3.5 Electromagnetic Fields and Electromagnetic Interference

Electromagnetic fields (EMF) describe electromagnetic radiation that is on the lower frequency end of the electromagnetic spectrum.[1] The electromagnetic spectrum includes the various wave forms of energy, from electrical fields to radio waves to light to x-rays. Energy frequencies at the high end of the spectrum are termed ionizing because they break chemical bonds and thereby can damage living cells and deoxyribonucleic acid (DNA). Energy frequencies at the lower end are termed non-ionizing since they do not break chemical bonds and would not have the same biological effects as ionizing radiation. EMF can also result in electromagnetic interference (EMI), which can cause disruptions and possibly malfunctions in sensitive equipment.

EMF is both naturally occurring and human-made. Movement within the earth's molten core generates a substantial electromagnetic field. Stars and sunspot activity generate EMF, as do certain biological processes. Human-made sources have become increasingly prevalent in the last 100 or so years and prominent among these are electrical equipment, telecommunications, and electricity supply facilities. Human-made sources of EMF and EMF's environmental effects are the focus of this section because electrification of Caltrain service would require an electrified overhead system and supporting traction power facilities, thereby increasing sources of EMF in the study corridor.

3.5.1 Existing Conditions

3.5.1.1 Regulatory Setting

Neither the federal government nor the State of California has set emission standards for EMF or EMI.

The Federal Drug Administration, Federal Communications Commission, Department of Defense, and United States Environmental Protection Agency (EPA) at various times have considered EMF guidelines, but none has been adopted.

The California Energy Commission (CEC) recommends that transmission lines be designed so electric fields at the edge of rights-of-way (ROW) do not exceed 1.6 kilovolt (kV)/meter (m); no recommendation is provided for magnetic fields, however. The CEC's current position is that EMF exposure at utility ROW limits should not constitute a significant effect "if emissions have been mitigated to the extent achieved by engineering practice" (Exponent Health Group 2001). The California Department of Education has established a policy of "prudent avoidance" for the location of schools in the vicinity of high-voltage power lines.

[1] The frequency of electromagnetic radiation is the rate at which the electromagnetic field changes direction, expressed in terms of cycles per second, or Hertz (Hz). Frequencies of less than around 3,000 Hz are considered extremely low frequency (ELF) and include alternating current electrical fields that oscillate at 60 Hz.

3.5.1.2 Environmental Setting

Background on EMF

Electrical systems produce both electric and magnetic fields. Electric fields result from the strength of the electric charge, while magnetic fields are generated from the motion of the charge. Together these fields are referred to as EMF, which are invisible, non-ionizing, low-frequency radiation. Electric field strength is measured in units of kV/m and is greater the higher the voltage. Magnetic field strength is measured in units of milliGauss (mG), or magnetic flux density, and is greater the higher the current flow. It is also higher for direct current (DC) than for alternating current (AC). Another common unit of magnetic field strength is the microTesla (μT), with 10 mG equivalent to one μT.

Electric field strength deteriorates rapidly with distance from the source and is easily blocked by most objects, including household objects, buildings, and vegetation. Magnetic fields also decrease rapidly with increasing distance from the source but, unlike electric fields, are not easily blocked. Magnetic fields pass readily through most objects. Magnetic fields are usually the radiation of concern when evaluating EMF.

EMF Exposure and Health Effects

As noted above, EMF can result in EMI, which can cause disruptions and possibly malfunctions in sensitive equipment. In certain situations with sufficiently high exposure, EMF can also result in adverse effects on human health. Considerable research has been undertaken to determine whether EMF at the low frequencies associated with commercial power systems has any health effects. Although some findings conclude otherwise, the great majority of peer-reviewed and accepted studies have found that scientific evidence for any health risks from extremely low-frequency EMF is weak. Objective scientific reviews of animal data, from which some human health risks have been extrapolated, have also concluded that the data are inadequate to indicate a potential risk of cancer, which is the main human health risk assumed for EMF exposure (WHO 2007, IARC 2002, NIEHS 1999).

One area of continuing debate has been associations of two forms of cancer and extended exposures to EMF: childhood leukemia and, in occupationally exposed adults, chronic lymphocytic leukemia. The associations between cancer and EMF, however, have not been demonstrated in scientifically controlled mechanistic (cause-effect) studies or experimental studies of animals, but according to the World Health Organization (WHO), EMF remains a concern (WHO 2007a).

EMF from human-made sources is common and increasing in urban areas. Most people are exposed on a daily basis to a variety of sources and field strengths. The average home in North America has background AC magnetic field levels of approximately 1 mG (WHO 2007b). Background EMF and the durations of EMF exposure at home or at work would be expected to increase in the future as electrical and electronic systems multiply.

Examples of magnetic field strengths of 60-Hz appliances commonly found in the home or office and of magnetic field strengths of electric transmission facilities found in many communities are listed in Table 3.5-1. For the first four appliances, exposure to the maximum field strength would be limited in duration due to the character of use of these appliances. The magnetic field strengths for the video display from a television or computer are for a range of models and represent the continuous level of exposure (appliance plus background) a person would experience while observing or working with the product over an extended period.

Table 3.5-1. Magnetic Field Strengths

Electrical Appliances in Home or Office	Magnetic Field Strengths
Dishwasher	30 mG (at 1 foot)
Vacuum Cleaner	200 mG (at 1 foot)
Hair Dryer	70 mG (at 1 foot)
Electric Shaver	100 mG (at 1 foot)
Video Display	6 mG (at 1 foot)
Other Environmental Sources	
Electric power distribution/subtransmission lines (4 to 24 kV)	
Within right-of-way	10 to 70 mG (at 1 foot)
Edge of right-of-way	NA
High-voltage transmission lines (115 kV to 500 kV)	
Within right-of-way	30 to 87 mG (at 1 foot)
Edge of right-of-way	7 to 29 mG (at 50 to 65 feet)

Source: NIEHS 2002.
kV = kilovolt
mG = milliGauss
NA = not available

Magnetic fields under and alongside the ROW of electric power transmission and distribution lines are also listed in Table 3.5-1. There is considerable range in levels which are a function of the voltage (e.g., a 500-kV line would generate fields approximately four times as strong as a 115-kV line), the height of the power line, and the width of the ROW for exposures measured at the edge of ROW. The duration of EMF exposure could be quite short if, for example, one is simply driving by, or extended, if one is in a residence or other structure adjacent to the power line ROW. At a distance of 300 feet and at times of average electricity demand, the magnetic fields from many lines can be similar to typical background levels found in most homes (NIEHS 2002).

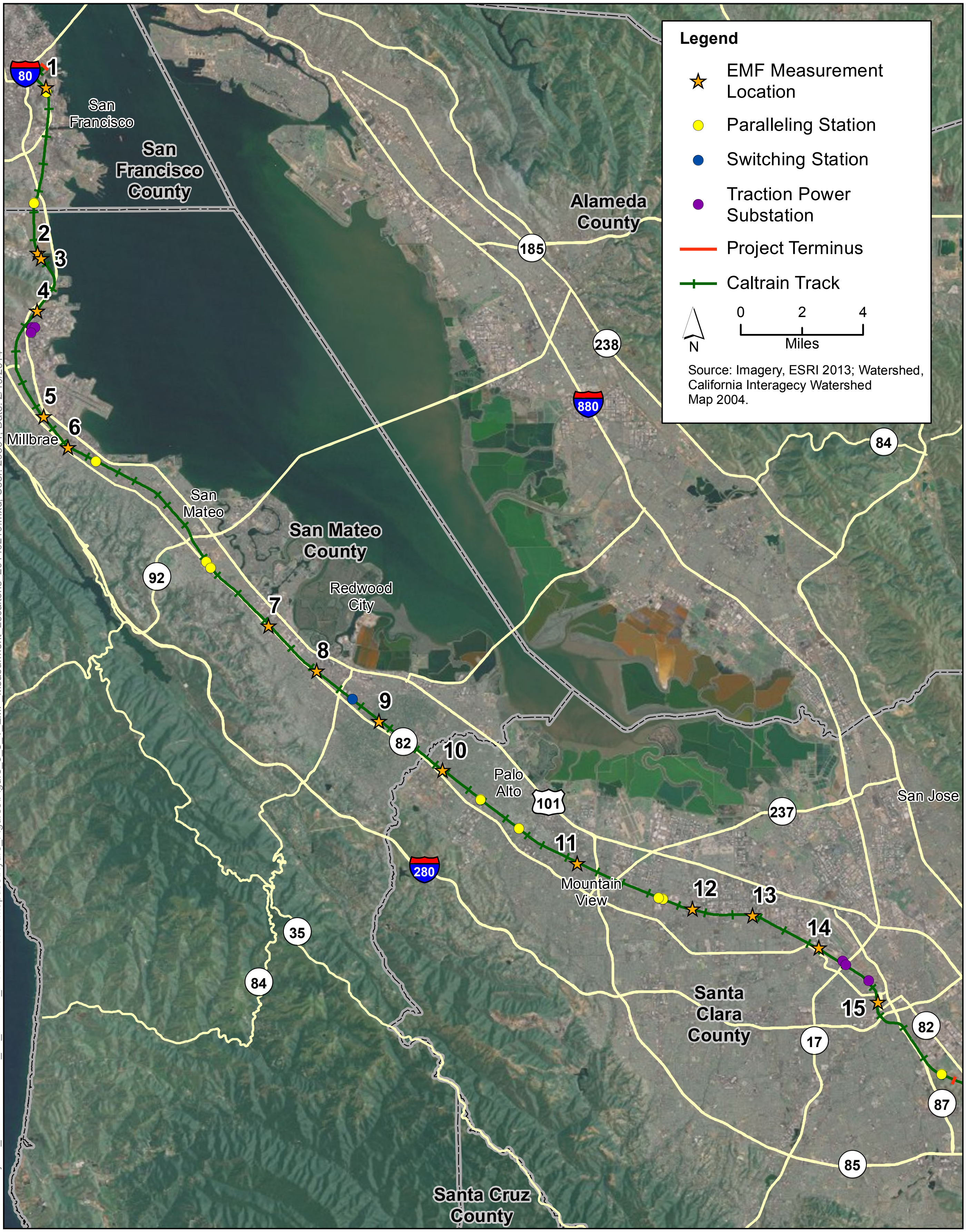
Caltrain Corridor

The Caltrain corridor proposed for electrification is approximately 51 miles long and passes through urban and suburban environments. Land uses within urbanized areas vary from industrial to commercial to residential. In May and June of 2010, electric and magnetic field measurements were collected at 15 sites along the project corridor from San Francisco to San Jose.[2]

[2] The measurements were collected for the California High Speed Rail analysis of existing conditions along the corridor. The electric field measurements were within the 10 kilohertz (kHz) to gigahertz (GHz) frequency bands, which are well above the frequency bands applicable to Caltrain. Therefore, background electric fields measurements from the study are not applicable to the Proposed Project and are not discussed further. Information on background electric fields at 60 Hz within the project area is currently unavailable.

These sites were selected to obtain a cross-section of typical emitters such as power lines and antenna towers, potentially sensitive facilities such as medical facilities and a university, and relatively quiet areas for comparison. The 15 sites, which are shown in Figure 3.5-1, are as follows:

1. **University of California San Francisco (UCSF)**: This location is near downtown San Francisco at the project corridor's closest location to UCSF, at 16th Street where I-280 crosses overhead. UCSF facilities close to the alignment are a potentially sensitive receptor location at the north end of the project corridor. University research facilities often have instrumentation that is susceptible to interference from magnetic field changes.
2. **Brisbane Fire and Police Departments**: This is a suburban location off of Bayshore Boulevard in Brisbane, adjacent to the proposed alignment near the Tunnel Avenue overpass.
3. **Brisbane quiet site**: Magnetic field measurements were recorded south of a small park-like area off of Bayshore Boulevard adjacent to the Brisbane Lagoon. This open area was selected as a potential quiet site.
4. **France Telecom Research &Development (R&D) facility, South San Francisco**: The France Telecom R&D facility is a potential commercial sensitive receptor site that is adjacent to a number of other bio-tech facilities, also sensitive receptors. Measurements were recorded adjacent to the Caltrain corridor on Executive Drive. This location has high-voltage transmission lines.
5. **Near San Francisco International Airport (SFO), South San Francisco**: Measurements were recorded on Madrone Avenue, a residential street in Millbrae situated between the airport and the Bay Area Rapid Transit (BART)/Caltrain alignment.
6. **Health Diagnostics and Burlingame Police Department, Burlingame**: Measurements were recorded at the intersection of Trousdale Drive and California Avenue. The Health Diagnostics Facility has magnetic resonance imaging (MRI) and computerized tomography (CT) imaging systems that are potentially sensitive.
7. **San Carlos quiet site**: This is an open area on the west side of the Caltrain corridor off El Camino Real. Magnetic fields were measured on both sides of corridor, with the east side location along a residential street.
8. **Valley Radiological, Redwood City**: Measurements were recorded along Brewster Avenue in Redwood City near a potentially sensitive medical facility with MRI equipment.
9. **Atherton Police Department**: The Atherton Police Facility, off Fair Oaks Lane in Atherton, is a potential emitter with Radio Frequency (RF) communication systems, adjacent to the Atherton Caltrain stop. Magnetic fields were recorded moving laterally from the Caltrain corridor in a southwest direction.
10. **Palo Alto Medical Center**: This facility is a potentially sensitive site with medical imaging systems. Measurements were recorded in the parking area near Urban Lane, and magnetic fields were recorded along the bike path behind the facility, closest to the Caltrain tracks.
11. **Mountain View Caltrain Station**: Magnetic field measurements were recorded along the Caltrain platform and stationary measurements were recorded next to the tracks to capture magnetic fields due to Caltrain and Santa Clara Valley Transportation Authority (VTA) operations.



Path: K:\Projects_3\Caltrain\00606_12_Caltrain_Modernization\mapdoc\Hydro_Figures\Figure_3_5_1_EMF_Measurement_Locaitons_20140219.mxd; User: 29391; Date: 2/19/2014

Figure 3.5-1
EMF Measurement Locations
Peninsula Corridor Electrification Project

12. **St. Jude Medical Center and Evans Analytical, Sunnyvale**: Both facilities near South Wolfe Avenue are potentially sensitive sites. Magnetic field measurements were recorded along both sides of the South Wolfe Avenue overpass, starting at Kifer Road.

13. **Motorola and Intel, Santa Clara**: These two sites are high-profile companies in Santa Clara that are potentially sensitive facilities. Magnetic field measurements were recorded around perimeter of one of the facilities on Walsh Avenue.

14. **Mineta San Jose International Airport:** Measurements were recorded at a site situated at the south end of Brokaw Road adjacent to the airport.

15. **PG&E substation, San Jose**: This measurement site is south of the San Jose Caltrain Diridon Station, at the end of Otterson Street, off South Montgomery Street.

Background DC Magnetic Fields

Table 3.5-2 summarizes the peak maximum, minimum, and range for static or DC magnetic fields at the measurement sites. The difference between the minimum and maximum measurements, referred to as the "shift," affects the potential for interference with sensitive instrumentation requiring a stable magnetic field environment. The greater the shift, the greater the likelihood for the magnetic field source to disturb the sensitive equipment (Electric Research & Management Vibro-Acoustic Consultants 2010).

Table 3.5-2. DC Magnetic Field Data Summary

		DC Field (milliGauss)		
ID[a]	Description	Min	Max	Range
1	University of California SF campus adjacent to Interstate 280	357.1	367.9	10.8
2	Brisbane Fire and Police Departments	466.9	470.1	3.2
3	Brisbane quiet site	484.2	486.8	2.7
4	France Telecom research and development facility	457.8	463.8	6
5	Near San Francisco International Airport/BART	430.5	533.5	103
6	Health Diagnostics and Burlingame Police Department	506.3	526.4	20.1
7	San Carlos quiet site	492.5	493.1	0.6
8	Valley Radiological	528.1	533.5	5.4
9	Atherton Police Department	508.8	515.4	6.6
10	Palo Alto Medical Center	638.8	640.1	1.3
11	Mountain View VTA and Caltrain station	357.8	466.1	108.4
12	St. Jude Medical Center	540	552.8	12.8
13	Motorola and Intel	481.1	484.5	3.4
14	Near Mineta San Jose International Airport	472.2	474.3	2.1
15	PG&E substation	450.9	455.7	4.8

Source: Electric Research & Management Vibro-Acoustic Consultants 2010
[a] See Figure 3.5-1 for the site locations.

As shown in Table 3.5-2, the two locations showing the greatest DC magnetic field variation were the Mountain View Caltrain platform (see Site 11 in Figure 3.5-1) with a shift of 108.4 mG, and a neighborhood street near the San Francisco International Airport (Site 5) with a shift of 103.0 mG. For the Mountain View location, large DC magnetic field shifts were produced by operation of VTA electric trains. For the location near the San Francisco International Airport location, DC magnetic field shifts were produced by operation of BART electric trains. At a number of locations, DC shifts were typically produced by passing vehicles. At Site 13, the 3.4 mG shift is due exclusively to a passing freight train. The location with the least shift was the open space set back from El Camino Real in San Carlos (Site 7), and the next least shift was at Palo Alto Medical Center, which is beside a bike trail and the Caltrain corridor. The 1.3 mG shift at this location (Site 10) was produced by a passing northbound Caltrain[3] (Electric Research & Management Vibro-Acoustic Consultants 2010).

Background AC Magnetic Fields

Table 3.5-3 summarizes the AC magnetic fields measured along 10-foot intervals moving away from the Caltrain ROW. The largest 60 Hz magnetic fields were recorded at Site 4, near transmission lines crossing the Caltrain corridor in South San Francisco, and at Site 15, adjacent to a PG&E substation. A wide range of magnetic fields were recorded at both the fixed locations and along the spatial profiles. The lowest fields were found at Site 2 near the Brisbane Fire Department facility and at the fixed location for Site 14 adjacent to the Mineta San José International Airport (not close to any power lines). Because the AC magnetic fields vary markedly with position, the spatial profiles are especially useful for providing context to the fixed position measurements. Fixed position measurements provide a general characterization of temporal variation at the test location, and the profile measurements provide a view of spatial variation. The highest fields are associated with close proximity to power lines or power company utility equipment (Electric Research & Management Vibro-Acoustic Consultants 2010).

Table 3.5-3. AC Magnetic Fields Measured along the Project Corridor

		60 Hz AC Field (milliGauss)	
ID[a]	Description	Min	Max
1	University of California SF campus adjacent to Interstate 280	0.07	8.35
2	Brisbane Fire and Police Departments	0.03	0.36
3	Brisbane quiet site	0.14	1.38
4	France Telecom research and development facility	0.75	18.4
5	Near San Francisco International Airport/BART	0.58	1.92
6	Health Diagnostics and Burlingame Police Department	1.21	9.43
7	San Carlos quiet site	0.14	9.15
8	Valley Radiological	0.26	10.77
9	Atherton Police Department	0.22	3.12
10	Palo Alto Medical Center	1.28	11.82
11	Mountain View VTA and Caltrain station	0.12	1.14
12	St. Jude Medical Center	0.22	2.77
13	Motorola and Intel	0.05	3.75
14	Near Mineta San Jose International Airport	0.06	0.99
15	PG&E substation	1.81	17.64

Source: Electric Research & Management Vibro-Acoustic Consultants 2010
[a] See Figure 3.5-1 for the site locations.

The measurement results summarized in Tables 3.5-2 through 3.5-3 are typical of built environments (Electric Research & Management/Vibro-Acoustic Consultants 2010).

[3] The existing diesel-powered Caltrain service has diesel-electric locomotives that generate an EMF through the electric motors powered by the diesel-engine. The EMF generated by the existing Caltrain service would be effectively replaced with EMF associated with the Proposed Project. The difference, or *delta*, in EMF between the existing service and the Proposed Project represents the net impact of the Proposed Project.

3.5.2 Impact Analysis

3.5.2.1 Methods for Analysis

Caltrain electrification would increase the electric and magnetic fields generated near the tracks above the background levels described in Tables 3.5-2 and 3.5-3 above. The proposed design for the system near major substations was incorporated into a model of two- and (existing) four-track electrified operations to calculate EMF fields at critical, maximum load points along the Caltrain corridor under electrification conditions. The system was simulated with peak and off-peak trains drawing power from the overhead contact system (OCS) and power supply network. EMF field strengths were estimated over an alignment cross-section extending 58 feet beyond the centerline of the outside track.[4] This yielded a profile of potential EMF exposures both within and alongside the railroad ROW. The maximum calculated EMF represents a worst case situation for EMF exposure.

Electric and magnetic field levels aboard passenger coaches and at track overpasses were not calculated for Caltrain as vehicle specifications have not yet been finalized. Average and maximum fields at these locations were estimated by examining the performance of two other relevant systems: Amtrak's electrified Northeast Corridor (NEC) service, which extends from Washington, D.C. to Boston, and France's Train A Grande Vitesse (TGV) system, which provides electrified high-speed intercity rail service.[5] These systems were assumed to be representative of Caltrain due to similarities in system design.

While equipment used to construct the Proposed Project could potentially generate EMF and EMI, the levels would not be substantially higher than those generated at a typical construction site. Consequently, construction of the Proposed Project would not cause significant EMF or EMI at nearby sensitive facilities. The following discussion therefore focuses on Proposed Project operations.

3.5.2.2 Thresholds of Significance

While there are no formally adopted federal or state EMF thresholds applicable to the Proposed Project, several professional organizations have developed guidelines for EMF exposure, including the International Commission on Non-Ionizing Radiation Protection (ICNIRP), the Institute of Electrical and Electronics Engineers (IEEE), and the American Conference of Governmental Industrial Hygienists (ACGIH). EMF standards suggested by these organizations address low-frequency (i.e., 60-hertz) EMF exposure to the general public and workers in an occupational setting. Based on published professional standards, Table 3.5-4 summarizes the EMF thresholds used to define a significant impact with respect to public and occupational exposure.

[4] This distance is roughly representative of the distance from the tracks to occupied structures. Distances vary and some occupied structures may be closer and others further from the tracks.

[5] Amtrak NEC is a 25kV, 60 Hz AC system, the same as the proposed electrified Caltrain system. The French TGV measurements apply 50 Hz AC powered segments, with power supply via a 24kV network.

Table 3.5-4. EMF Thresholds of Significance for Public and Occupational Exposure

Receptor	Electric Field (kV/m)	Magnetic Field (mG)
General Public[a]	4.2	833
Employees[b]	25	10,000

[a] These levels are based on the ICNIRP (1998), Maximum Permissible Exposure limits for the general public.
[b] These levels are based on the ACGIH (2013) recommended standards for occupational exposures.
kV/m = kilovolt per meter
mG = milliGauss

For evaluating interference levels for sensitive equipment, significant impacts would occur if the Proposed Project would substantially increase background magnetic field levels.

3.5.2.3 Impacts and Mitigation Measures

Impact EMF-1	Substantially increase electromagnetic fields along the Caltrain corridor
Level of Impact	Less than significant

Operation

Sources of EMF associated with the Proposed Project would be the TPFs (which are the traction power substations, paralleling stations and a switching station), the OCS, and train motors on the electrical multiple units (EMUs). Passengers and employees onboard the trains, as well as receptors adjacent to the Caltrain corridor (e.g., general public, maintenance workers) may be exposed to EMF generated by the Proposed Project.

Table 3.5-5 summarizes the calculated field strengths for electrified Caltrain service at five general locations: aboard coaches/passenger cars, at rail overpasses, within the Caltrain ROW, alongside the railroad ROW, and proximate to traction power substations. Traction power substations would generate the most substantial EMF of the TPFs). Amtrak's electrified NEC service and France's TGV were used as proxies to define field strengths aboard passenger cars, near the traction power substations, and at overpasses. This approach was used because new Electric Multiple Unit (EMU) vehicle specifications for Caltrain are not yet finalized and it is likely that Caltrain EMF levels would be somewhat similar to these values (i.e., similarities of the proposed Caltrain power delivery system to that of the NEC system). EMF exposure levels outside the track ROW and at the edge of the ROW were estimated for Caltrain using the methodology described above.

Table 3.5-5. Estimated EMF Field Strength for Caltrain Operations

		Magnetic Field (mG)	
Location	Electric Field (kV/m)	Average/Off-Peak	Max
Passenger Coach [a]	1.5–2.0	52	305
Overpass [b]	N/A	118	467
Outside track right-of-way [c]	0.35	1.9–4.5	11.4
Edge of right-of-way [d]	0.48	4–11	35–41
Traction power substation [e]	0–22.2	15	110
Threshold [f]	25	833–10,000	833–10,000

[a] Data are from Amtrak's Northeast Corridor (NEC) (Exponent Health Group 2001); because of the similarity of the proposed Caltrain power system to the NEC system, measurements of magnetic fields within NEC passenger cars can be used as estimates of field intensities in Caltrain passenger coaches. For reference, average and maximum magnetic field levels measured for France's Train A Grande Vitesse (TGV) are 31 and 165 mG, respectively. It is assumed the NEC and TGV values would bracket the Electromagnetic fields (EMF) field strengths generated in Caltrain passenger cars operating on an electrified system.

[b] Data are from France's TGV (Federal Railroad Administration 1993).

[c] Calculations were made for 58 feet (four tracks) from the track centerline. This represents approximately where structures might be located or where there are public rights-of-way. Current distributions assumed in the analysis are higher than predicted under future service levels and therefore represent a worst case analysis (Exponent Health Group 2001).

[d] The calculated field strength at the right-of-way edge, approximately 15 feet from the track. Current distributions assumed in the analysis are higher than predicted under future service levels and therefore represent a worst case analysis (Exponent Health Group 2001).

[e] Data are from Amtrak's NEC (Exponent Health Group 2001).

[f] Thresholds from Table 3.5-4.

Kv/m = kilovolt per meter

mG = milliGauss

The EMF fields from electrified Caltrain operations along the ROW would be highest during peak operations, lessening during lower volume periods to become nominal during the late night when Caltrain service is discontinued or only line maintenance is proceeding. As shown in Table 3.5-5, average EMF fields for the NEC were measured at 1.5 to 2 kV/m (electric) and 52 mG (magnetic). EMF fields within the passenger coaches were not estimated for Caltrain because new vehicle specifications are yet to be finalized. Maximum magnetic field strength, experienced when a vehicle is accelerating rapidly or operating a dense, multi-train track segment, was found to be several times the average EMF exposure, measured at 305 mG on NEC trains. It is assumed that EMF field strengths generated in Caltrain passenger cars operating on an electrified system would be similar to these average and maximum values.

Wayside EMF exposure levels would vary by proximity to the outside track's centerline. The field strengths for Caltrain of 0.35 kV/m (electric) and 1.9 mG average and 11.4 mG maximum (magnetic) were estimated at approximately 58 feet from the track. This approximates where public access points and occupied structures would be located. Estimates for locations at the edge of the railroad ROW were 0.48 kV/m (electric) and ranged from 4 mG to 41 mG (magnetic). The higher values at the edge of ROW, which would be expected because that location is closer to the source of electric current (OCS), are about three times the field strength at 58 feet from centerline.

Additional information on expected EMF generated from the Proposed Project can be derived from the Federal Railroad Administration's 2006 report *EMF Monitoring on Amtrak's Northeast Corridor (NEC): Post-Electrification Measurements and Analysis* (FRA 2006). The dominant field from Amtrak's NEC is 25-kV from a 60-Hz ac system, the same as the Proposed Project; therefore, it is reasonable to assume that the measured effects of NEC's electrification would be similar to the potential effects of the Proposed Project. Table 3.5-6 summarizes the measured EMF field strengths for several systems, including detailed measurements taken within the Amtrak NEC. Measurements were taken in proximity to traction power stations, near the tracks during train pass-bys, and inside passenger compartments.

Table 3.5-6. Measured Magnetic and Electric Field Values - Amtrak Northeast Corridor [a]

Magnetic Field Measurements Proximate to Traction Power Stations [b]			
(frequency 0–3,000 Hz) magnetic field expressed in expressed in mG	**Minimum**	**Maximum**	**Average**
Pre-Electrification Measurements	0.0	12.9	1.6
Post-Electrification Measurements	0.1	110.3	14.7
Electric Field Measurements Proximate to Traction Power Stations [b]			
(frequency 0–3,000 Hz) electric field expressed in kV/m	**Minimum**	**Maximum**	**Average**
Pre-Electrification Measurements	0	3.16	0.33
Post-Electrification Measurements	0	22.2	4.1
Magnetic Field Measurements at Three Distances from Five Electrified Train Pass-Bys			
(frequency 0–3,000 Hz) magnetic field expressed in mG	**5 m (16.5 feet)**	**10 m (33.0 feet)**	**15 m (49.5 feet)**
Minimum	25	3	negligible
Maximum	84	25	7
Average	54.4	11.4	2.0
Magnetic Field Measurements within Passenger Compartments [c]			
(frequency 2–3,000 Hz) magnetic field expressed in mG	**Head**	**Waist**	**Ankle**
Average Values	19.2	18.4	19.1

[a] Data collected as part of Post-Electrification Measurement & Analysis study, for electrified portion of Northeast Corridor extending from New Haven, Connecticut to Boston, Massachusetts.

[b] Long-term measurements taken at 10 traction power station locations.

[c] Measurements averaged from seven train systems operating along Northeast Corridor.

Source: FRA 2006.

hZ = herz

kV/m = kilovolt per meter

m = meter

mG = milliGauss

As shown in Table 3.5-6, post-electrification magnetic field measurements near traction power substations were substantially higher than the pre-electrification values; the same is true for the electric field measurements. However, the measured post-electrification values were far below established public health exposure limits. Magnetic field measurements associated with train pass-bys and inside passenger compartments were an order of magnitude less than the TPS values. Similar exposure levels are expected along the Caltrain ROW, which as shown in Table 3.5-5, would also well below the EMF exposure limits for the general public and employees, and which would be minor in comparison with the background levels (see Tables 3.5-2 and 3.5-3).

In addition to reducing the number of large primary substations, another advantage of the auto-transformer feed arrangement proposed for implementation along the Caltrain corridor is its potential to reduce EMF and EMI. These fields are reduced because the arrangement includes two parallel aerial feeders, one on each side of the alignment in which currents in the parallel feeders flow in the opposite direction to that in the main catenary conductors. This tends to cancel EMF and EMI effects created by current flow in the main OCS.

For the reasons discussed above, there would be no significant health risks from the electrified Caltrain operations. This impact would be less than significant.

Impact EMF-2	Substantially increase electromagnetic interference along the Corridor
Level of Impact	Significant
Mitigation Measure	EMF-2: Minimize EMI effects during final design
Level of Impact after Mitigation	Less than significant

Operation

The main sources, or generators, of transient EMI disturbances from electrification would be switching currents produced by switching loads, relays, power controllers, and switch mode power supplies associated with operation of the OCS or the TPFs. High-current electronic switches and controls are capable of producing transient signals that can be transmitted along the power supply network to other electronic systems. Magnetic fields would also be generated by paralleling and switching stations, as well as traction power substations.

As described in Chapter 2, Project Description, the Proposed Project will protect the existing railroad signal system, the grade crossing system, and the Positive Train Control system from electromagnetic interference created by the 25kv AC system by:

- designing the catenary system using proven solutions that minimize the effect of EMI;
- providing sufficient shielding for electronic equipment;
- installing specialized components, such as filters, capacitors, and inductors; and
- ensuring that the electric vehicles are designed with a frequency that does not interfere with the frequency of the grade crossing warning system.

However, the generation of new EMFs could result in interference with sensitive equipment located adjacent to the Caltrain corridor (such as at the Palo Alto Medical Center) or could affect other equipment such as adjacent BART train control and communication circuits.

However, as shown in Table 3.5-6, magnetic fields generated by the Proposed Project outside the Caltrain ROW would be minor in comparison with background concentrations and threshold levels. The intensity of these fields would dissipate as a function of distance. Accordingly, generated magnetic fields generated by the Proposed Project would decrease rapidly with distance and would be substantially lower at nearby sensitive receptors where sensitive equipment may be located. As noted above, the autotransformer power system proposed for use tends to reduce EMF and EMI effects because of the self-cancelling resulting from bi-directional current flows in the feeder and contact wires.

The auto-transformer system was chosen for the Proposed Project over the direct center feed system in large part because of the success of similar installed and operating systems in the United States, Europe and other parts of the world in minimizing the effects of both EMI and EMF. The Proposed Project's spacing of the traction power substations, paralleling stations and switching station, and, hence, of the auto-transformers, is about 5 miles (10 facilities along 51 miles). The Amtrak NEC system has the auto-transformers spaced 6 to 8 miles apart. During the design of the NEC project, the assessment of potential longitudinal induced voltages showed that they should not be greater than what occurs with typical utility distribution systems of comparable voltage. In this respect, the NEC project was designed and tested to levels of less than 20 volts during actual trainload, and significantly less than the 430-volt design recommendation during fault conditions.

However, despite the extremely low potential for adverse EMI effects, there remains the possibility of effects on sensitive equipment. Therefore, Mitigation Measure EMF-2 will require that EMI be further assessed on a site-specific basis during final project design to ensure avoidance of significant EMI effects above baseline conditions. With the current design and site-specific considerations included in Mitigation Measure EMF-2, EMI impacts would be less than significant.

Mitigation Measure EMF-2: Minimize EMI effects during final design

The potential for EMI effects shall be minimized by ensuring that all electronic equipment is operated with a good electrical ground and that proper shielding is provided for electronic system cords, cables, and peripherals. Installing specialized components, such as filters, capacitors, and inductors, can also reduce EMI susceptibility of certain systems. The design of the system will consider and incorporate, where practicable, the latest standards relevant to minimizing the effects of EMI on other systems, including the Caltrain and BART signal systems.

During final design, detailed analyses shall be undertaken to determine the specific levels of any voltages that could be induced onto paralleling longitudinal conductors and, if significant voltages were to be identified, mitigation measures shall be developed in accordance with the relevant industry accepted IEEE and/or MIL (Military) standards. The final design shall utilize proven technologies for catenary system components, and the technical specifications shall be written to assure that damage during construction to the conductors or hardware will be minimized to the greatest extent practicable.

Proven design standards have been developed and shall be followed to mitigate any identified effects. For instance, the NEC installed 25 kV electrification system, counter poise ground wires were installed in some locations, and additional bonding between the aerial ground conductors was used as well. The specific design features shall be developed during final design, in accordance with the published standards.

During final design, the JPB will make a good faith effort to coordinate with local cities, BART, UCSF, France Telecom, Health Diagnostics, Valley Radiological, Palo Alto Medical Foundation, St. Jude Medical Center, Evans Analytical, Motorola and Intel (and any other facilities located adjacent to the ROW with sensitive equipment and requesting such consultation) to determine whether their facilities would be susceptible to EMI effects. If substantial negative effects associated with the Proposed Project were to be identified above baseline conditions, specific design measures shall be developed by the JPB to address localized EMI effects of the Proposed Project.