:

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Call sign	Licensee	Freq. (MHz)	Site A	Site B
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KVY60	BNSF Railway Co	6795.00	Fryburg	Dickinson
KAP54	NEXSTAR INC.	6925.00-6950.00	Dickinson	-

5.2 Second Fresnel zone clearance results

Using the retrieved FCC ULS records and referring to Table 3, Spectrum-E™ calculates the following for each licensed microwave link:

- Either (1) the minimum separation distance (in meters) between the proposed wind turbine rotor blade and the worst-case second Fresnel zone of the microwave link or (2) the worst-case second Fresnel zone incursion, which is indicated by a negative value;
- The azimuth Azi (in degrees) of the wind turbine blade when it is closest to the worst-case second Fresnel zone or causing the worst-case incursion; and
- The azimuths Azi_1 and Azi_2 (in degrees) of the wind turbine blade before incursion.

The results of the Spectrum-E calculations are in Table 3

Table 3: Separation distances and azimuths

Call sign	Min. separation distance (m)	Azi (°)	Azi_1 (°)	Azi_2 (°)
KVY58	2913.6	356.1	-	-
KAP54	5795.1	119.4	-	-

6 Conclusion

Point-to-point microwave links are communications systems that transmit their signals via beams of radio waves. Although 60% clearance of the first Fresnel zone is usually sufficient to guarantee undisturbed performance of a microwave link, in the case of wind turbines, the recommendation is to keep the second Fresnel zone 100% clear since wind turbines are not static obstacles.

The second Fresnel zone volumes of existing microwave links obtained from the FCC ULS were compared to the rotor volume of the proposed wind turbine. The nearest that the potential 3-dimensional rotor swept volume of the wind turbine approaches the second Fresnel zone of an existing microwave link is 2913.6 meters; therefore, interference to the microwave link is not expected.