Exhibit No.:	
Issue(s):	EMF Interference
Witness:	J. Michael Silva
Type of Exhibit:	Surrebuttal Testimony
Sponsoring Party:	Ameren Transmission Company of Illinois
File No.:	EA-2015-0146
Date Testimony Prepared:	November 16, 2015

MISSOURI PUBLIC SERVICE COMMISSION

File No. EA-2015-0146

SURREBUTTAL TESTIMONY

OF

J. MICHAEL SILVA

ON

BEHALF OF

AMEREN TRANSMISSION COMPANY OF ILLINOIS

Campbell, California
November, 2015

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OF

J. MICHAEL SILVA

FILE NO. EA-2015-0146

Q. Please state your name, business address and present position.

A. My name is J. Michael Silva. I am a research engineer and President of Enertech Consultants, 494 Salmar Avenue, Campbell, California.

Q. On whose behalf are you testifying in the current proceeding?

A. I am testifying on behalf of Ameren Transmission Company of Illinois ("ATXI"), a wholly-owned subsidiary of Ameren Corporation, in support of its request for a Certificate of Public Convenience and Necessity ("CCN") for a transmission line project in northeast Missouri.

Q. What is the purpose of your surrebuttal testimony?

A. The purpose of my surrebuttal testimony is to address issues related to the proposed Mark Twain 345-kV transmission line and use of the Global Positioning System ("GPS") for agricultural operations near the proposed Project. Specifically, my testimony responds to certain testimony given by Charles E. Kruse and Noel Palmer, both of whom have submitted testimony on behalf of Neighbors United Against Ameren's Power Line ("Neighbors United").

Q. Please summarize your educational background and professional experience.

A. I grew up in St. Charles, Missouri, and I received a Bachelor's degree in engineering from the University of Alabama in 1971 and a Master's degree in engineering from Auburn University in 1976. I am a registered professional engineer in Electrical Engineering in

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A. I grew up in St. Charles, Missouri, and I received a Bachelor's degree in engineering from the University of Alabama in 1971 and a Master's degree in engineering from Auburn University in 1976. I am a registered professional engineer in Electrical Engineering in

California and also hold a professional engineering license in seven other states. I have 43 years of experience related to electric power facilities, electromagnetic compatibility and applied research projects, and have designed transmission lines up to 500-kV.

I founded Enertech Consultants in 1982. The focus of my work has been applied research on electric and magnetic fields, electromagnetic compatibility, instrumentation and software development and scientific consulting on new technologies, such as the Global Positioning System (GPS). My company designs, manufactures and sells high quality electromagnetic measurement instrumentation in 59 countries. I have performed a number of projects related to use of GPS. I directed Enertech's development of the Global Positioning System Personal Acquisition Logger (GPS-PAL), a portable, wearable GPS device, which collects and stores position data obtained using GPS. These GPS meters were used by the University of Washington in a study to evaluate and collect location data on children in the state of Washington for exposure assessment of pesticides in orchards and on farms. Enertech also helped develop the software for a system using GPS to monitor the position of commercial fishing boats at sea. The on-board GPS system would continuously monitor boat locations to protect against fishing within restricting areas. We also assisted in the development of a system that uses GPS and other instrumentation for detecting the location of oil leaks from underground high pressure cable systems.

I have performed a technical study of the potential for electric power facilities to affect use of GPS. The study characterized user aspects of GPS, assessed possible sources of interference and evaluated the potential for electric facilities to affect GPS use. Enertech is currently involved in a study with the University of California-Los Angeles (UCLA) to accurately determine distance from buildings to the nearest overhead electric transmission line using high precision survey-grade GPS equipment under the lines. In addition, I have taught a series of 14 one-day GPS seminars attended by over 400 people at locations across the United States; topics included a detailed technical overview of the GPS system, differential correction concepts, satellite signals, power system environments, performance considerations and GPS accuracy augmentations. Further, Enertech has also performed numerous studies related to a variety of electromagnetic compatibility issues. For example, we have done studies for Washington University in St Louis, Missouri, to evaluate and mitigate potential interference to the University's Nuclear Magnetic Resonance equipment from magnetic fields created by operation of the MetroLink light rail system. We have also done electromagnetic interference evaluations for the US Air Force, Amtrak, Stanford University, IBM, Walt Disney Company, and the U.S. Army Corps of Engineers, among others.

I have served as a past advisor to the U.S. Department of Energy on various research projects and have participated in the U.S. Technical Exchange Program organized by the U.S. Department of State with the former Soviet Union. I was a Lloyd Hunt Distinguished Lecturer in Power Engineering at the University of Southern California and an invited lecturer in distinguished lecturer programs at Ohio State University and the University of Texas. I am a Life Senior Member of the Institute of Electrical and Electronics Engineers (IEEE) and a former member of the Institute of Navigation (ION). I have served as a technical reviewer for a number of scientific publications and journals. I have received awards and recognition for some of my published technical papers. In 2014, I was named a Distinguished Engineering Fellow of the College of Engineering at the University of Alabama.

A summary of my relevant publications and presentations is included in my Biographical Outline, attached to my testimony as **Schedule JMS-SR1**.

Q. You have indicated that you will address issues related to the Mark Twain transmission line and the use of GPS systems in agricultural operations. Before you address specific issues, is there any background information that would be helpful in understanding your testimony?

A. Yes. High-voltage transmission lines are a commonplace element of a nation's infrastructure. In the United States, transmission lines are general classified in the 115-kV to 765-kV range, although some companies may include 69-kV lines as well. There are over 300,000 miles of high-voltage transmission lines in North America rated at 115-kV and above. Despite the varying voltages of these lines, all alternating current (AC) power lines in North America operate at the same frequency—at 60 Hertz ("60 Hz"), or 60 cycles per second, and this would include the proposed Mark Twain transmission line. 60 Hz is in the Extremely Low Frequency (ELF) portion of the range of frequencies that engineers call the electromagnetic spectrum.

Q. Please explain the significance of the fact that power lines operate at the extremely low frequency portion of the electromagnetic spectrum?

A. Frequency is important because it affects the characteristics and interactions of electromagnetic fields. Attached as **Schedule JMS-SR2** is a depiction of the bands or range of frequencies (measured in Hertz) which make up the electromagnetic spectrum, and a depiction of devices that operate at the different frequencies across the spectrum. On the far left is the ELF range of the spectrum, where many appliances and electric power lines operate. The spectrum increases in frequency as it moves to the right. AM radios, for example, operate at a higher frequency, approximately one million Hz (or 1 MHz). FM radio operates at an even higher frequency, approximately 100 million Hz (100 MHz). Television signals are at several hundred million Hz while the microwave frequency range starts at about a billion Hz (1,000 MHz, or 1 GHz). Notably, GPS operates in this microwave frequency range—between about 1.2 billion and 1.5 billion Hz. Cell phones also operate in microwave frequency bands just below and just above GPS, at about 0.9 and 1.8 billion Hz.

Q. How can cell phones operate at frequencies so close to GPS and not cause interference to GPS?

A. This is an example of the principle of frequency separation. If there is sufficient separation between the frequencies of two different radio frequency systems, then they are able to operate without interfering with each other. The reason is that radio receivers incorporate devices called filters that suppress certain frequencies and pass others. Since these filters are not perfect, the greater the separation of frequencies, the lesser the interference. Because there is sufficient separation between their frequencies, a community can have a number of radio and TV stations in the same area with no interference. In practice, cell phones also have co-located GPS chips in their hardware, and both cellular and GPS systems operate successfully without interference to each other, and this is primarily due to the principle of frequency separation.

Q. Can a high-voltage electric power line sometimes generate static noise that can be heard on an AM radio used close to the line?

A. Yes. Occasionally when it rains, radio noise close to transmission lines can sometimes be heard as static on the lower-frequency radio stations of AM radios if the AM station signal strength is not adequate. Part of this issue stems from the amplitude modulation (AM) signal method used on AM radios. Steps are taken in the engineering design of modern transmission lines to minimize this situation. The intensity of the static noise decreases rapidly at higher frequencies, so it generally has little or no effect on devices designed to operate at frequencies above AM radio or systems that use different signal modulation methods, such as FM radio. Static noise or interference to an AM radio can also be caused by broken or damaged equipment (such as a damaged insulator) on any power line, including (and more commonly) a low-voltage distribution line. These sources of static noise can be located and repaired.

Q. You have testified that the greater frequency separation there is, the less likely there will be interference. Does this apply to GPS systems, which operate at very high frequencies and the proposed Mark Twain transmission line, which will operate at extremely low frequency?

A. Yes. Because the frequencies of GPS and the transmission line are separated so far on the electromagnetic spectrum, any interference to a GPS-dependent device (operating at a frequency range of 1.2 billion to 1.5 billion Hertz) would not be due to the extremely low frequency of the Mark Twain transmission line (operating at 60 Hertz).

Q. Before we address the issues raised by Neighbors United regarding GPS use in agriculture and the proposed Mark Twain transmission line, would you provide a brief overview of the GPS system?

A. Yes. GPS was originally designed by the U.S. military to provide year-round navigation and positioning data. The primary components of GPS are the GPS satellites, ground control stations, and the user’s GPS receiver (sometimes called the rover). In addition, there may be a supplemental source used for GPS error correction that is broadcast to the user to improve accuracy. The GPS space segment consists of a constellation of satellites transmitting microwave radio signals to users. The Air Force manages the constellation to ensure the availability of at least 24 GPS satellites, 95% of the time. For the past several years, the Air Force has been flying 31 operational GPS satellites, plus three to four decommissioned satellites ("residuals") that can be reactivated if needed. Each of the GPS satellites travel at a speed of about 9,000 mph and circle the earth twice a day; they are located in six equally-spaced orbital planes surrounding the earth. These satellites are used by GPS receivers to determine position, velocity and time. There are many modern applications that rely on GPS, including the U.S. military, precision agriculture, maritime navigation, mining operations, commercial and general aviation, automobile and truck navigation, and emergency services guidance and location functions.

It is important to understand that there are always some systematic errors in using GPS. These errors are caused by things like atmospheric effects and small errors in the satellite orbits and in their clocks. The errors are not important for many GPS applications, but these errors must be minimized for precision applications in agriculture, surveying, and aviation.

Q. How are errors in the GPS system minimized for these precision applications?

A. Many modern applications, such as precision agriculture, surveying, or agricultural aviation, require greater accuracy than GPS receivers alone can deliver. Accuracy improvements were developed for precision applications by evaluating the systematic errors that I mentioned earlier at some fixed location and broadcasting corrections to significantly reduce these errors for the nearby user. This is generally called differential corrections and these methods have improved over time to provide enhanced accuracy. There are several methods available to provide error corrections depending on the accuracy required. In general, the error correction information is supplied to the user from a satellite or terrestrial base station (corrections can also be supplied over the internet via a cell phone link). A popular approach to greatly improving accuracy is accomplished by a method called Real Time Kinematic, or RTK. This method is used in many precision agriculture applications. Another popular error correction method is called the Wide Area Augmentation System (WAAS), and it is used in many aviation applications, including agricultural aviation or aerial applications.

Q. Could you describe how RTK works?

A. RTK is an improved method for determining location that is also used in precision GPS applications. With RTK, the GPS satellite signals are used in a different way than was originally intended in GPS design and this can greatly enhance the accuracy. With RTK, GPS users rely on the basic GPS satellite carrier phase signals and also use external microwave radio signals that are broadcast from a base station source on the farm or at a local farm dealership or farm cooperative. This supplemental signal is used with the GPS satellite signal to greatly improve accuracy. With the best use of RTK, some receivers claim to achieve GPS accuracy on the order of one inch.

For purposes of explanation, **Schedule JMS-SR3** depicts GPS accuracy improvement using RTK. It shows a GPS user or rover, in this case a tractor with a GPS antenna on top. The rover is receiving a microwave signal from a GPS satellite in space. Although multiple satellites are used in actuality, I have only depicted one for purposes of demonstration. There are also RTK base stations depicted—one option is on the farm on a tripod and the other option is located off the farm, at a farm equipment dealership or cooperative, for example. The tractor GPS unit receives the GPS satellite signals and also communicates with a local RTK base station using microwave radios (operating at about 450 MHz or 900 MHz) to receive additional information to allow RTK accuracy.

Q. Could you describe how WAAS works?

A. The Wide Area Augmentation System (or WAAS) is another improved method for determining location that is also used in precision GPS applications. WAAS is an air navigation aid developed by the Federal Aviation Administration (FAA) to augment the GPS by improving its accuracy and availability. WAAS is intended to enable aircraft to rely on GPS for all phases of flight. For purposes of explanation, **Schedule JMS-SR4** depicts GPS accuracy improvement using WAAS. This system uses a network of ground-based reference stations that monitor the GPS satellites' signals and send error correction to master stations, which send the correction messages to geostationary WAAS satellites. Those WAAS satellites then broadcast the correction messages back to earth, where WAAS-enabled GPS receivers use the appropriate corrections while computing their positions to improve accuracy.

Q. Testifying on behalf of Neighbors United, Charles Kruse asserts that "[i]t has been shown that numerous structures such as ones proposed by ATXI can have an adverse effect on receiving satellite signal and thereby causing serious problems for agriculture." Generally speaking, in what ways could GPS satellite signals be affected in an agricultural setting?

A. One problem could be when there is some electronic interference that is very close to the same frequency at which GPS operates. Also, since GPS use requires an unobstructed view of the sky, an obstruction could potentially affect a satellite signal.

Q. Let's address the first issue. You have already testified that any interference to a GPS-dependent device would not be due to the extremely low frequency of the Mark Twain transmission line based upon the principle of frequency separation. How certain are you?

A. Quite certain. In fact, one practical example of successful use of GPS and other microwave signals near powers lines is the common practice of mounting cell phone base station antennas and high accuracy GPS antennas directly onto high-voltage transmission line towers throughout North America. Cell phones are just small, low power microwave radios that operate at frequencies of around 1 to 2 billion cycles per second, very similar in frequency to GPS. Across the United States and in Canada, cell phone base station antennas are mounted directly on transmission line towers and poles. This is significant because the microwave cell phone signals from distant users are received by the base station antennas which are located on towers much closer to high-voltage conductors than a tractor on the ground. **Schedule JMS-SR5** contains photographs that I took of cell telephone antennas mounted directly on high-voltage transmission line structures.

In addition to cell phone antennas, GPS antennas used for precision timing by cellular networks are also mounted on high-voltage towers as well. Electric power companies themselves use GPS for many applications, such as precision timing, and system control and data collection applications. These GPS antennas are sometimes mounted inside high-voltage substations. **Schedule JMS-SR6** contains photographs that I took of GPS antennas mounted directly on high-voltage transmission line structures.

The point to all this is that neither the cell phone industry nor the electric power companies would be mounting system-critical antennas on high-voltage transmission line towers if any type of interference from transmission lines were a concern.

Q. If the transmission line would not interfere with GPS operation, are there other possible causes of electronic interference with GPS satellite signals?

A. The most common causes of electronic interference to GPS satellites are things like proximity to strong FM radio station antennas, the quartz oscillator in a computer or a clock radio, some vehicle ignition systems, and certain two-way radios, including walkie-talkies. The harmonics of certain TV, FM radio stations and marine aviation and military radars have also been known to interfere with GPS. Transmission lines, on the other hand, do not produce or convey higher frequency harmonics near GPS frequencies.

Q. Mr. Silva, let's address the second potential cause of interference with GPS signals—obstruction. Please explain how a GPS signal can be affected by obstruction.

A. An obstruction would have to be close to the GPS antenna and large enough and exactly in line of sight with one of the moving GPS satellites. Obstructions such as trees, very dense foliage or the walls of buildings, silos, or tall fences or other objects can partially block a satellite signal so the GPS receiver may temporarily lose its lock or lose the information from one satellite. But in general, losing one satellite is not a problem because GPS receivers track and use several satellites at once. Also, modern GPS software has methods to compensate for temporary "loss of lock."

Q. Would the Mark Twain transmission line have, as Mr. Kruse suggests, an adverse effect on receiving GPS signals?

A. In my professional engineering judgment, I do not think this is likely to occur.

Q. Have you performed any research to reach the conclusion that high-voltage transmission lines are not likely to interfere with a GPS satellite signal?

A. Yes. I evaluated the potential for high-voltage power lines to affect GPS signals in two ways. I did a theoretical analysis of GPS signals in relation to transmission lines. I also completed a number of practical measurements at different locations in the United States directly under transmission lines up to 500-kV and including 345-kV lines. The theoretical work and the practical measurements were conducted together as part of the same research projects.

Q. What were the results of your research to evaluate GPS satellite signal use under transmission lines?

A. The results of my theoretical analysis indicate it is unlikely that high-voltage transmission lines can interfere with GPS satellite signals. I evaluated the potential for interference due to partial blocking of the satellite signals by overhead wires or the overhead conductors, a process called signal scattering. The result of this analysis showed that interference was not possible due to the small electrical size of power line conductors relative to a GPS microwave signal wavelength and the relatively large height above ground of electrical wires. In other words, because power line conductors are much smaller than the GPS signal wavelength, very little blocking of the signals would occur when they pass around the conductor or conductors. And the conductors are high enough above the ground that any blocking is insignificant.

Q. In addition to your theoretical analysis, you said that you also used direct measurements to evaluate GPS satellite signal use under transmission lines. Please describe what you did.

A. I conducted many practical experiments in which I performed measurements using a precision agriculture GPS receiver under transmission lines up to 345-kV and higher. This was done to see if there was any change in either the positioning accuracy or the strength of the received satellite signals while driving under transmission lines. I performed this test in both fair and in rainy weather to evaluate various weather conditions.

Q. What were the results of the tests you conducted?

A. **Schedule JMS-SR7** depicts GPS satellite signal strength measurements that I recorded in my testing, which involved driving under double circuit 345-kV transmission lines[1]

[1] When I say double circuit 345-kV transmission lines, I mean that there are two sets of three-phase wires; consequently, my test location with two of these double circuit 345-kV lines would be equivalent to four times as many 345-kV lines as this Project is proposing to use.

at two different locations. At the top is a sketch of the five satellites I tracked when I was measuring and logging this data at the first site location of the double circuit 345-kV transmission line. Each GPS Satellite is designated by a number given by the U.S. Air Force. The dark line at the base of the three-dimensional chart labeled “345 kV Line” depicts the double circuit 345-kV line location for my first drive under the line. You can see the constellation of satellites dispersed on both sides of the transmission line. I started far away from the line and drove toward, and then under, the 345-kV transmission line, logging the strength of the GPS signals that I received using a commercially available precision Ag GPS receiver. I recorded the readings to determine whether there would be any change in the strength of the received GPS satellite signals. I began measuring the signal strength about 240 feet away from the 345-kV line and continued recording strengths as I drove directly toward and then under the transmission line and across the whole right-of-way. These measurements are recorded in the graph labeled “GPS C/N vs Distance Across 345 kV Easement (Site #1)” on **Schedule JMS-SR7**. The results recorded in this graph demonstrate that the satellite signal strengths are unaffected by multiple 345-kV circuits. The signal strength of one of the GPS satellite signals started to decrease as I drove off the right-of-way and under some large trees, but the strength of the other four GPS satellites remained the same (because the trees were not between the other satellites and the GPS receiver on my vehicle).

I then repeated my testing at a separate location that has two double circuit 345-kV lines, a double circuit 120-kV line, and a small 13.2-kV distribution line. The results of this second test are depicted in the graph at the bottom of **Schedule JMS-SR7**, entitled “GPS C/N vs Distance Across 230/345/345 kV Easement (Site #2).” The results of this second test of GPS satellite signal strength demonstrate that there is no effect on the received GPS signal strength due to the multiple 345-kV transmission lines. This is what we would have expected due to our theoretical calculations which indicated that high-voltage transmission lines have no interfering effect on GPS signals.

Q. Do you consider line-of-sight signal blockage of the GPS satellite signals from space likely to occur in agricultural operations?

A. As I have just explained, my research has confirmed this to be highly unlikely. For the proposed Mark Twain transmission line, this is even more unlikely due to the use of tubular steel poles, which are much smaller than large, steel lattice towers. In reality, mobile farm equipment with a GPS receiver operated close to any obstruction, such as a building, a tall fence, silo, tree or other farm equipment such as a crop wagon could also experience temporary blockage of a satellite, depending on the instantaneous alignment of the satellite and the user. But as I have explained, these satellites are moving all the time, so the amount of time that a potential blockage would occur in those circumstances is brief. Even if one satellite signal was very briefly blocked by a transmission pole, it would be temporary and because there are many satellites used, the temporary loss of one out of six or eight satellites being used at the time would not affect the use of GPS. GPS manufacturers have robust designs that can tolerate brief loss of satellites because this is a known and common occurrence near obstacles and also because the moving satellites themselves drop below the "mask angle" set for the earth's horizon by GPS receivers. (The mask angle is the minimum GPS satellite elevation angle above the horizon permitted by a particular receiver. Satellites near the horizon are subject to signal fade or interference caused by signal reflection, called multipath, and is subject to more atmospheric noise than satellites orbiting higher above the horizon. Satellites that move below this angle are dropped and are not used in position solutions. Satellites are added to the position solution as they move above this angle.)

Q. You testified earlier about RTK, a method used in precision agriculture applications to improve GPS accuracy. Is line-of-sight signal blockage due to transmission poles likely for RTK base station signals?

A. No. The concern has to do with the placement of a transmission line pole in the direct line-of-sight between a base station RTK antenna and the antenna on mobile farm equipment and its possible interference with RTK corrections service. While this might occur if a GPS antenna was taken off a tractor, for example, and then held directly against a conductive object such as a tree or transmission line pole or tower; otherwise, the transmission line poles or towers are not large enough to cause interference problems. At distances of more than a few feet from mobile farm equipment, typical power line structures essentially would be electrically invisible. The base station 450/900 MHz frequency signal is not pencil thin but spreads out as it moves away from the transmitting antenna. In addition, this radio frequency wave is diffracted (bends) around obstructing objects if they are not too big—for example, as big as a building. Diffraction allows radio waves to propagate behind obstructions. Also, communications links such as RTK base stations have a system operating margin above the minimum necessary signal strength to account for typical radio wave path loss. Finally, modern GPS equipment used in precision agriculture can maintain the performance and full functionality even when temporary line of sight obstructions occur. For example, John Deere offers an RTK receiver that can maintain the performance and full functionality of an RTK system following the loss of a base station signal for 2-15 minutes (depending on how long the receiver has been powered).

Q. Mr. Silva, what is your conclusion with respect to the concern that GPS devices used for precision agriculture may experience interference when in proximity to the proposed transmission line?

A. Based on my practical measurements, my technical analysis and my best engineering judgment, I believe GPS receivers will be able to receive both the satellite and base station signals used in precision agriculture when near the proposed 345-kV transmission line. Consequently, a GPS unit in farming equipment should work properly with a high degree of accuracy underneath the transmission line. Moreover, ATXI can provide landowners with the transmission structure's GPS points to aid them in navigating farm equipment around the transmission structures.

Q. One last question for you, Mr. Silva. Noel Palmer has testified on behalf of Neighbors United that he has experienced GPS interference with aerial applications near high-voltage lines. How would you evaluate this claim in light of your testimony thus far?

A. Mr. Palmer doesn't explain why or how he concluded that the transmission line itself was the cause of GPS interference. As I have stated in my earlier testimony regarding frequency separation, the frequencies of the Mark Twain transmission line would not be a cause for interference with GPS systems, as they operate at very high frequencies. Line-of-site obstruction would be an unlikely cause, as well, for any GPS interruption, especially given the speeds at which an aerial application plane would routinely operate. Also, as I explained earlier, Ag aviation would use WAAS to augment GPS for precision aerial applications, and all the necessary signals (both GPS and WAAS error corrections) would be coming from satellites in space above the transmission line. In an effort to determine what might be causing Mr. Palmer's GPS problems, I contacted a technical service representative from a leading supplier of GPS hardware and software applications for precision agriculture worldwide. I learned that aerial maneuvers involved in typical aerial uses of GPS are a potential cause of temporary loss of GPS lock due to the fact that the GPS antenna is experiencing non-linear travel and GPS signal reflections (also called multipath). In fact, the representative stated that he "would almost guarantee some sort of signal loss would be present." A different technical representative for precision application products for agricultural pilots and dealers told me that they see GPS problems near strong FM radio antennas and due to some cockpit radios, but were unaware of any GPS-receiver problems due to transmission line interference. In my opinion, the GPS problems Mr. Palmer may be experiencing are more likely due to normal aerial operation, although perhaps he may notice it at times when he is flying near transmission lines.

Q. With regard to the opinions you have stated in your testimony, Mr. Silva, do you hold these opinions within a reasonable degree of engineering certainty?

A. Yes.

Q. Does this conclude your surrebuttal testimony?

A. Yes, it does.

BEFORE THE PUBLIC SERVICE COMMISSION
OF THE STATE OF MISSOURI

In the Matter of the Application of Ameren Transmission Company of Illinois for Other Relief or, in the Alternative, a Certificate of Public Convenience and Necessity Authorizing it to Construct, Install, Own, Operate, Maintain and Otherwise Control and Manage a 345,000-volt Electric Transmission Line from Palmyra, Missouri, to the Iowa Border and an Associated Substation Near Kirksville, Missouri.	File No. EA-2015-0146

AFFIDAVIT OF J. MICHAEL SILVA

STATE OF)
) **ss**
COUNTY OF)

J. Michael Silva, being first duly sworn on his oath, states:

1. My name is J. Michael Silva. I work in Campbell, California and I am a research engineer and President of Enertech Consultants.

2. Attached hereto and made a part hereof for all purposes is my Surrebuttal Testimony on behalf of Ameren Transmission Company of Illinois consisting of 17 pages, and Schedule(s) JMS-SR1 - JMS-SR7 all of which have been prepared in written form for introduction into evidence in the above-referenced docket.

3. I hereby swear and affirm that my answers contained in the attached testimony to the questions therein propounded are true and correct.

J. Michael Silva

J. Michael Silva

A notary public or other officer completing this certificate verifies only the identity of the individual who signed the document to which this certificate is attached, and not the truthfulness, accuracy, or validity of that document.

State of California
County of Santa Clara

Subscribed and sworn to (or affirmed) before me on this 10th day of November ,2015, by James Michael Silva, proved to me on the basis of satisfactory evidence to be the person (s) who appeared before me.

CATHERINE ANN PIANTO
Commission # 2081735
Notary Public - California
Santa Clara County
My Comm. Expires Sep 15, 2018

NNA1

(Seal)

Signature ____________

Catherine Ann Pianto,
Notary

Biographical Outline

J. **Michael Silva, BSE, MSE**

Mr. Silva is the President of Enertech Consultants, a scientific consulting firm located in California. He holds a BS (University of Alabama) and MS (Auburn University) in Engineering in 1971 and 1976, respectively. He is a registered professional electrical engineer in California and also holds a PE license in 7 other U.S. states. He has over 40 years of experience related to electric power facilities and a wide variety of applied research projects. Early in his career, at the Southern Company (1971-76), he was responsible for supervising the design of 46-500 kV transmission lines, special environmental studies on corona, audible noise, vibration studies, and electric & magnetic fields, and applied research relating to electric power transmission lines. He worked for approximately 1-1/2 years at the Electric Power Research Institute in Palo Alto, CA (1977-1978) as a Project Manager for AC and DC overhead lines. In this position, he directed many research projects relating to electric power transmission lines, including: an evaluation of electric field effects of transmission lines (work done at Project UHV), instrumentation development for HVDC lines and stations, design data for ±600 kV to ±1200 kV HVDC lines, and many other research projects. He has also worked as the manager of a variety of applied research projects at GAI in Pittsburgh, PA (1979-82). In 1982, he founded Enertech Consultants and has a focused on applied research on electric and magnetic fields (EMF), electromagnetic compatibility (EMC), hardware and software development, scientific consulting, and new technologies such as GPS. Enertech designs, manufacturers, and sells high-quality EMF instrumentation around the world in 59 countries. Mr. Silva is also assisting the Electric Power Research Institute by managing EPRI research related to EMF and Wireless Technology.

Mr. Silva directed Enertech's development of the **G**lobal **P**ositioning **S**ystem **P**ersonal **A**cquisition **L**ogger (GPS-PAL), a portable, wearable GPS device, which collects and stores position data obtained using GPS. These GPS meters were used by the University of Washington in a study to evaluate and collect location data on children in the Seattle area for exposure assessment of pesticides in orchards and on farms. Enertech also helped develop the software for a system using GPS to monitor the position of commercial fishing boats at sea. The on-board GPS system would continuously monitor boat locations to protect against fishing within restricting areas. If a violation was determined, the system would use INMARSAT telecommunication satellites to send a message to the Coast Guard or other regulatory agencies identifying the boat location and boundary violation. Enertech has also assisted in the development of a system for detecting the location of oil leaks from underground high pressure cable systems. A perfluorocarbon tracer gas (PFT) injected into the cable system was detected using a portable gas chromatograph and mobile GPS monitoring system mounted in a vehicle. The system would be driven through city streets to simultaneously measure PFT levels and GPS locations to identify leak locations for follow-on crews to repair.

Enertech performed a technical study of the potential for electric power facilities to affect use of the global positioning system (GPS). The study evaluated user aspects of GPS, evaluated possible sources of interference and characterized the potential for electric facilities to affect GPS use. Enertech is currently involved in a study with the University of California Los Angeles (UCLA) to accurately determine distance from buildings to the nearest overhead electric transmission line. Enertech is using state-of-the-art GPS survey-grade equipment in conjunction with laser distance rangefinders to precisely characterize power line structure locations and residences. Mr. Silva has also taught a series of fourteen one-day GPS seminars attended by over 400 people at locations across the United States. Topics included a detailed technical overview of the GPS system, differential correction networks, satellite signals, power system environments, performance considerations, and GPS accuracy augmentations. His company has also done studies for Washington University in St Louis, MO to evaluate and mitigate potential interference to the university's Nuclear Magnetic Resonance equipment from magnetic fields created by operation of the MetroLink light rail system.

Mr. Silva has served as a past advisor to the U.S. Department of Energy on various research projects; he also participated as an expert on electric transmission lines in the U.S. Technical Exchange Program between the United States and the former Soviet Union, and has delivered a number of lectures and training seminars on research issues. He was the 1979 Lloyd Hunt Distinguished Lecturer in Power Engineering at the University of Southern California and an invited lecturer in programs at Ohio State University and the University of Texas.

He is a Life Senior Member of the Institute of Electrical and Electronics Engineers (IEEE) and has presented research at the Institute of Navigation. He has served as a publication referee (technical paper reviewer) for IEEE, BEMS, Journal of Exposure Analysis and Environmental Epidemiology, and the American Journal of Epidemiology. He has received awards and recognition for some of his published technical papers. In 2014 he was named a Distinguished Engineering Fellow of the College of Engineering at the University of Alabama.

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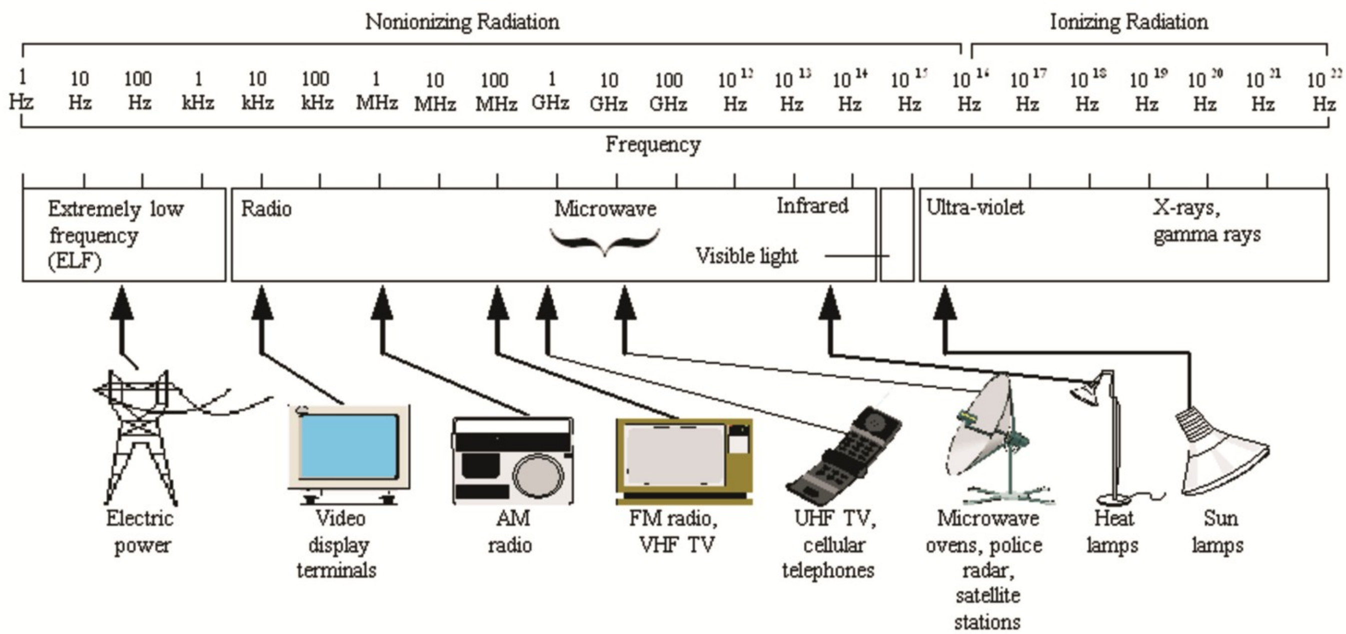
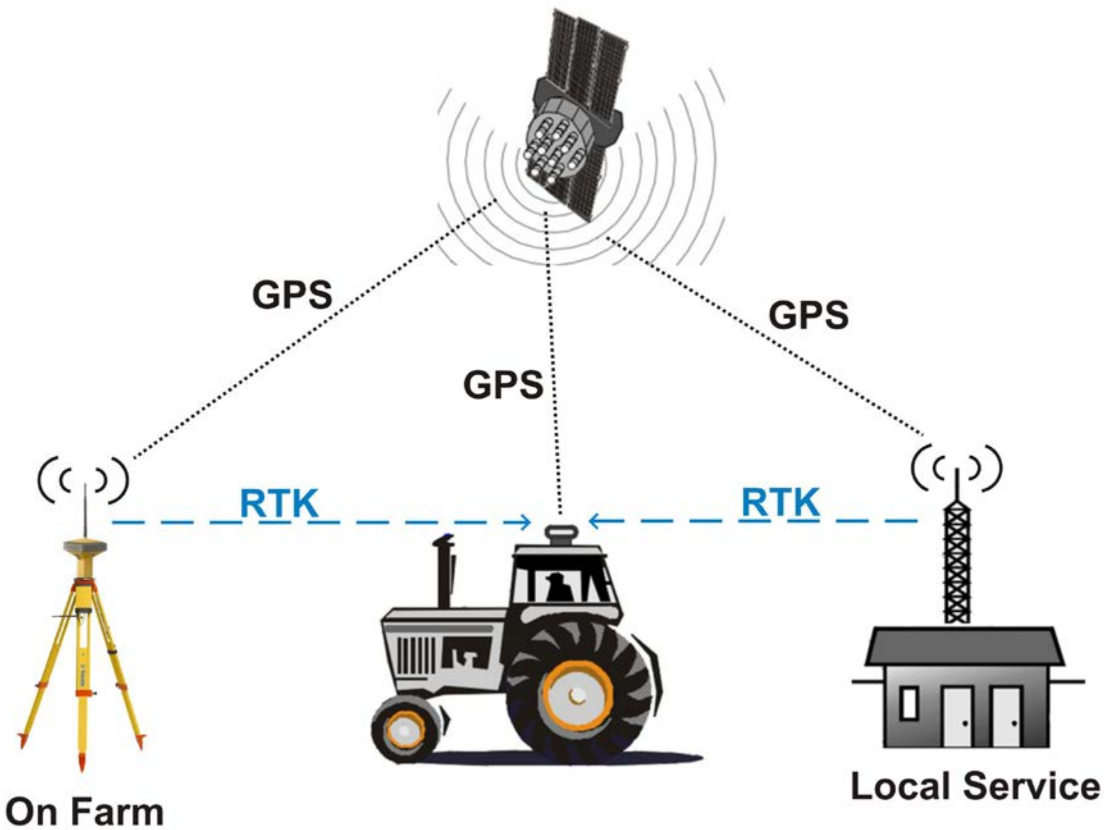
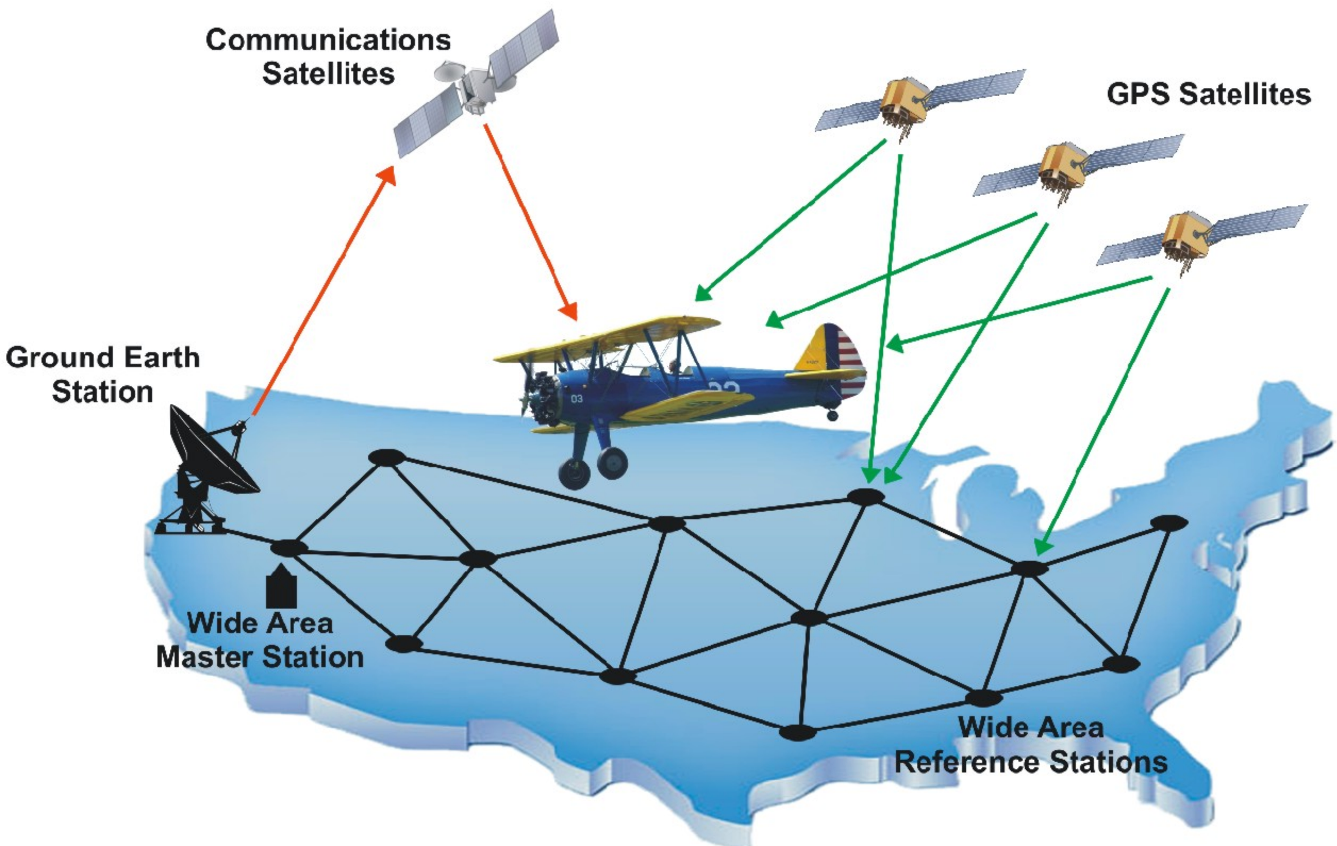
Electromagnetic Spectrum



RTK Accuracy Improvement

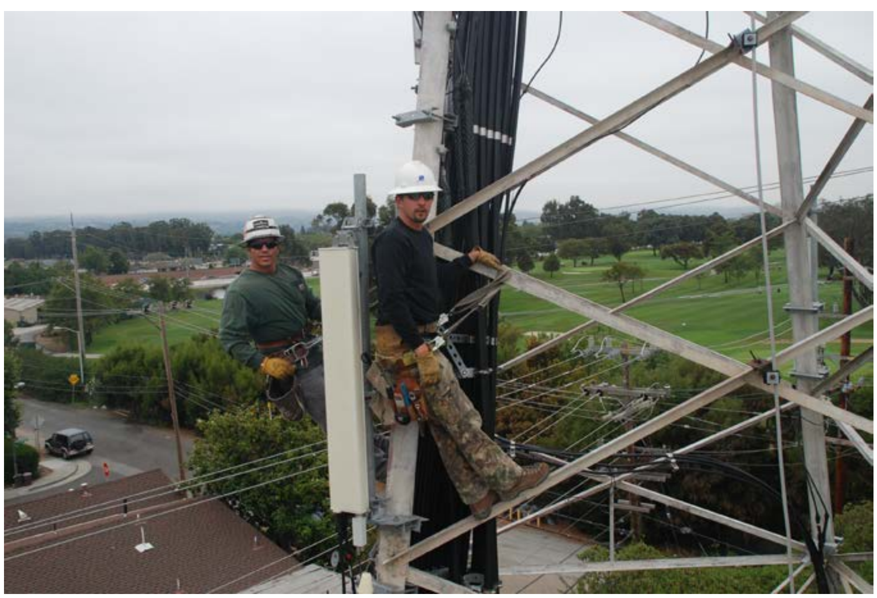


WAAS Accuracy Improvement



Wide Area Augmentation System (WAAS)

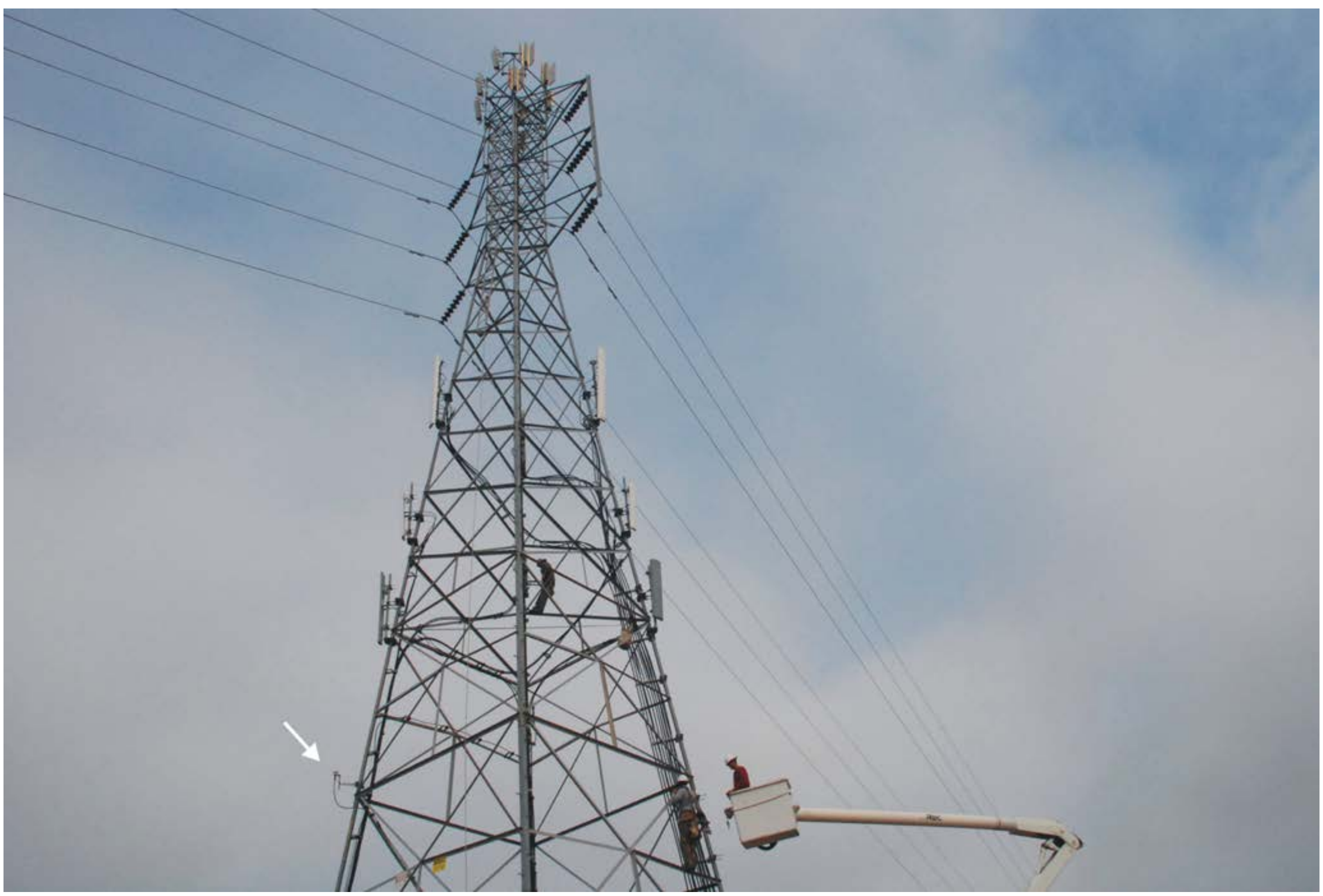
Cell Phone Antennas Installed on 230 kV, 345 kV and 500 kV Transmission Lines.

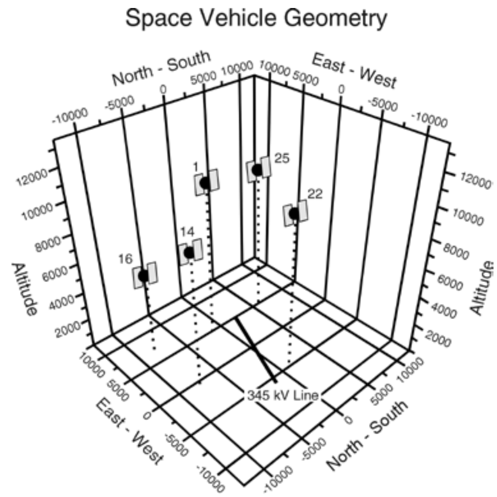


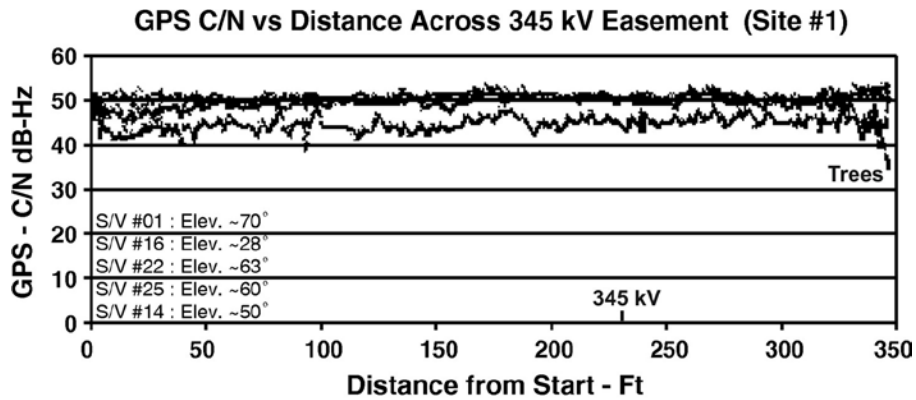
Cellular antennas and equipment sheds utilize transmission line towers.

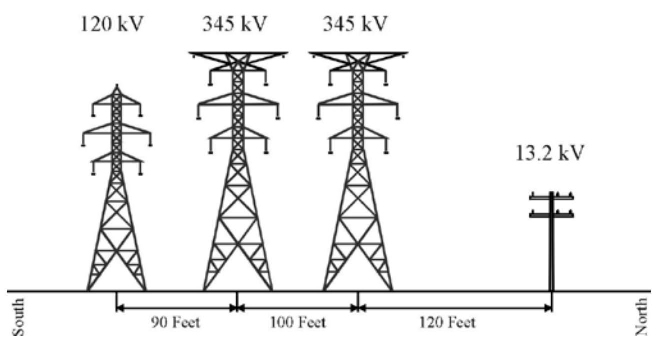
Communications and Cellular Antennas mounted on 500 kV transmission lines.

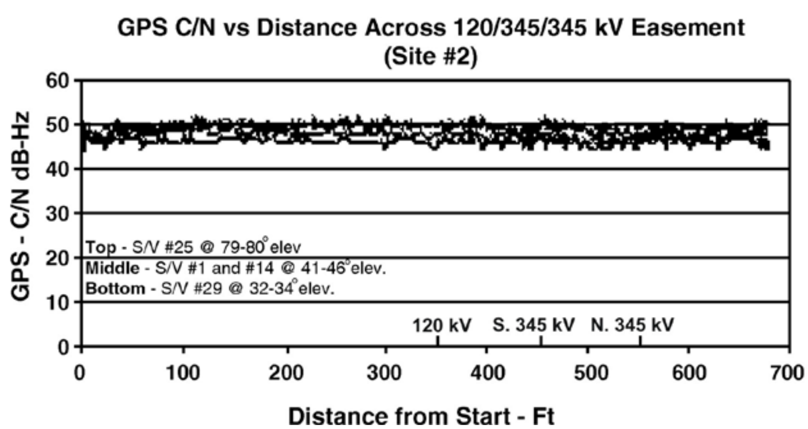
GPS Antennas Installed on Transmission Lines











GPS Signal Strength Measurements- driving under 345 kV lines. GPS signal strength was tracked using 5 GPS satellites. The GPS signal strength did not change while driving under the 345 kV lines.

Schedule JMS-SR7