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XCEL ENERGY

Colorado's Power Pathway

345 kV Line Audible Noise & Magnetic Field Report

Final

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POWER ENGINEERS

345 KV LINE AUDIBLE NOISE & MAGNETIC FIELD REPORT

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"Issued For" Definitions:
- "Prelim" means this document is issued for preliminary review, not for implementation
- "Appvl" means this document is issued for review and approval, not for implementation
- "Impl" means this document is issued for implementation
- "Record" means this document is issued after project completion for project file

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EXECUTIVE SUMMARY

POWER Engineers, Inc. (POWER) was tasked with performing calculations and providing results for the investigation of audible noise (AN) and magnetic field related to Public Service Company of Colorado's (Public Service or the Company) proposed new double circuit 345 kV transmission line located in eastern Colorado to tie together seven existing and new substations: Fort St. Vrain, Canal Crossing, Pawnee, Goose Creek, May Valley, Tundra, and Harvest Mile. This report provides documentation of data, assumptions, analysis techniques, and results for audible noise and magnetic field of the 1272 ACSR Bittern conductor, as well as the alternative conductor selection of 556 twisted pair (T2) ACSR Dove, each on a double circuit structure.

The audible noise results [dB(A)] generated in this study were measured at 25 feet beyond the edge of the right-of-way (ROW) and the magnetic field results were measured at the edge of the ROW, consistent with Colorado Public Utilities Commission (PUC) Rule 3206(f) and (e), respectively. The purpose of these analyses is to support the Public Service's application for a CPCN for the transmission line and certain related substations. The results of these analyses, including this report, will be submitted to the PUC with the CPCN application.

At 25 feet beyond the edge of the ROW, the calculated AN results for both conductor types are below 50 dB(A), which is the most stringent noise level (for residential areas) deemed reasonable under PUC Rule 3206(f). The magnetic field results at the edge of the ROW for both conductor types are below the 150 milliGauss (mG) level deemed reasonable by PUC Rule 3206(e) at 25%, 50% and 100% of the conductor current carrying capacity. The results for 1272 ACSR Bittern conductor are provided in Table 1. The full results for the 1272 ACSR Bittern and the alternative 556 twisted pair (T2) ACSR Dove conductors are provided in Section 4.

Table 1: Results Summary

Case	Location	Deemed Reasonable Level (PUC Rule 3206)	Results
Audible Noise	25 Feet Outside Edge of ROW	50 dB(A) (Residential – most stringent level)	49.8 dB(A)
Magnetic Field	Edge of ROW	150 mG	54.7 mG

PROJECT NEED

In 2018, Public Service announced the Company's vision to reduce carbon emissions 80 percent by 2030 company-wide from 2005 levels and to provide 100 percent carbon-free electricity by 2050. In order to achieve an 80 percent reduction by 2030, extra high voltage transmission infrastructure will need to be constructed to assist bringing renewable generation from northeastern, eastern and/or southern parts of Colorado to the Denver Metro area and the Company's existing transmission system.

PROJECT DESCRIPTION

Colorado's Power Pathway project will consist of a double circuit 345 kV transmission line that will connect with seven existing and new stations: Fort St. Vrain, Canal Crossing, Pawnee, Goose Creek, May Valley, Tundra, and Harvest Mile. Figure 1 shows the larger project area with the double circuit 345 kV transmission line.

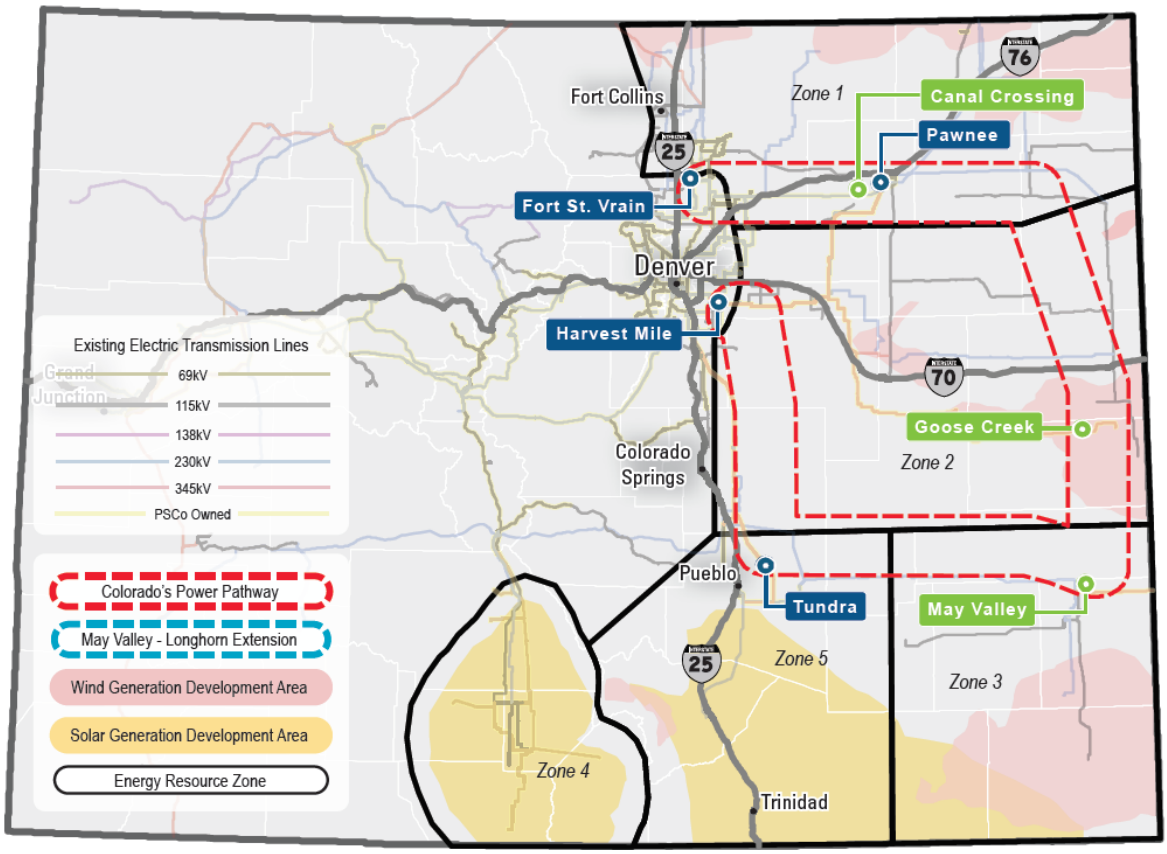


Figure 1: 345 kV Transmission Line General Area Overview

DATA

The two conductor types analyzed were 1272 ACSR Bittern and 556 twisted pair (T2) ACSR Dove. Table 2 provides the loading of each conductor (in percentage as a function of the conductor current carrying capacity) as provided by Public Service, to be used in this study and the equivalent conductor diameter. Both conductors are two-conductor bundle with a horizontal spacing of 18 inches.

Table 2: Conductor Loading and Sizes				
Conductor	Loading (amperes)			Diameter (inches)
	25%	50%	100%	
1272 ACSR Bittern	723	1,445	2,890	1.345
556 T2 Dove	786	1,571	3,142	1.517

The double circuit structure reviewed is provided in Appendix A. Dimensions shown for the double circuit structure in Appendix A were used in calculations to obtain audible noise and magnetic field results. Figure 2 shows the phasing for the double circuit structure.

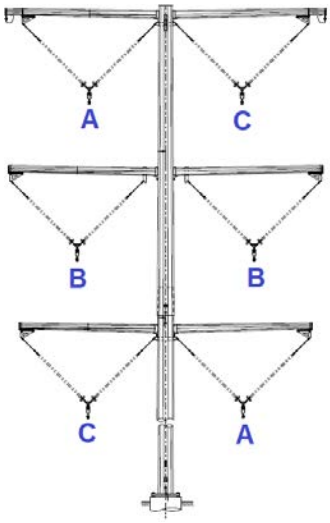


Figure 2: Double Circuit Phasing

Additional data used in the audible noise and magnetic field calculations are listed below.

- Average line altitude: 7,000 feet
- Right-of-Way (ROW) width: 150 feet
- Operating voltage: 345 kV
- Conductor minimum height: 30.5 feet
- Lower conductor average height: 51.5 feet
- Shield Wires: Two AFL DNO-10723 OPGW, 0.555-inch diameter

The shield wires were assumed to have 10-foot less sag than the phase conductors.

Any changes to the conductors, dimensions, or the phase arrangement could affect the results of the study.

PUC RULES AND STUDY METHODOLOGY

Applicable Rules for Magnetic Fields and Audible Noise

PUC Rule 3206 – Construction or Extension of Transmission Facilities (4 CCR 723-3-3206) requires new transmission facilities comply with Rule 3206 (f) for audible noise and 3206 (e) for magnetic fields.

Magnetic Field levels are detailed in section 3206(e), which states the following:

> The filing shall include the expected maximum level of magnetic fields that could be experienced under design conditions at the edge of the transmission line right of way or Station boundary, at a location of one meter above ground.

In addition, Rule 3206(e)(III) provides that "[p]roposed magnetic field levels of 150 mG (milliGauss) and below are deemed reasonable by rule and need not be mitigated to a lower level."

Audible Noise levels are detailed in section 3206(f), which states the following:

> The filing shall include the projected noise radiating beyond the property line or right-of-way (as applicable) at a distance of 25 feet.

Rule 3206(f)(II) provides that proposed levels of noise at or below the values listed below, by land use zoning designations, are deemed reasonable by rule and need not be mitigated to a lower level:

(A)	Residential	50 db(A)
(B)	Commercial	55 db(A)
(C)	Light industrial	65 db(A)
(D)	Industrial	75 db(A)

Rule 3206(f)(III) further provides that for land that has a zoning designation other than one of the four designation enumerated above, proposed noise levels will not be subject to further review if the proposed noise threshold is 50 dB(A) or below regardless of use of land.

Colorado's Power Pathway will generally be a greenfield construction project and will be approximately 560 miles in length. The transmission line will span several counties in Colorado and will likely cross through multiple different zoning districts with different zoning designations.

Transmission Line Magnetic Fields and Audible Noise Analysis Methodology and Assumptions

The audible noise and magnetic field analysis was performed using the Bonneville Power Administration's (BPA) Corona and Field Effects Program (CAFEP) software version 3, which is a utility standard program for noise and magnetic field modeling. CAFEP uses the electrical and

physical characteristics of the transmission line to calculate resulting fields and interference effects from the transmission lines.

The audible noise is primarily a function of the maximum operating voltage of conductors but is also impacted by the diameter of the conductors, distance of the conductors from each other, and elevation of the line above sea level. Audible noise was analyzed at the average conductor height along a span, as is standard in the industry.

Magnetic fields were primarily a function of the line current loading, which varies over time. The magnetic fields calculations were performed at 25%, 50% and 100% conductor current carrying capacity, as defined for each conductor in Table 2. For the analysis, magnetic fields were analyzed at a minimum conductor height (near mid-span, at maximum sag), as this location will produce the worst-case scenario (*i.e.* the highest magnetic field values).

Audible Noise (AN)

Audible noise is measured as an equivalent A-weighted sound-pressure level in decibels [dB(A)]. The L50 audible noise values represent the predicted average noise levels. The actual value is expected to be at or below this calculated L50 value 50% of the time, and above the value the other 50% of the time. Values are calculated at a height of five feet above the ground per IEEE Std 656-2018, using an estimated average conductor height of two-thirds the MOT (Maximum Operating Temperature) sag to approximate the average values along the entire line. In general, audible noise is highest during foul weather conditions (rain) as can be seen in the Results section for Audible Noise.

A single pole structure was modeled for audible noise. The new 345 kV lines are generally anticipated to be located in the center of a 150-foot-wide ROW.

Magnetic Fields

The reported magnetic field values are the magnetic flux density at a given point in space. Magnetic flux density is measured in gauss or milligauss (mG). Magnetic fields were analyzed at minimum conductor height above ground. Magnetic fields are analyzed at the edge of right-of-way for transmission lines and at a height of one meter (3.28 ft) above ground per IEEE Std 644-2019 and consistent with PUC Rule 3206(e).

A transmission line was modeled using a single pole structure. The new 345 kV lines are generally anticipated to be located in the center of a 150-foot-wide ROW.

RESULTS

Results for audible noise and magnetic field calculations are shown as to allow a comparison of results by conductor types.

Audible Noise (AN) Results

The calculated results of the audible noise (AN) for each specified conductor type are shown in Table 3. Audible Noise results are analyzed at the centerline, at the edge of right-of-way, and at 25 feet beyond the edge of right-of-way.

Table 3: Audible Noise Results

Conductor	Audible Noise [dB(A)] Per Location					
	Rain			Fair		
	25 Feet Beyond ROW	Edge of ROW	Centerline	25 Feet Beyond ROW	Edge of ROW	Centerline
Most stringent deemed reasonable level [Residential] (PUC Rule 3206)	*50*	*N/A*	*N/A*	*NA*	*N/A*	*N/A*
Bittern	49.8	50.7	52.9	24.8	25.7	27.9
T2 Dove	47.6	48.5	50.7	22.6	23.5	25.7

Figure 3 and Figure 4 show plots of the audible noise results for foul weather (rain) conditions and fair weather (dry) conditions, respectively, by conductor type.

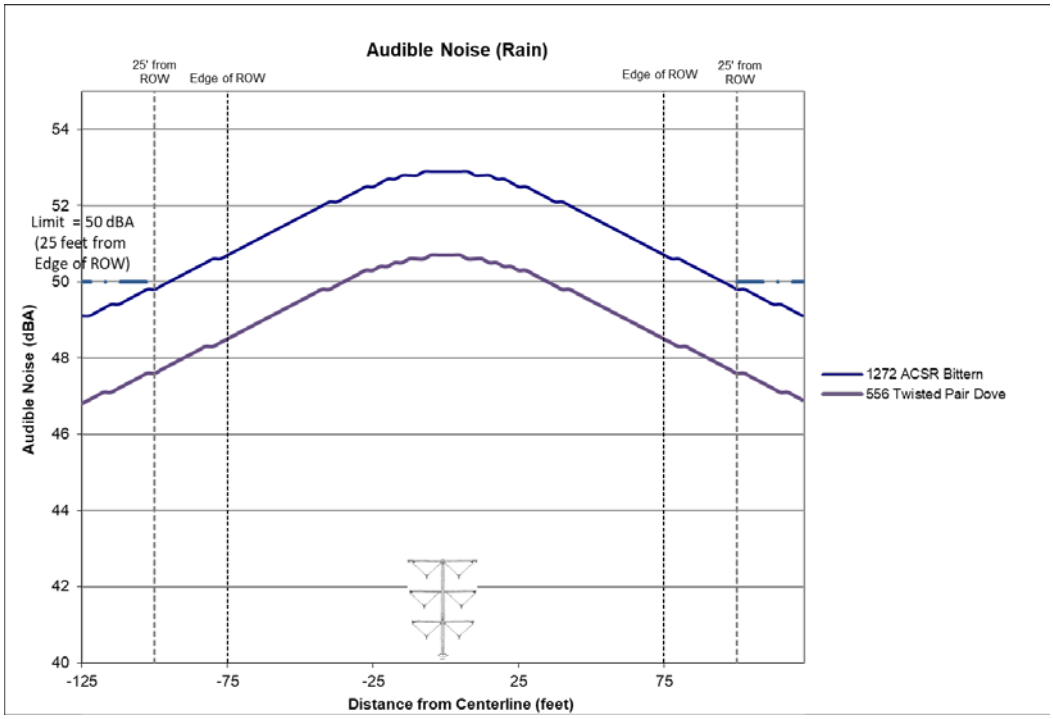


Figure 3: Audible Noise (AN) – Rain

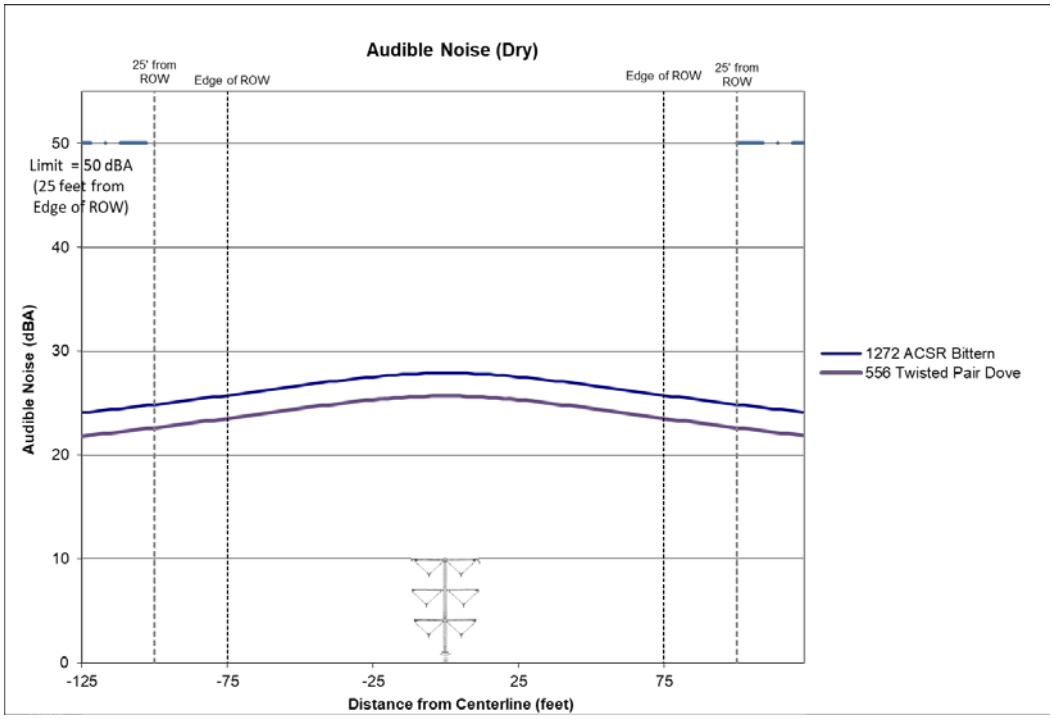


Figure 4: Audible Noise (AN) – Fair Weather (Dry)

The audible noise results for both foul weather (rain) conditions and fair conditions are below 50 dB(A) at 25 feet from both sides of the edge of the ROW. The audible noise levels are below all levels deemed reasonable by Commission rule, including the Commission's most stringent 50 dB(A) residential noise limit set forth in Rule 3206(f).

Magnetic Fields

The calculated magnetic field results are shown in Table 4. Magnetic field results are analyzed within the right-of-way for maximum value and at the edge of right-of-way for each 25%, 50%, and 100% of the conductor current carrying capacity.

Table 4: Magnetic Field Results

Conductor	Edge of ROW Magnetic Field (mG)		
	25% Capacity	50% Capacity	100% Capacity
Deemed reasonable level (PUC Rule 3206)	*150*	*150*	*150*
Bittern	13.7	27.4	54.7
T2 Dove	14.9	29.7	59.5

Figure 5, Figure 6, and Figure 7 show plots of the magnetic field results at 25%, 50% and 100% capacity, respectively, by conductor type.

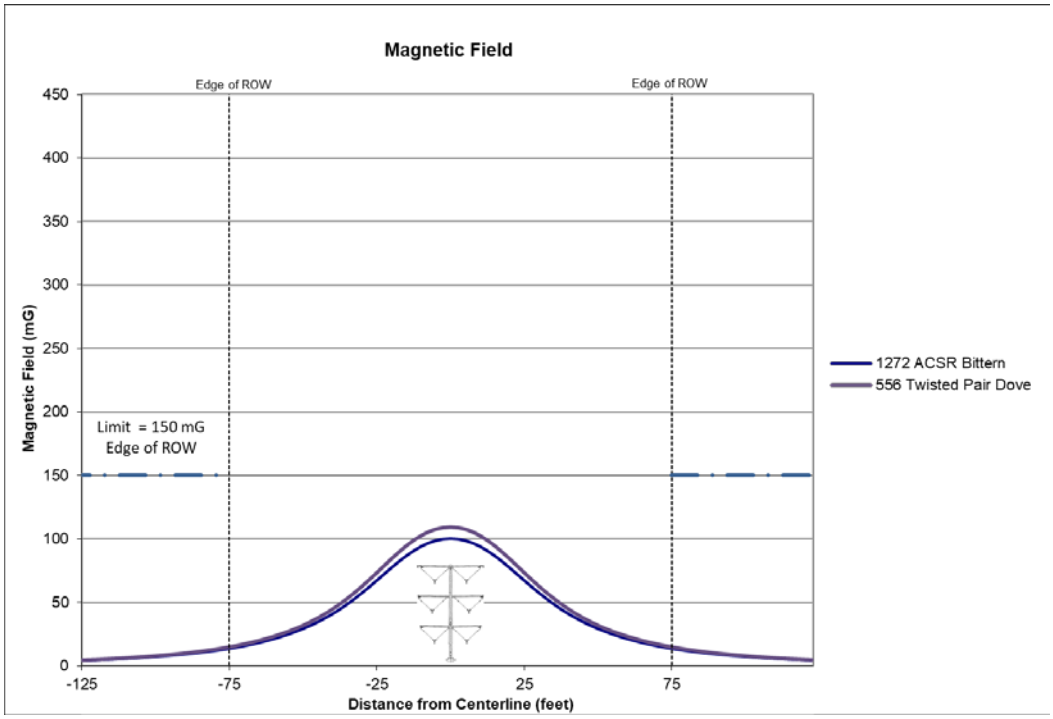


Figure 5: Magnetic Field (MF) – 25% Capacity

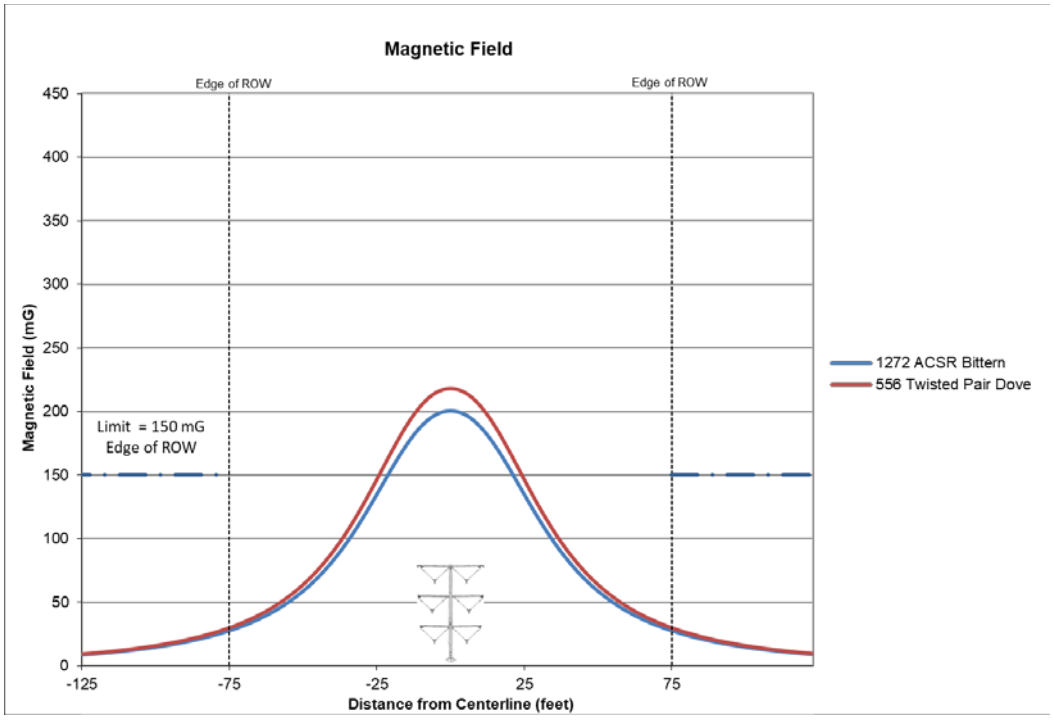


Figure 6: Magnetic Field (MF) – 50% Capacity

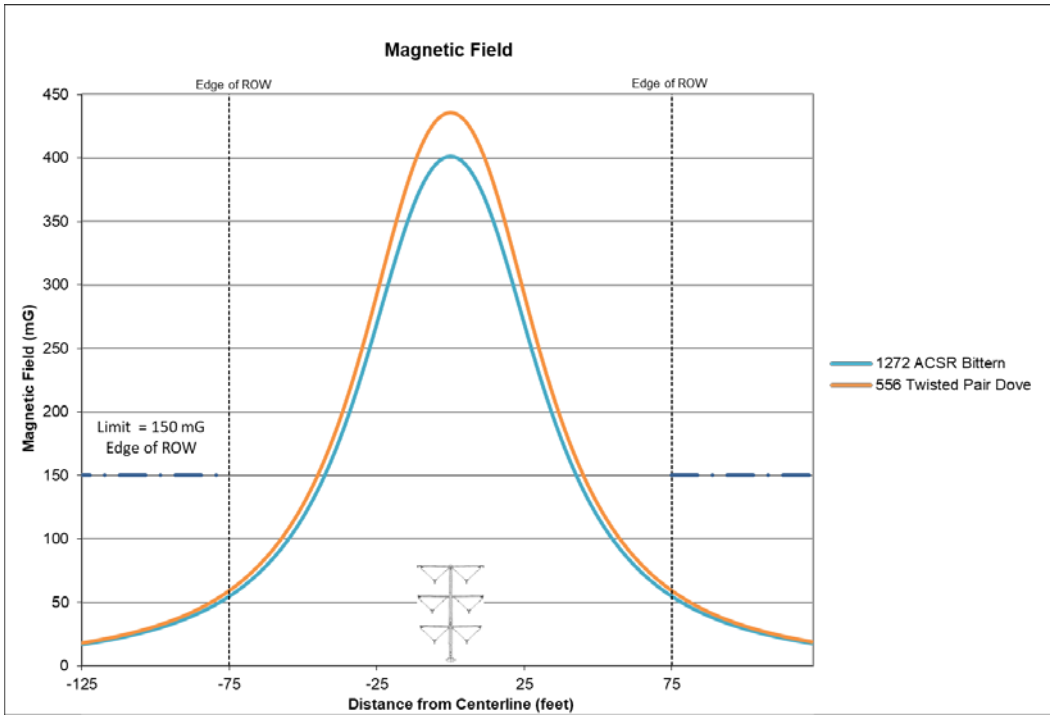


Figure 7: Magnetic Field (MF) – 100% Capacity

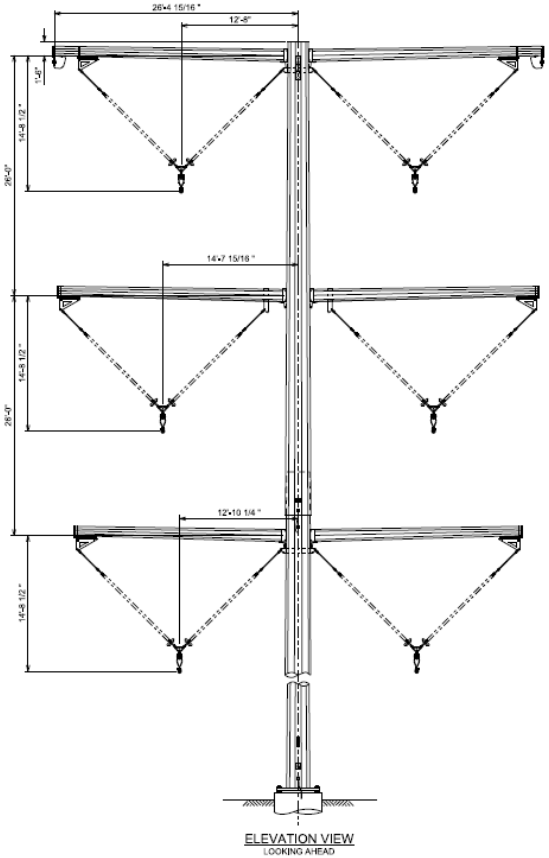
The magnetic field results for all conductor current carrying capacity are well below the 150 mG deemed reasonable at the edge of the ROW by PUC Rule 3206(e).

CONCLUSIONS

Audible noise levels [dB(A)] were analyzed at the centerline, at the edge of right-of-way, and at 25 feet beyond the edge of right-of-way. The results indicate that the noise levels in both fair and wet conditions from both potential conductor types reviewed (1272 ACSR Bittern and 556 twisted pair ACSR Dove) would fall below all audible noise levels deemed reasonable by the Rule 3206(f), including the most stringent residential level 50 dB(A) at 25 feet beyond the edge of the ROW.

Magnetic Fields were analyzed at the edge of the ROW and the magnetic fields from both potential conductor types are below the 150 mG magnetic field level that is deemed reasonable by Rule 3206(e).

APPENDIX A – STRUCTURE DRAWINGS AND REFERENCE DATA



ELEVATION VIEW
LOOKING AHEAD

REV	DATE	WBS 4	REVISION DESCRIPTION

I hereby certify that this plan, specification, or report was prepared by me or under my direct supervision and that I am a duly Licensed Professional Engineer under the laws of the state of Minnesota.

Signature: _____

Typed or Printed Name: _____

Date: _____

License Number: _____

ISSUED BY ENGINEERING DEPT FOR: CONSTRUCTION

CIRCUIT 345 kV
STRUCTURE DRAWING - TANGENT - STEEL - D,C, - SINGLE POLE
0-2 DEGREE, V-STRING, VERTICAL

Xcel Energy® | ERP_345-TAN-2CKT | SCALE NONE | REV. 0

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