

Exhibit AA

Electromagnetic Frequencies from Transmission Lines

**Carty Generating Station
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Prepared for



Portland General Electric Company

Prepared by



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Acronyms and Abbreviations

AC	alternating current
BCP	Boardman Coal Plant
BESS	battery energy storage system
BLM	Bureau of Land Management
BPA	Bonneville Power Administration
CAFE	Corona and Fields Effect Program
Certificate Holder / PGE	Portland General Electric Company
CGS / Facility	Carty Generating Station
Council	Oregon Energy Facility Siting Council
dB	decibel
ELF	extremely low frequency
EMF	electromagnetic field
EMR	electromagnetic radiation
FCC	Federal Communications Commission
GHz	gigahertz
GPS	Global Positioning System
Hz	hertz
ICES	International Committee on Electromagnetic Safety
ICNIRP	International Commission on Non-Ionizing Radiation Protection
IEEE	Institute of Electrical and Electronics Engineers
kHz	kilohertz
kV	kilovolt
m	meter
MHz	megahertz
mG	milligauss
MW	megawatt
OAR	Oregon Administrative Rules
RFA	Request for Amendment
$\mu\text{V/m}$	microvolt per meter

1.0 Introduction

The Portland General Electric Company (PGE or Certificate Holder) is submitting a Request for Amendment (RFA) 4 to the Site Certificate for the Carty Generating Station (CGS or Facility). The Facility is located approximately 13 miles southwest of Boardman, in Morrow County, Oregon. As currently approved, the Facility is capable of generating up to 450 megawatts (MW) from the natural gas-fueled combined-cycle unit (Unit 1).

In RFA 4, the Certificate Holder is proposing photovoltaic solar energy generation with approximately 200 MW alternating current (AC) of nominal and average generating capacity and BESS with the capability of storing up to 200 MW AC. The overall CGS additions proposed with RFA 4 (including the BESS) are referred to throughout this request as the Carty Solar Farm with proposed RFA 4 changes. The solar generation is proposed in two separate solar areas referred to as the Northern Solar Area, located north of the Carty Reservoir, and the Southern Solar Area, located south of the reservoir [see Figure 2 in RFA 4's Division 27 document (Request for Amendment 4 for the Carty Generating Station)].

This Exhibit AA was prepared to meet the submittal requirements in Oregon Administrative Rules (OAR) 345-021-0010(1)(aa). Analysis in this exhibit incorporates and/or relies on reference information, analysis, and findings found in the Application for Site Certificate, previous RFAs, and Oregon Department of Energy Final Orders to demonstrate that the Facility, as modified by RFA 4, continues to comply with applicable Site Certificate conditions and the standard in OAR 345-021-0010(1)(aa). OAR 345 Division 22 does not provide an approval standard specific to Exhibit AA. This exhibit also includes the submittal requirements outlined in the Specific Standards for Transmission Lines under OAR 345-024-0090:

(1) Can design, construct and operate the proposed transmission line so that alternating current electric fields do not exceed 9 kV per meter at one meter above the ground surface in areas accessible to the public;

(2) Can design, construct and operate the proposed transmission line so that induced currents resulting from the transmission line and related or supporting facilities will be as low as reasonably achievable.

1.1 EMF Background Information

Electromagnetic fields (EMFs) occur both naturally and as a result of the generation, transmission, and use of electric power. The earth itself generates steady-state magnetic and electric fields. Electromagnetic fields are present around any conductors or devices that transmit or use electrical energy; as a result, exposure to EMF is common from an array of electrical appliances and equipment, building wiring, and electric distribution and transmission lines. The electrical power system in the United States is an alternating current (AC) system operating at a frequency of 60

hertz (Hz)¹, resulting in “power frequency” or “extremely low frequency (ELF)” EMF.² While electric and magnetic fields are often referred to and thought of collectively, each arises through a different mechanism and can have differing effects.

Electric fields around transmission lines are produced by the presence of an electric charge, measured as voltage, on the energized conductor. Electric field strength is directly proportional to the line’s voltage; that is, increased voltage produces a stronger electric field. The strength of the electric field is inversely proportional to the square of distance from the conductors; the electric field strength declines as the distance from the conductor increases. The strength of the electric field is measured in units of kilovolts (kV) per meter (m) or kV/m. Electric fields are readily weakened or blocked by conductive objects such as trees or buildings. The direction of force within the electric field alternates at a frequency of 60 Hz, in direct relation to the charge on each conductor. However, the overall transmission line voltage, and therefore the overall strength and reach of the electric field, remains practically steady and is not affected by the common daily and seasonal fluctuations in usage of electricity by customers.

Magnetic fields around transmission lines are produced by the movement of electrical charge, measured in terms of amperage, through the conductors. Like the electric field, the magnetic field alternates at a frequency of 60 Hz. Magnetic field strength is expressed in units of milligauss (mG).³ The magnetic field strength is directly proportional to the amperage; that is, increased current flow resulting from increased power flow through the line produces a stronger magnetic field. As with electric fields, the magnetic field is inversely proportional to the square of the distance from the conductors, declining in strength as the distance from the conductor increases. Magnetic fields are not blocked or shielded by most materials. Unlike voltage, the amperage and the resulting magnetic field around a transmission line fluctuate daily and seasonally as the usage of electricity varies and the resulting amount of current flow varies.

Each AC three-phase circuit carries power over three conductors. One phase of the circuit is carried by each of the three conductors. The AC voltage and current in each phase conductor is out of sync with the other two phases by 120 degrees, or one-third of the 360-degree cycle. The fields from each of these conductors tend to cancel each other out because of this phase difference. However, since the conductors are separated from each other, when a person stands under a transmission line, one conductor is somewhat closer than the others and will contribute a net uncanceled field at the person’s location.

¹ Hertz is a measure of cycles per second. In a 60-Hz transmission system, the charge and direction of current flow on each conductor will cycle from positive to negative and back to positive 60 times per second. The direction of force in the electric and magnetic fields will also cycle in direct relation to the charge and direction of flow on the conductor.

² The electric transmission system in the U.S. operates at 60 Hz, while in Europe and other parts of the world, the systems operate at 50 Hz; both produce fields that are referred to as power frequency or ELF EMF.

³ Magnetic field strength may also be measured in terms of the Tesla, an International System unit of measurement. 1 Gauss = 0.0001 Tesla, or 1 Tesla = 10,000 Gauss; 1 Gauss = 1,000 mG.

1.2 EMF Standards

No federal regulations or guidelines apply directly to the EMF levels for transmission lines. The National Institute of Environmental Health Sciences performed an extensive review of field-related issues in the 1990s that resulted in the decision that regulatory actions are unwarranted (NIEHS 1999).

Although there are no federal regulations on power-frequency EMF in the United States, international recommendations and guidelines exist. Table AA-1 lists power-frequency EMF guidelines recommended by the European Union, the International Committee on Electromagnetic Safety (ICES), and the International Commission on Non-Ionizing Radiation Protection (ICNIRP), which is an affiliate of the World Health Organization (EU 1999, ICES 2002, ICNIRP 2010).

Table AA-1. International Guidelines for Alternating Current Power-Frequency EMF Levels

Agency	Exposure	Electric Field (kV/m)	Magnetic Field (mG)
European Union	General public	4.2	833
ICES ¹	Occupational	20	27,100
	General public	5	9,040
	General public within right-of-way	10	NA
ICNIRP	Occupational	8.3	10,000
	General public	4.2	2,000
Magnetic fields are measured in gauss (G) and milligauss. 1 G = 1,000 mG NA = Not Applicable (no requirements) 1. ICES recommendations have been adopted as standards by the Institute of Electrical and Electronics Engineers (IEEE); see Standard C95.6 -2002 (R2007).			

Transmission line projects in Oregon must comply with the electric field standard found in OAR 345-024-0090, which requires that the applicant design, construct, and operate the proposed transmission line so that AC electric fields do not exceed 9 kV/m at 1 meter above the ground surface in areas accessible to the public. There is no similar Oregon design standard for magnetic fields.

Six other states have adopted limits for electric field strength either at the edge or within the right-of-way of the transmission line corridor. Only Florida and New York currently limit magnetic field levels from transmission lines. The magnetic field levels set in those two states only apply at the edge of the right-of-way and were developed to prevent magnetic fields from increasing beyond levels currently experienced by the public. Table AA-2 shows the AC electric field and magnetic field standards that have been adopted by states in the U.S.

Table AA-2. Other State Alternating Current Power-Frequency EMF Standards

State		Location	Electric Field (kV/m)	Magnetic Field (mG)
Florida	230 to 500 kV lines	Within right-of-way	10	NA
		Edge of right-of-way	2	200 ¹
	230 kV or less	Within right-of-way	8	NA
		Edge of right-of-way	2	150
Minnesota		Within right-of-way	8	NA
Montana		Within right-of-way: road crossing	7	NA
		Edge of right-of-way	1 ²	NA
New Jersey		Within right-of-way	NA	NA
		Edge of right-of-way	3	NA
New York		Within right-of-way: open	11.8	NA
		Within right-of-way: public road	7	NA
		Within right-of-way: private road	11	NA
		Edge of right-of-way	1.6	200
North Dakota		Within right-of-way	9	NA
		Edge of right-of-way	NA	NA
Oregon		Within right-of-way	9	NA
		Edge of right-of-way	NA	NA
NA = Not Applicable (no requirements)				
1. Magnetic field strength is limited to 250 mG for new double-circuit 500-kV lines constructed on a previously existing right-of-way.				
2. Can be waived by landowner.				

In fall 2009, the Oregon Energy Facility Siting Council (Council) commissioned a review of existing information to prepare for the review of several transmission lines under discussion at that time. That review was conducted by Dr. Kara Warner and presented to the Council on November 20, 2009, during a regular Council meeting. The prevailing conclusions were that there is a need to continue to monitor the science on EMF; that low-cost, prudent avoidance measures of public EMF exposure are appropriate; and that health-based limits are not appropriate given the scientific data available (Council 2009).

2.0 Facility EMF – OAR 345-021-0010(1)(aa)(A)

OAR 345-021-0010(1)(aa) Exhibit AA. If the proposed energy facility is a transmission line or has, as a related or supporting facility, a transmission line of any size:

OAR 345-021-0010(1)(aa)(A) Information about the expected electric and magnetic fields, including:

The Carty Solar Farm with proposed RFA 4 changes includes one segment of proposed 500-kV generation-tie transmission line and one segment of 34.5-kV overhead collector line. The transmission line will connect the proposed collector substation to the existing electrical transmission dead-end structure for a 500-kV transmission line, which used to serve the BCP. The new substation will connect to the existing dead-end structure, which is 100 feet tall, via the new transmission line that will be approximately 300 feet in length. On the existing dead-end structure, old switch components and operators will be replaced with new equipment, but there will be no modifications made to the structure. Once connected to the existing dead-end structure, the energy will be conveyed through the existing BCP 500-kV transmission line to the existing Grassland Switchyard. From the Grassland Switchyard, electrical output from the Carty Solar Farm with proposed RFA 4 changes will be routed to BPA's existing Slatt Substation through the existing 500-kV Grassland to Slatt transmission line (approximately 17 miles long).

Based on the proposed siting of the 300-foot-long transmission line between the proposed collector substation and existing dead-end structure, the new segment of transmission line will be inaccessible to the public. The new segment will be located behind multiple security fences and within the chain-link perimeter fencing for the collector substation, which will be up to 11 feet in height and include an additional 1 foot of razor or barb wire. Other existing fencing around the Facility perimeter will further preclude public access to the transmission line; therefore, it will be unlikely for members of the public to experience any impacts from alternating current electric fields. Based on the proposed siting of the transmission line, and because the 9-kV per meter standard and modeling requirements of OAR 345-024-0090(1) are required for areas accessible to the public, the 9-kV per meter standard and modeling of electric fields are not applicable to the 300-foot-long segment of proposed transmission line and it is not analyzed further in this exhibit.

One segment of 34.5-kV collector line will be installed aboveground. This segment will extend from the perimeter fence on the north side of the Southern Solar Area, along the eastern shore of the Carty Reservoir, and then west along the southern end of the Northern Solar Area to where it will enter the proposed collector substation. The aboveground segment will be approximately 2-miles long, in the center of a new 80-foot-wide right-of-way, using the support pole design approved for this same segment of line in RFA 1. See Figure 2 in RFA 4's Division 27 document (Request for Amendment 4 for the Carty Generating Station).

2.1 Analysis Area – OAR 345-021-0010(1)(aa)(A)(i)(ii)(iii)

OAR 345-021-0010(1)(aa)(A)(i) The distance in feet from the proposed center line of each proposed transmission line to the edge of the right-of-way;

OAR 345-021-0010(1)(aa)(A)(ii) The type of each occupied structure, including but not limited to residences, commercial establishments, industrial facilities, schools, daycare centers and hospitals, within 200 feet on each side of the proposed center line of each proposed transmission line;

OAR 345-021-0010(1)(aa)(A)(iii) The approximate distance in feet from the proposed center line to each structure identified in (A);

The aboveground segment of proposed 34.5-kV collector line will be approximately 2-miles long, in the center of a new 80-foot-wide right-of-way. There are no occupied buildings, residences, or other sensitive receptors within 200 feet of the center line of the proposed 34.5-kV overhead collector line route. See Figure 2 in the RFA 4's Division 27 document (Request for Amendment 4 for the Carty Generating Station). The collector line extends from the perimeter fence on the north side of the Southern Solar Area, along the eastern shore of the Carty Reservoir, and then west along the southern end of the Northern Solar Area to where it will enter the proposed collector substation. The areas within 200 feet to the north of the proposed collector line are all associated with the Facility and there are no existing or proposed buildings, residences, or other sensitive receptors. The area within 200 feet to the east is all vacant land owned by Threemile Canyon Farms, LLC, and under a conservation easement. The area within 200 feet to the south is either the Carty Reservoir or will all be part of the Southern Solar Area. The area within 200 feet to the west of the collector line is all the Carty Reservoir or associated shoreline.

2.2 Modeling Results – OAR 345-021-0010(1)(aa)(A)(iv)

OAR 345-021-0010(1)(aa)(A)(iv) At representative locations along each proposed transmission line, a graph of the predicted electric and magnetic fields levels from the proposed center line to 200 feet on each side of the proposed center line;

Table AA-3 shows calculated electric field values for the proposed aboveground 34.5-kV collector line. Table AA-4 shows calculated magnetic field values for the 34.5-kV collector line.

Table AA-3. Calculated Electric Field Values

Line Description	Figure	Electric Field (kV/m)		
		200 feet Left	Peak Value	200 feet Right
34.5-kV Collector Line	AA-1 AA-3	0.004	0.378, 8 feet right of centerline	0.005

Table AA-4. Calculated Magnetic Field Values

Line Description	Figure	Magnetic Field (mG)		
		200 feet Left	Peak Value	200 feet Right
34.5-kV Collector Line	AA-1 AA-3	3.13	193.2, 4 feet right of centerline	3.59

The analysis results of the Bonneville Power Administration (BPA) Corona and Fields Effect Program, Version 3 (CAFE) model presented in Table AA-3 demonstrate that the proposed 34.5-kV collector line can be constructed and operated such that the AC electric field will not exceed 9 kV/m at 1 meter above the ground surface, as required by OAR 345-024-0090(1). See Figure AA-1 for the electric field graph for the 34.5-kV collector line, and Figure AA-2 for the magnetic field graph for the 34.5-kV collector line. The analysis results for the 34.5-kV collector line are provided in

Attachment AA-1. The modeling assumptions related to the collector line are intentionally conservative, producing worst-case EMF results. EMF levels under normal operating conditions will be lower than indicated by this analysis.

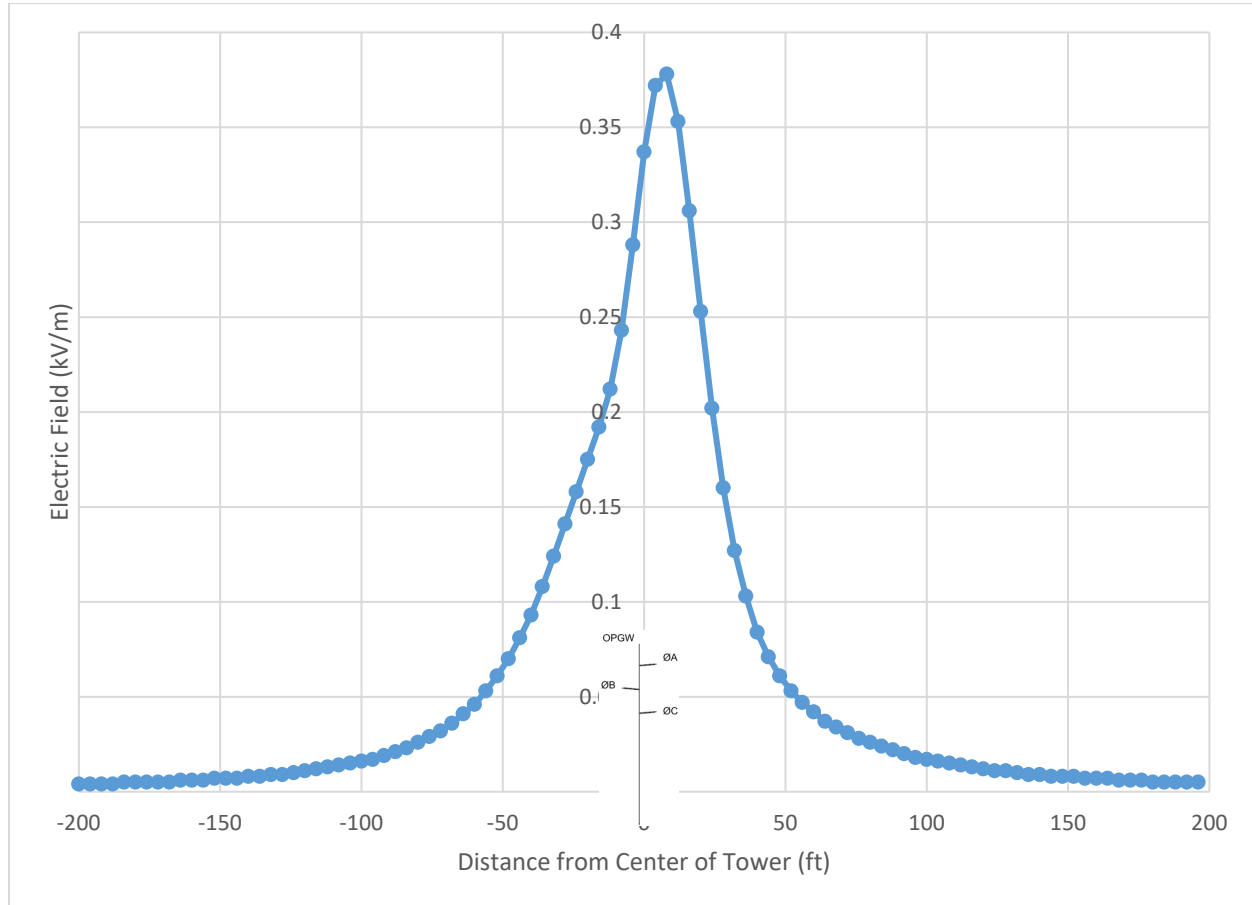


Figure AA-1. Electric Field, 34.5-kV Collector Line

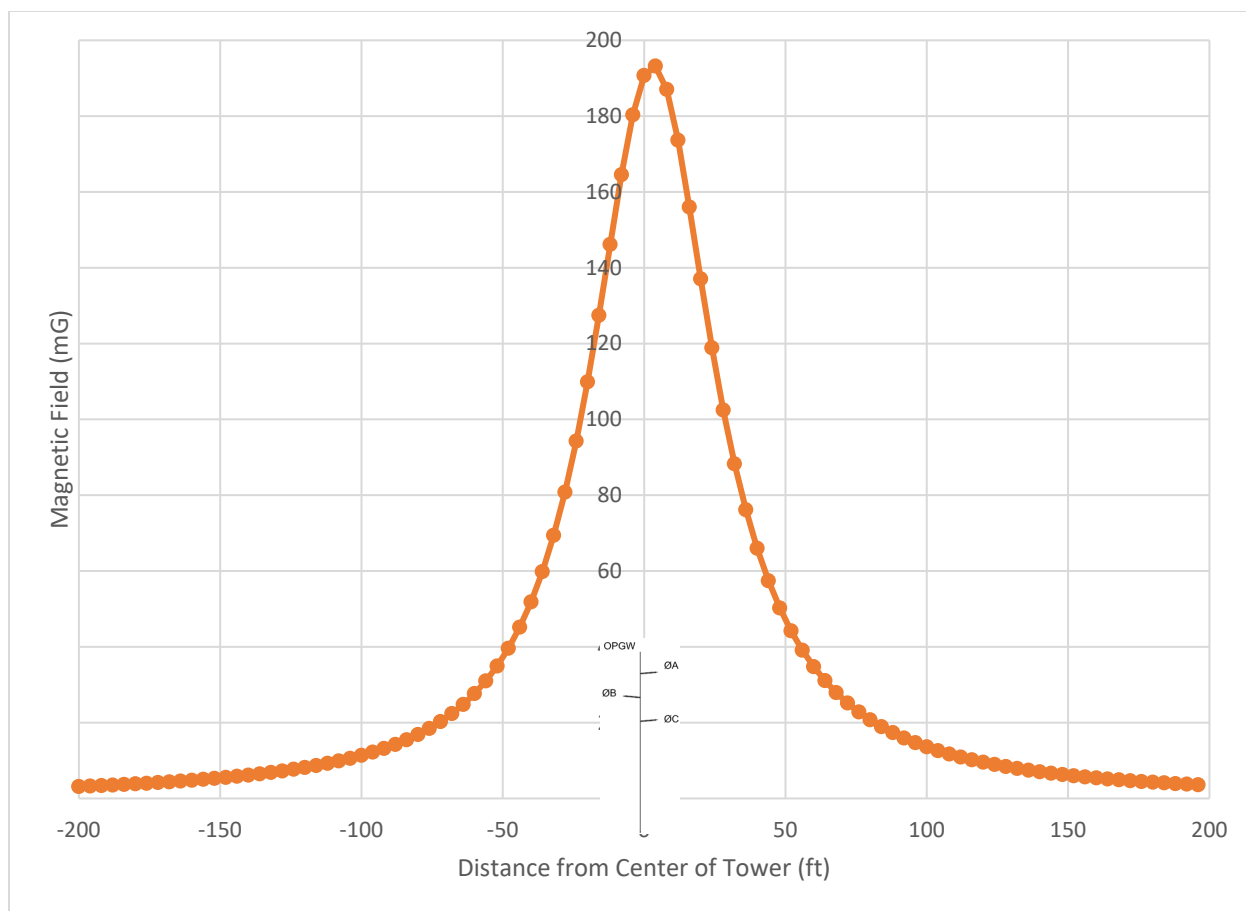


Figure AA-2. Magnetic Field, 34.5-kV Collector Line

2.3 EMF Calculation Methods – OAR 345-021-0010(1)(aa)(A)(vi)

OAR 345-021-0010(1)(aa)(A)(vi) The assumptions and methods used in the electric and magnetic field analysis, including the current in amperes on each proposed transmission line;

The following assumptions are used for the calculation of the electric and magnetic field analysis of the aboveground segment of the 34.5-kV collector line. The planned 34.5-kV collector line configuration is shown in Figure AA-3.

Assumptions for modeling are as follows:

- Environmental parameters – 1 inch of precipitation per hour, 2.0 miles per hour wind speed (for modeling wet-weather conditions)
- Height for both electrical and magnetic field measurements – 1 meter, or 3.28 feet above ground.
- 34.5-kV collector line information:

- Overhead pole height – 70 feet
- Line amperage – 1,687 amps, maximum output value of southern portion of the Facility.
- Line voltage – 34.5-kV phase/phase or 19.92-kV phase/ground
- Conductor type – Single 795- thousand circular mils aluminum-conductor steel-reinforced cable conductors per phase, 1.11” in diameter as shown in Figure AA-3.
- Ground wire – one optical ground wire, 0.5” in diameter, as shown in Figure AA-3. Minimum height from ground is 45 feet.
- Minimum height of conductor from ground – 25 feet.
- A phase is located on the upper arm of the transmission structure at 39 feet minimum height and 5 feet right of centerline.
- B phase is located on the central arm of the transmission structure at 32 feet minimum height and 5 feet left of centerline.
- C phase is located on the lower arm of the transmission structure at 25 feet minimum height and 5 feet right of centerline.

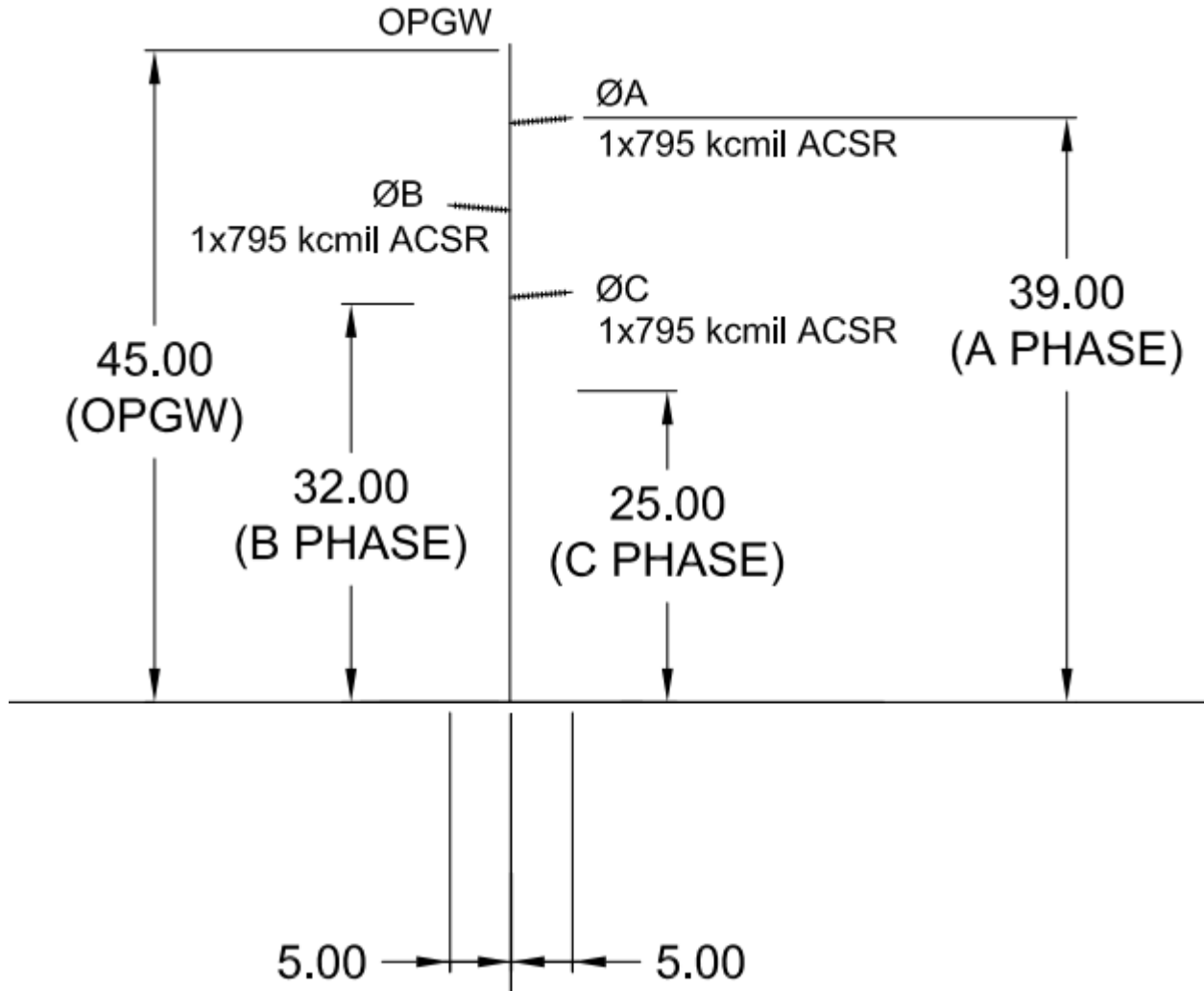


Figure AA-3. Typical Overhead Collector Line for Facility

3.0 EMF Mitigation Measures – OAR 345-021-0010(1)(aa)(A)(v)

OAR 345-021-0010(1)(aa)(A)(v) Any measures the applicant proposes to reduce electric or magnetic field levels;

The Certificate Holder will comply with the existing Site Certificate Conditions 7.1 and 7.9 to limit EMF and induced current impacts in the Third Amended Site Certificate (Council 2022).

4.0 EMF Monitoring Program – OAR 345-021-0010(1)(aa)(A)(vii)

OAR 345-021-0010(1)(aa)(A)(vii) The applicant's proposed monitoring program, if any, for actual electric and magnetic field levels; and

No program for monitoring actual EMF levels before or after construction is proposed at this time.

5.0 Radio and TV Interference – OAR 345-021-0010(1)(aa)(B)

OAR 345-021-0010(1)(aa)(B) An evaluation of alternate methods and costs of reducing radio interference likely to be caused by the transmission line in the primary reception area near interstate, U.S. and state highways.

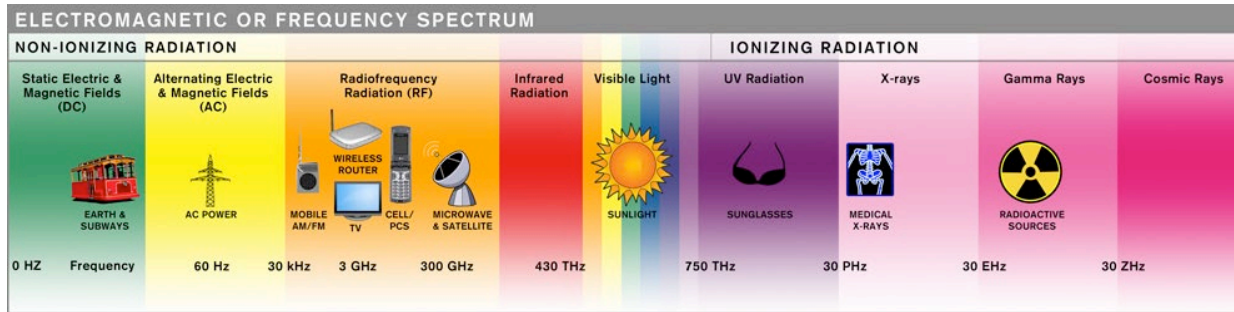
5.1 Background

5.1.1 Electromagnetic Interference

Electromagnetic interference from power transmission systems in the U.S. is governed by the Federal Communications Commission (FCC) Rules and Regulations (FCC 1988). A power transmission line is categorized by the FCC as an “incidental radiation device.” It is defined as “a device that radiates radio frequency energy during the course of its operation although the device is not intentionally designed to generate radio frequency energy.” Such a device “shall be operated so that the radio frequency energy that is emitted does not cause harmful interference. In the event that harmful interference is caused, the operator of the device shall promptly take steps to eliminate the harmful interference.” In this case, “harmful interference” is defined as “any emission, radiation or induction which endangers the functioning of a radio navigation service or of other safety services or seriously degrades, obstructs or repeatedly interrupts a radio communication service operating in accordance with this chapter” (FCC 1988). Oregon does not have regulatory standards for either radio or TV interference.

Modern communications systems all rely on electromagnetic radiation (EMR) to transmit information. AM and FM radio, TV, shortwave radio, cellular telephones, radar, Global Positioning System (GPS) devices and satellite communications, cordless telephones, Bluetooth, and wireless computer networks such as Wi-Fi or wireless local area network all utilize a region of the electromagnetic spectrum known as “radio frequency” EMR, which extends from the very low-frequency end at about 30 kilohertz (kHz) up into the high-frequency microwave range at about 300 gigahertz (GHz). Each type of technology uses a specific segment of the electromagnetic frequency spectrum; older technology such as AM radio is at the low-frequency end, while newer

technologies such as GPS and Wi-Fi utilize high-frequency signals. Figure AA-4 provides a visual representation of typical communications frequencies.



Source: EMF & Radio Frequency Solutions. Available at: <http://www.emfrf.com/index.php/emf-rf/emf-overview/electromagnetic-spectrum-or-frequency-spectrum.html>.

Figure AA-4. Communications Frequency Spectrum

The level of interference can be partially determined by how similar or different the signal frequency is compared to the noise frequency. In general, there is very little interaction between signals of differing frequency; radio signals, TV signals, cellular phone signals, and GPS signals can all coexist in the same space and time without interfering with each other. For interference to occur, frequencies must be similar.

EMR and resulting interference can be an indirect product of electric transmission lines. EMR arises not from the lines themselves, but from the interaction of the strong electric field at the surface of the conductors and other energized components with the surrounding air. Two types of interactions may occur that create electromagnetic interference: corona discharge and gap discharge.

5.1.1.1 *Corona Discharge*

High-voltage power transmission lines generate a strong electric field at the surface of the conductor, which can be strong enough to split the surrounding air molecules, resulting in the emission of electromagnetic energy in the form of ultraviolet and near-ultraviolet light and broadband radio frequency EMR (corona discharge also produces audible sound, which is addressed in Exhibit Y; audible sound is not discussed further in this exhibit). The former can sometimes be seen by humans under the right conditions or with specialized equipment, while the latter can sometimes be heard as electronic “noise,” or interference with radio signal reception. Broadband corona EMR discharge typically occurs in the frequency spectrum from below 100 kHz to approximately 1,000 megahertz (MHz), which overlaps with the frequencies used for AM and FM radio and some TV signals. With sufficient corona activity, low-frequency radio and TV interference can be noticeable within a few hundred feet of the transmission line. These effects are most pronounced directly underneath the line conductors and decrease with distance from the transmission line.

Corona on a transmission line conductor depends on several factors such as operating voltage, conductor diameter, overall line geometry, weather conditions, and altitude. Conductor size, line voltage and line geometry are taken into consideration when designing a transmission line so that the electric fields at the conductor surface are minimized. However, for a high-voltage line, any incidental irregularities on the conductor surface (for example, water droplets, dust, debris, and nicks or scratches in the conductor) act as points where the electric field may be intensified sufficiently to produce corona. Thus, the level of corona activity is elevated during foul weather when raindrops on the conductor surface act as points producing corona.

5.1.1.2 *Gap Discharge*

A gap discharge occurs when current arcs across a gap between two conductive objects. Gap discharges can produce radio noise in the lower frequencies (AM radio frequencies) and well into the microwave range (analog TV frequencies). These discharges can be produced by loose connections, a problem that more commonly occurs on low-voltage distribution lines but rarely occurs on high-voltage transmission lines (Trinh 2012). Unlike corona discharge, which may occur anywhere along a high-voltage transmission line conductor, gap discharge occurs at mechanical connectors and components that are used to hold the conductors in place. Gap discharge is controlled through proper construction and maintenance practices to ensure all mechanical connectors and components are properly assembled. Because gap discharge is an intermittent, temporary, and readily resolved problem, and results only in localized electrical interference issues, the potential for interference with TV signals or higher-frequency communications is not considered a significant problem.

5.1.2 *Radio Interference Effects*

The corona-induced broadband EMR from transmission lines can produce interference to AM signals, such as a commercial AM radio audio signal (i.e., radio noise) or the video portion of an older analog broadcast TV station (i.e., TV noise). Technologies that use frequency modulation, such as FM radio stations and the audio portion of older analog broadcast TV signals, are generally not affected by noise from a transmission line. As digital signal processing has been integrated into these communication systems, the potential interference impact of corona-generated radio noise has decreased.

The level of interference caused by radio noise from a transmission line to the reception of a radio signal depends on the location of the radio transmitter, the radio receiver, and the transmission line. A transmission line that is directly between a radio transmitter and a listener's receiver may be more likely to interfere with that listener's reception, whereas a transmission line behind or beside the listener in relation to the transmitter will not necessarily cause interference, depending on the radio receiver's antennae. The radio noise generated by a transmission line is very low in power and decreases rapidly as distance from the line increases. It is experienced only when in close proximity to the transmission line.

In general, complaints related to corona-generated interference are infrequent. Moreover, the advent of cable and satellite TV service, and the federally mandated conversion to digital TV broadcast in June 2009 have greatly reduced the occurrence of corona-generated interference. Low-frequency corona-induced EMR does not interact with the higher-frequency satellite signals or with wired communication systems, while digital TV receivers are equipped with systems to filter out interference. Many radio stations also broadcast in digital, reducing the likelihood of corona-induced EMR interference. Electric power companies are able to operate very effectively under the present FCC rule because harmful interference can generally be eliminated or effectively mitigated.

Radio noise is measured in units of decibels (dB) based on its field strength referenced to a signal level of 1 microvolt per meter (Institute of Electrical and Electronics Engineers [IEEE] 1986). Corona-induced radio noise during fair weather is calculated to be approximately 40 dB (dB-1 microvolt per meter [$1 \mu\text{V/m}$]) at the edge of the right-of-way. This is considered an acceptable level (IEEE 1971). When the transmission line is in proximity to roadways (for example, interstate, U.S., and state highways), such as when it passes over these roadways, radio interference may be experienced for short distances while in proximity to the line. Interference may be more noticeable near the line particularly during foul weather, when corona activity is elevated.

5.1.3 Interference with Other Electronic Communications

Wireless computer network systems, cell phones, GPS units, and satellite receivers operate at high frequencies in the tens to hundreds of MHz or even GHz. These systems also often use FM or digital coding of the signals so they are relatively immune to electromagnetic interference from transmission line corona. GPS units are used in a wide range of activities, including several important agricultural activities such as monitoring pivot irrigation, tracking wheeled and tracked equipment movements during farming operation, and checking the orientation of aerial spraying aircraft. GPS units operate in the frequency range of 1.2 to 1.6 GHz. Satellite receivers operate at frequencies of 3.4 GHz to 7 GHz and have shown no effect from transmission lines unless the receiver was trying to view the satellite through the transmission tower or conductor bundle of the transmission line (Chartier et al. 1986). Repositioning the receiver by a few feet was sufficient to eliminate the obstruction and reduced signal. Mobile phones operate in the radiofrequency range of about 800 MHz to 1,900 MHz or higher. As a result of the high frequencies used by these devices, modulation and processing techniques, and the typically lower-frequency corona-induced EMR, effects from interference are unlikely.

The voltages and currents associated with the transmission line have the potential to induce voltage and current in nearby conductors (e.g., ungrounded metal fences and ungrounded metal irrigation systems). This effect is more likely where ungrounded fences or irrigation systems are parallel and long (1 mile or more). These induced voltages could result in a “nuisance” shock to anyone who touches such a fence or irrigation system. These shocks are known as nuisance or “startle” shocks as they will not physically harm someone, but may be noticed by some people and provoke a startle reaction. An example of an ungrounded metal irrigation system would be a center

pivot system on rubber tires. By contrast, the Vermeer-type metal irrigation system is grounded through its metal wheels and therefore presents less of a shock hazard.

A GPS unit in farming equipment should work properly within the vicinity of a transmission line. GPS devices continually pull signals from a number of satellites, not just one and may also utilize a fixed base station. A signal may be blocked temporarily if the transmission structure is between the receiver and a weak signal, but it will return as the farm equipment moves past the structure. It is also common for GPS receivers to drop and pick up signals even in the absence of transmission lines and structures. If the base station signal is weak or blocked, additional or alternate locations may improve the signal and performance.

Signal interference occurs when other signals at the same frequency as the satellite signal are present. Multipath occurs when objects such as buildings, structures, or tractor parts reflect a GPS satellite signal, causing the satellite signal to arrive at the receiver later than it would have if it followed a straight line from the satellite. A study commissioned by the Electric Power Research Institute found that signal interference is “unlikely” based on the design of GPS receivers and their ability to separate the GPS signal from background noise (Silva and Olsen 2002). Another study compared the accuracy of real-time kinematic GPS receivers at different locations to transmission lines and towers (Gibbins et al. 2001). This study concluded that multipath from transmission towers could result in GPS-initialization errors (e.g., the system reports the wrong starting location) 1.1 percent to 2.3 percent of the time. This study also reported that GPS software was able to identify and correct these initialization errors within the normal startup time. This study reported initialization errors caused by electromagnetic interference from energized overhead transmission lines when the GPS receiver was located outside the vehicle, but concluded that “most, if not all of this effect can be eliminated by shielding the receiver and cables.” Placing the receiver inside the vehicle significantly reduced initialization errors.

5.2 Evaluation of Alternate Methods and Costs to Reduce Interference

Design options for reducing the radio noise from the collector line include use of larger diameter conductors, or use of more conductors within the conductor bundles. Increasing the distance between phases of the lines (conductor bundles) may also result in a decrease in the radio noise. These line design options have been employed to minimize the generation of radio noise to acceptable levels.

6.0 Conclusion

Exhibit AA demonstrates that the Facility, with the addition of the Carty Solar Farm with proposed RFA 4 changes, will continue to ensure public health and safety with respect to EMFs. Also, this exhibit demonstrates that the AC electric fields and induced currents of the Carty Solar Farm with proposed RFA 4 changes will comply with the Specific Standards for Transmission Lines provided under OAR 345-024-0090.

7.0 References

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Attachment AA-1. CAFE EMF Output

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INPUT DATA LIST

```

12/26/2023      07:50:38
PGE Carty 34.5 kV Transmission Line
Run 1 20231226
1,0, 3, 4,0.0, 2.00, 1.00, .00

```

(ENGLISH UNITS OPTION)

(GRADIENTS ARE COMPUTED BY PROGRAM)

PHYSICAL SYSTEM CONSISTS OF 4 CONDUCTORS, OF WHICH 3 ARE ENERGIZED PHASES

OPTIONS: EF MF AN

4.921,	6.562,	9.842,	1.000,	1.000,	75.000,	3.280,	6.700,	3.280
'A	','A',	5.00,	39.00,	1,	1.110,	.000,	19.920,	.000,
1.687,	.000							
'B	','A',	-5.00,	32.00,	1,	1.110,	.000,	19.920,	120.000,
1.687,	.000							
'C	','A',	5.00,	25.00,	1,	1.110,	.000,	19.920,	240.000,
1.687,	.000							
'G	','A',	.00,	45.00,	1,	.500,	.000,	.000,	.000,
.000,	.000							
100	-200.0	4.0						

1ELECTRIC FIELD CALCULATIONS

PGE Carty 34.5 kV Transmission Line
Run 1 20231226

	DIST. FROM REFERENCE FEET	HEIGHT FEET	MAXIMUM GRADIENT (KV/CM)	SUBCON. DIAM. (IN)	NO. OF SUBCON.	PHASE ANGLE (DEGREES)
A	5.00	39.00	2.55	1.11	1	.0
B	-5.00	32.00	2.54	1.11	1	120.0
C	5.00	25.00	2.54	1.11	1	240.0
G	.00	45.00	.68	.50	1	.0

SENSOR HT. = 3.3 FEET

DIST FROM REFERENCE EX-FIELD FEET	E-FIELD THETAX (KV/METER)	THETA SPACE POTENTIAL (DEGREES)	EY-FIELD (KV/METER)	THETAY (DEGREES)
--	---------------------------------	--	------------------------	---------------------

(KV/METER)	(DEGREES)	(VOLTS)		
-200.0	.004	88.1	.004	-121.5
.000	-107.2	3.8		
-196.0	.004	88.1	.004	-120.9
.000	-106.4	4.0		
-192.0	.004	88.0	.004	-120.3
.000	-105.5	4.1		
-188.0	.004	88.0	.004	-119.6
.000	-104.7	4.3		
-184.0	.005	87.9	.005	-119.0
.000	-103.8	4.5		
-180.0	.005	87.9	.005	-118.3
.000	-102.8	4.7		
-176.0	.005	87.8	.005	-117.6
.000	-101.9	4.9		
-172.0	.005	87.8	.005	-116.8
.000	-100.9	5.2		
-168.0	.005	87.7	.005	-116.0
.000	-99.9	5.4		
-164.0	.006	87.7	.006	-115.2
.000	-98.8	5.7		
-160.0	.006	87.6	.006	-114.3
.000	-97.7	6.0		
-156.0	.006	87.5	.006	-113.5
.000	-96.6	6.3		
-152.0	.007	87.5	.007	-112.5
.000	-95.4	6.7		
-148.0	.007	87.4	.007	-111.6
.000	-94.2	7.0		
-144.0	.007	87.3	.007	-110.6
.000	-93.0	7.4		
-140.0	.008	87.2	.008	-109.5
.000	-91.7	7.9		
-136.0	.008	87.1	.008	-108.4
.000	-90.4	8.4		
-132.0	.009	87.0	.009	-107.2
.000	-89.0	8.9		
-128.0	.009	86.9	.009	-106.0
.001	-87.6	9.5		
-124.0	.010	86.8	.010	-104.8
.001	-86.2	10.1		
-120.0	.011	86.7	.011	-103.4
.001	-84.7	10.9		
-116.0	.012	86.6	.012	-102.1
.001	-83.1	11.7		
-112.0	.013	86.5	.013	-100.6
.001	-81.5	12.6		
-108.0	.014	86.3	.014	-99.1
.001	-79.9	13.6		
-104.0	.015	86.2	.015	-97.5
.001	-78.2	14.7		
-100.0	.016	86.0	.016	-95.8

.001	-76.5	16.0		
-96.0	.017	85.8	.017	-94.1
.001	-74.7	17.4		
-92.0	.019	85.6	.019	-92.3
.002	-72.8	19.1		
-88.0	.021	85.4	.021	-90.4
.002	-70.9	21.0		
-84.0	.023	85.2	.023	-88.4
.002	-68.9	23.2		
-80.0	.026	85.0	.026	-86.3
.002	-66.9	25.7		
-76.0	.029	84.8	.029	-84.2
.003	-64.8	28.6		
-72.0	.032	84.6	.032	-81.9
.003	-62.5	32.1		
-68.0	.036	84.3	.036	-79.6
.004	-60.2	36.1		
-64.0	.041	84.1	.041	-77.1
.004	-57.7	40.8		
-60.0	.046	83.9	.046	-74.6
.005	-55.0	46.4		
-56.0	.053	83.7	.053	-71.9
.006	-52.1	52.9		
-52.0	.061	83.5	.060	-69.1
.007	-48.8	60.7		
-48.0	.070	83.3	.070	-66.1
.009	-45.1	69.9		
-44.0	.081	83.3	.080	-63.0
.010	-40.7	80.6		
-40.0	.093	83.3	.093	-59.5
.012	-35.2	93.0		
-36.0	.108	83.4	.107	-55.7
.014	-28.2	107.2		
-32.0	.124	83.8	.123	-51.4
.016	-18.8	122.9		
-28.0	.141	84.3	.140	-46.3
.018	-5.9	139.6		
-24.0	.158	85.0	.157	-39.9
.021	11.0	156.6		
-20.0	.175	85.7	.174	-31.7
.027	30.0	173.1		
-16.0	.192	85.8	.191	-20.8
.037	47.5	189.7		
-12.0	.212	84.7	.211	-6.9
.050	61.1	209.9		
-8.0	.243	82.7	.241	9.3
.062	71.3	239.9		
-4.0	.288	82.0	.285	24.9
.068	80.2	282.7		
.0	.337	83.7	.335	37.4
.061	91.3	329.8		
4.0	.372	87.2	.372	46.6
.044	112.6	363.9		

8.0	.378	91.2	.378	53.4
.033	157.1	369.9		
12.0	.353	94.9	.351	59.2
.041	-163.3	345.8		
16.0	.306	97.8	.303	64.7
.048	-145.7	301.1		
20.0	.253	99.7	.249	70.5
.048	-136.8	249.2		
24.0	.202	100.7	.199	77.0
.042	-130.8	200.0		
28.0	.160	100.9	.157	84.3
.035	-125.7	158.8		
32.0	.127	100.5	.125	92.1
.027	-120.6	126.5		
36.0	.103	99.6	.101	100.1
.021	-115.3	102.2		
40.0	.084	98.6	.084	108.1
.016	-109.6	84.2		
44.0	.071	97.7	.070	115.8
.012	-103.4	70.8		
48.0	.061	96.8	.060	122.8
.009	-96.9	60.8		
52.0	.053	96.1	.053	129.1
.007	-90.2	53.0		
56.0	.047	95.6	.047	134.6
.006	-83.5	46.8		
60.0	.042	95.2	.042	139.5
.005	-76.9	41.7		
64.0	.037	94.9	.037	143.8
.004	-70.7	37.4		
68.0	.034	94.6	.034	147.5
.003	-64.8	33.8		
72.0	.031	94.4	.031	150.8
.003	-59.5	30.7		
76.0	.028	94.3	.028	153.8
.002	-54.6	28.0		
80.0	.026	94.1	.026	156.4
.002	-50.2	25.6		
84.0	.024	94.0	.023	158.7
.002	-46.2	23.5		
88.0	.022	93.8	.022	160.8
.002	-42.7	21.6		
92.0	.020	93.7	.020	162.7
.001	-39.4	19.9		
96.0	.018	93.6	.018	164.5
.001	-36.5	18.4		
100.0	.017	93.5	.017	166.1
.001	-33.9	17.1		
104.0	.016	93.4	.016	167.6
.001	-31.5	15.9		
108.0	.015	93.3	.015	168.9
.001	-29.3	14.8		
112.0	.014	93.2	.014	170.2

.001	-27.3	13.8			
116.0	.013	93.1	.013	171.4	
.001	-25.4	12.9			
120.0	.012	93.0	.012	172.5	
.001	-23.7	12.1			
124.0	.011	93.0	.011	173.5	
.001	-22.1	11.3			
128.0	.011	92.9	.011	174.5	
.001	-20.7	10.7			
132.0	.010	92.8	.010	175.4	
.001	-19.3	10.0			
136.0	.009	92.7	.009	176.3	
.000	-18.0	9.5			
140.0	.009	92.7	.009	177.1	
.000	-16.8	8.9			
144.0	.008	92.6	.008	177.9	
.000	-15.6	8.4			
148.0	.008	92.5	.008	178.6	
.000	-14.6	8.0			
152.0	.008	92.5	.008	179.3	
.000	-13.5	7.6			
156.0	.007	92.4	.007	180.0	
.000	-12.6	7.2			
160.0	.007	92.4	.007	-179.4	
.000	-11.7	6.8			
164.0	.007	92.3	.006	-178.8	
.000	-10.8	6.5			
168.0	.006	92.3	.006	-178.2	
.000	-9.9	6.2			
172.0	.006	92.2	.006	-177.6	
.000	-9.2	5.9			
176.0	.006	92.2	.006	-177.1	
.000	-8.4	5.6			
180.0	.005	92.1	.005	-176.6	
.000	-7.7	5.4			
184.0	.005	92.1	.005	-176.1	
.000	-7.0	5.2			
188.0	.005	92.0	.005	-175.6	
.000	-6.3	4.9			
192.0	.005	92.0	.005	-175.2	
.000	-5.7	4.7			
196.0	.005	92.0	.005	-174.7	
.000	-5.0	4.5			

1MAGNETIC FIELD CALCULATIONS

SENSOR HT. = 3.3 FEET

DIST FROM REFERENCE FEET	B-FIELD (GAUSS)	THETA	BY-FIELD (GAUSS)	THETAY	BX-FIELD (GAUSS)	THETAX
--------------------------------	--------------------	-------	---------------------	--------	---------------------	--------

-200.0	.00312929	13.8	.00279439	-42.1	.00311016	44.7
-196.0	.00325249	14.0	.00290868	-41.8	.00323224	45.0
-192.0	.00338305	14.2	.00303005	-41.4	.00336162	45.3
-188.0	.00352159	14.4	.00315907	-41.1	.00349890	45.7
-184.0	.00366874	14.6	.00329640	-40.7	.00364472	46.1
-180.0	.00382525	14.8	.00344274	-40.3	.00379981	46.4
-176.0	.00399190	15.0	.00359891	-40.0	.00396497	46.8
-172.0	.00416960	15.2	.00376578	-39.5	.00414109	47.3
-168.0	.00435934	15.4	.00394432	-39.1	.00432916	47.7
-164.0	.00456221	15.6	.00413564	-38.7	.00453028	48.2
-160.0	.00477944	15.8	.00434095	-38.2	.00474570	48.6
-156.0	.00501243	16.0	.00456161	-37.7	.00497679	49.1
-152.0	.00526271	16.2	.00479917	-37.2	.00522511	49.7
-148.0	.00553203	16.4	.00505534	-36.7	.00549242	50.3
-144.0	.00582235	16.6	.00533207	-36.1	.00578071	50.8
-140.0	.00613590	16.7	.00563154	-35.5	.00609222	51.5
-136.0	.00647521	16.8	.00595624	-34.9	.00642953	52.2
-132.0	.00684316	16.9	.00630898	-34.3	.00679558	52.9
-128.0	.00724305	17.0	.00669296	-33.6	.00719372	53.6
-124.0	.00767868	16.9	.00711184	-32.9	.00762782	54.4
-120.0	.00815441	16.9	.00756979	-32.1	.00810237	55.3
-116.0	.00867533	16.7	.00807160	-31.3	.00862255	56.2
-112.0	.00924736	16.5	.00862276	-30.4	.00919445	57.2
-108.0	.00987744	16.1	.00922960	-29.5	.00982515	58.2
-104.0	.01057381	15.6	.00989945	-28.5	.01052304	59.4
-100.0	.01134621	-165.1	.01064075	-27.5	.01129803	60.6
-96.0	.01220638	-166.1	.01146335	-26.3	.01216193	61.9
-92.0	.01316844	-167.2	.01237863	-25.1	.01312886	63.3
-88.0	.01424958	-168.6	.01339992	-23.8	.01421583	64.8
-84.0	.01547076	-170.1	.01454275	-22.3	.01544346	66.4
-80.0	.01685759	-171.8	.01582534	-20.7	.01683677	68.2
-76.0	.01844136	-173.4	.01726903	-19.0	.01842638	70.1
-72.0	.02026024	-174.9	.01889897	-17.1	.02024983	72.2
-68.0	.02236075	-176.0	.02074502	-14.9	.02235321	74.5
-64.0	.02479971	-176.6	.02284278	-12.5	.02479308	76.9
-60.0	.02764691	-176.5	.02523548	-9.8	.02763843	79.6
-56.0	.03098843	-175.7	.02797676	-6.7	.03097243	82.5
-52.0	.03493078	-174.1	.03113586	-3.0	.03489282	85.6
-48.0	.03960565	-171.7	.03480664	1.2	.03950935	89.0
-44.0	.04517493	-168.4	.03912450	6.1	.04493453	92.6
-40.0	.05183477	-164.1	.04429651	11.8	.05126129	96.6
-36.0	.05981662	-158.7	.05065045	18.6	.05851760	101.0
-32.0	.06938050	-152.2	.05870113	26.4	.06658490	105.8
-28.0	.08079238	-144.4	.06920142	35.1	.07507384	111.3
-24.0	.09427235	-135.1	.08307515	44.4	.08318862	117.8
-20.0	.10989640	-124.3	.10104210	53.8	.08973894	126.2
-16.0	.12743730	-111.6	.12274880	62.7	.09376035	137.8
-12.0	.14614880	-97.2	.14549230	70.8	.09657374	154.6
-8.0	.16454920	-80.9	.16329470	78.5	.10472820	177.1
-4.0	.18033980	-63.0	.16799320	86.6	.12622570	200.1
.0	.19070070	-43.9	.15411860	97.2	.15719580	217.3
4.0	.19319130	-24.1	.12666930	114.2	.18181430	228.7
8.0	.18701530	-4.6	.10428800	141.0	.18659670	236.8

12.0	.17363630	13.9	.10189450	170.1	.17013590	243.8
16.0	.15599380	30.7	.10900860	190.0	.14123870	251.3
20.0	.13704500	45.6	.11178520	201.6	.11053830	260.2
24.0	.11884950	58.7	.10747320	208.8	.08477704	-88.8
28.0	.10246690	69.9	.09840176	214.0	.06613825	-76.1
32.0	.08824831	-100.3	.08733004	218.1	.05387428	-62.8
36.0	.07615256	-91.8	.07612749	221.6	.04607277	-50.3
40.0	.06596371	-84.5	.06577550	224.8	.04089242	-39.7
44.0	.05741246	-78.1	.05666495	227.8	.03708790	-31.1
48.0	.05023427	-72.5	.04885945	230.7	.03398522	-24.2
52.0	.04419360	-67.5	.04226668	233.4	.03127038	-18.8
56.0	.03909032	-63.2	.03673469	236.0	.02881171	-14.5
60.0	.03475866	-59.3	.03210091	238.6	.02655751	-10.9
64.0	.03106314	-55.8	.02821443	241.0	.02448689	-8.0
68.0	.02789365	-52.7	.02494412	243.3	.02258871	-5.5
72.0	.02516093	-49.8	.02218003	245.5	.02085371	-3.3
76.0	.02279253	-47.3	.01983173	247.6	.01927197	-1.5
80.0	.02072951	-45.0	.01782561	249.6	.01783270	.2
84.0	.01892379	-42.9	.01610204	251.4	.01652455	1.6
88.0	.01733592	-40.9	.01461282	253.2	.01533614	2.9
92.0	.01593345	-39.1	.01331890	254.9	.01425640	4.1
96.0	.01468951	-37.5	.01218860	256.5	.01327485	5.1
100.0	.01358179	-36.0	.01119612	258.0	.01238177	6.1
104.0	.01259164	-34.6	.01032033	259.5	.01156826	7.0
108.0	.01170339	-33.3	.00954389	260.8	.01082622	7.8
112.0	.01090385	-32.1	.00885246	262.1	.01014838	8.5
116.0	.01018186	-30.9	.00823417	263.3	.00952821	9.2
120.0	.00952789	-29.9	.00767909	264.5	.00895988	9.9
124.0	.00893382	-28.9	.00717888	265.5	.00843818	10.5
128.0	.00839269	-28.0	.00672655	266.6	.00795851	11.0
132.0	.00789849	-27.1	.00631615	267.6	.00751672	11.6
136.0	.00744602	-26.3	.00594265	268.5	.00710914	12.1
140.0	.00703079	-25.5	.00560173	269.4	.00673253	12.6
144.0	.00664889	-24.8	.00528968	-89.8	.00638395	13.0
148.0	.00629687	-24.1	.00500330	-89.0	.00606082	13.4
152.0	.00597175	-23.4	.00473984	-88.2	.00576082	13.8
156.0	.00567089	-22.8	.00449690	-87.5	.00548187	14.2
160.0	.00539195	-22.2	.00427238	-86.8	.00522212	14.6
164.0	.00513287	-21.6	.00406445	-86.2	.00497989	14.9
168.0	.00489185	-21.1	.00387150	-85.5	.00475371	15.3
172.0	.00466725	-20.6	.00369212	-84.9	.00454221	15.6
176.0	.00445762	-20.1	.00352505	-84.4	.00434420	15.9
180.0	.00426169	-19.6	.00336917	-83.8	.00415858	16.2
184.0	.00407828	-19.2	.00322352	-83.3	.00398436	16.5
188.0	.00390638	-18.8	.00308719	-82.8	.00382064	16.7
192.0	.00374503	-18.4	.00295941	-82.3	.00366663	17.0
196.0	.00359340	-18.0	.00283946	-81.8	.00352157	17.2