4.7 ELECTROMAGNETIC FIELDS

4.7.1 INTRODUCTION

This section presents information on electromagnetic fields and interference and discusses impacts related to the SVRTC alternatives. Information in this section is based on the *Electromagnetic Fields (EMF) Report* (Earth Tech 2003).

4.7.1.1 Electromagnetic Fields and Electromagnetic Interference

Electromagnetic fields (EMF) are associated with electromagnetic radiation, which is energy in the form of photons. Radiation energy spreads as it travels and has many natural and human-made sources. The electromagnetic spectrum, the scientific name given to radiation energy, includes light, radio waves, and x-rays, among other energy forms. For purposes of describing the EMF setting for the SVRTC and effects of the SVRTC project, human-made sources of radiation energy and associated EMF are relevant.

The commonly known human-made sources of EMF are electrical systems such as electronics, telecommunications, electric motors, and other electrically powered devices. The radiation from these sources is invisible, non-ionizing, and low frequency. Generally, in most living environments, the level of such radiation plus background natural sources of EMF are low and not considered hazardous. Under extreme conditions, however, EMF can become intense and hazards include shock and burn. Such conditions are nevertheless rare. The more pertinent concern over EMF exposure is the potential biological and health effects to individuals as the number of EMF-generating activities increases. As more sources of EMF are introduced, the extent and level of human exposure increases. The potential biological and health effects are under much study and intense debate.

Another concern over EMF generation is the potential interference to other electromagnetic systems that can result when new or more intense sources of radiation are introduced into the environment. These effects are better understood than health effects and are well documented. Electromagnetic interference (EMI) may include interruption, obstruction, or other degradation in the effective performance of electronics and electrical equipment. Depending upon the critical nature of this equipment, the effects can have serious consequences for the health and safety of individuals. Perhaps of less concern, but nonetheless important, is that the efficiency of affected systems may be reduced.

With the increasing number of personal computer systems in use in homes and businesses, a common problem is magnetic interference to computer monitors when used near alternating current (AC) or varying direct current (DC) magnetic fields. Computer monitors, particularly large screen monitors, are susceptible to interference created from nearby electrical sources, such as electrical panels, transformers, currents within internal systems wiring, or transmission and distribution lines.

Data corruption can also occur on magnetic or film media from very high magnetic fields. It is commonplace for data files to be transported using pocket-size magnetic or film media, particularly floppy or zip diskettes. The potential for computer monitor interference and data corruption on magnetic media from the operation of the BART Alternative is extremely small. It is worth noting that magnetic media materials (fare cards, credit cards, laptop computers with hard drives, and so forth) are routinely carried by passengers, not only on BART but also on many other DC powered transit systems throughout the world, with no reported negative effects.

As the name implies, EMF has electrical and magnetic field components. With respect to electrical systems, electric fields result from the strength of the electric charge (voltage), with DC generating stronger EMFs than AC at a given voltage, while magnetic fields result from the motion of the charge (current). Electric field strength is measured in units of volts per meter (V/m) and is greater the higher the voltage. Field strength deteriorates rapidly with distance from the source. Magnetic field strength has several units of measure; the most commonly used are milligauss (mG) and microTesla (µT). Ten milligauss equal one microTesla. Magnetic fields also deteriorate with distance but readily pass through most objects. Magnetic fields are typically the radiation of concern when evaluating EMFs.

Although modern society increasingly relies on electromagnetic systems, strong EMF fields are not associated with the normal living and working environment. Examples of EMF intensities from human activities include the following:

- Overhead power transmission line: 32 to 57 mG (range of exposure to utility workers)
- Household appliances: 8 to 165 mG (at a distance of 27 cm, or 12 inches)
- Computer video display: 2 to 4 mG (at 35 cm, or 16 inches)
- Rail vehicle (electrically powered): 400 mG (at 110 cm, or 43 inches from the vehicle floor) to 1,500 mG (at floor level)[1]

For comparison, in the natural environment apart from human activity, the earth's static magnetic field varies from 300 mG (30 µT) at the equator to over 600 mG (60 µT) at the magnetic poles. In the San Jose area, the earth has a natural static magnetic field of about 510 mG (approximately 50 µT).

4.7.1.2 Health Concerns

Although short-term human health effects from exposure to elevated levels of EMFs are well established, such as effects on the central nervous system and heating of the body, the long-term effects from exposure to lower levels of EMFs continue to be studied. Several reports have proposed a link between EMF exposures and such health problems as cancer, including childhood leukemia. The preponderance of authoritative scientific studies, however, has found no firm evidence of long-term health risks from low-intensity EMF exposures. Despite the lack of scientific evidence of harm, the public continues to express concern, and health and regulatory agencies continue to study the matter.

4.7.2 EXISTING CONDITIONS

4.7.2.1 Existing Setting

The existing EMF environment in the study area varies depending upon location, as EMF levels are typically site-specific. For example, commercial/industrial centers using major electrical systems and areas near high voltage lines or other power transmission networks would likely have higher EMF levels than residential and undeveloped areas. Because EMF levels in the study area are not likely to be affected by implementation of either the No-Action or Baseline alternative, the following discussion of existing conditions is based on implementation of the BART Alternative and measured EMF levels along the BART corridor.

The BART alignment would pass through agricultural, urban, and suburban environments. Land uses within urbanized areas vary from industrial to commercial to residential. Field measurements to establish existing EMF conditions at specific locations along the corridor were completed in December 2001. Both DC and power frequency AC magnetic fields were measured. Table 4.7-1 shows measurements taken at points along the BART alignment to establish current EMF levels.

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[1] *Safety of High Speed Guided Ground Transportation Systems, EMF Exposure Environments Summary Reports*, Federal Railroad Administration, August 1993.

Table 4.7-1: EMF Levels at BART Alternative Corridor Locations	
Location	**Vertical Field Peak (in Gauss / µT)**
Southwest corner of 28th and East Santa Clara streets	1.7 G / 170 µT
At Berryessa Road crossing of proposed ROW	1.1 G / 110 µT
Center island of Montague Expressway (east side) at North Capitol Avenue (VTA – Tasman East LRT line right-of-way)	1.4 G / 140 µT
Along north side of East Santa Clara Street between Market Street and North 1st Street	.9 – 1.4 G 90 µT – 140 µT
Along north side of West Santa Clara Street between Terraine Street and Notre Dame Street	1.0 – 1.4 G 100 µT – 140 µT
At Caltrain Depot on Railroad Avenue at Palm Drive, Santa Clara (near airport)	.9 – 1.1 G 90 µT – 110 µT
Source: Earth Tech, Inc., 2003.	

The BART Alternative project area contains no known sources of high-level radiation or severe EMF risks to the general public. EMF exposures, although common, are low-level.

The San Jose Medical Center was targeted as a location of particular concern because operation of magnetic resonance imaging (MRI) systems housed at the facility could be at risk for electromagnetic interference. Table 4.7-2 shows the measurements taken at and around the San Jose Medical Center to establish current EMF levels at that location.

Table 4.7-2: EMF Measurements at the San Jose Medical Center	
Location	**Vertical Field Peak (in Gauss / µT)**
South 16th Street and East Santa Clara Street	1.1 G / 110 µT
Front of main lobby at East Santa Clara Street	1.3 G / 130 µT
Outside east lobby	1.1 G / 110 µT
Near MRI trailers, corner of parking lot	1.5 G / 150 µT
Along south side of East St. John Street between North 15th Street and North 14th Street	1.0 – 1.3 G 100 µT – 130 µT
Along east side of North 14th Street from East St. John Street halfway towards East Santa Clara Street	.7 – .8 G 70 µT – 80 µT
Along east side of North 14th Street approaching East Santa Clara Street, along East Santa Clara to main lobby entrance	.9 – 1.3 G 90 µT – 130 µT
Along north side of East Santa Clara Street from main lobby to corner of North 16th Street	1.0 – 1.3 G 100 µT – 130 µT
Along south side of East Santa Clara Street between South 15th Street and South 14th Street	1.0 – 1.4 G 100 µT – 140 µT
Along south side of East Santa Clara Street between South 14th Street and South 13th Street	1.1 – 1.5 G 110 µT – 150 µT
Along east side of North 13th Street between East Santa Clara Street and East St. John Street	1.1 – 1.4 G 110 µT – 140 µT
Source: Earth Tech, Inc., 2003.	

4.7.2.2 Regulatory Setting

Government

Neither the federal government nor the State of California has set standards for EMF exposures. The Federal Drug Administration, Federal Communications Commission, United States Department of Defense, and USEPA at various times have considered guidelines. 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. Several states and other countries have standards for electrical field exposures.

Professional Organizations

The American Conference of Governmental Industrial Hygienists (ACGIH) publishes annual threshold limit values (TLVs) for chemical substances and physical agents, as well as biological exposure indices (BEIs). In the 2001 TLVs and BEIs published by the ACGIH, threshold limit values are recommended for static (DC) magnetic flux densities to which it is believed that nearly all persons may be repeatedly exposed day after day without adverse health effects. According to the ACGIH, these values may be used as guides in the control of exposure to static magnetic fields but should not be regarded as fine lines between safe and dangerous levels.

The ACGIH guidelines suggest that routine occupational exposures should not exceed 60,000 µT to the whole body, or 600,000 µT to the body's limbs on a daily, time-weighted average basis (ACGIH 2001). Recommended ceiling values are 2 Tesla (2,000,000 µT) for whole body, and 5 T for the limbs. Safety hazards may exist from the mechanical forces exerted by the magnetic field upon ferromagnetic tools and medical implants. Cardiac pacemakers and similar medical electronic device wearers should not be exposed to field levels exceeding 0.5 T (500,000 µT). These values are listed in Table 4.7-3.

Table 4.7-3: ACGIH Guidelines for EMF Exposure

	Whole Body	**Limbs**
Daily Average	60,000µT	600,000µT
Ceiling Values	2T	5T
Medical Device Wearers	0.5T	N/A

Source: ACGIH, 2001.

The International Commission on Non-Ionizing Radiation Protection (ICNIRP) has published reference levels for general public exposure to time-varying magnetic fields (unperturbed rms values) of 40,000 µT for frequencies below 1 hertz (ICNIRP 1998). This reference level is given for the condition of maximum coupling of the field to the exposed individual, thereby providing maximum protection. The value is obtained from the basic restrictions by mathematical modeling and by extrapolation from the results of laboratory investigation. The ICNIRP guidelines on limits of exposure to static magnetic fields suggest that continuous exposure of the general public should not exceed a magnetic flux density of 40,000 µT (ICNIRP 1994).

The guidelines published by ICNIRP and ACGIH both recommend exposure limits well above those typically found within the passenger or pedestrian exposure fields from BART. Since the BART Alternative would employ the same vehicles and propulsion system as those currently in use on BART, EMF influence on operators or passengers within the vehicles will not change from current operation levels.

4.7.3 IMPACT ASSESSMENT AND MITIGATION MEASURES

4.7.3.1 Impacts

No-Action and Baseline Alternatives

The No-Action Alternative and Baseline Alternative would not introduce major new EMF generators into the study area environment. (See Section 3.2.1.2 for a list of future projects under the No-Action Alternative.) Their transit improvements would be primarily related to expanded bus service. Although buses have electrical systems that would generate EMF, the potential exposure to riders would differ little from the exposure an individual would experience when riding in a non-electric private automobile, for example.

BART Alternative

EMF effects of the SVRTC project pertain mainly to the BART Alternative, including the MOS Scenarios, which would have the same EMF impacts. The extension would result in new sources of EMF generation and exposure to passengers and to individuals working on the systems or passing in the vicinity of such systems. The main sources of EMF generation would include train power distribution systems; traction power substations with connecting lines to the major utility lines; passenger facilities, with their various electrical systems for lighting, communications, utilities, fare machines, among other systems, and their proximity to power distribution networks; and electrically-powered rail passenger vehicles. Since BART uses DC traction power along the ROW, contributions from BART to the magnetic field levels of the ambient power frequency (60 hertz AC) would be negligible.

Magnetic field measurements were made along existing BART operations at the Lake Merritt Station and near the Dublin/Pleasanton Station that are representative of those expected along the BART Alternative. DC magnetic field measurements were also made around the perimeter of the BART Dublin substation during early morning operations. Tables 4.7-4 and 4.7-5 show the measured EMF values found above and below BART rails. The values in these tables are well below the guidelines presented in Section 4.7.1.3 above.

Table 4.7-4: Vertical Field Peak Measurements Above Existing, Operating BART Tracks at Hopyard Overpass, Pleasanton

Location	Vertical Field Peak (in Gauss / µT)
Over eastbound I-580 lanes – approximately 14 meters (46 feet) above rails, approximately 35° from rail center	2.1 G / 210 µT
Over eastbound I-580 lanes – approximately 14 meters (46 feet) above rails, directly over rail center	2.1 G / 210 µT
Source: Earth Tech, Inc., 2003.	

EMF intensities associated with trains vary considerably. The greatest potential fields would be within the electric rail vehicle. Therefore, the greatest potential for exposure would be for passengers, train operators, and attendants onboard the train. Passengers and workers would also be exposed to EMF fields in stations, and further exposure would occur to workers at traction power substations. Strong

Table 4.7-5: Vertical Field Peak Measurements Below Existing, Operating BART Pleasanton Line at Rodeo Park Underpass at BART / I-580	
Location	**Vertical Field Peak (in Gauss / µT)**
Approximately 6 meters (20 feet) directly below eastbound rails – no train present	1.7 G / 170 µT
Approximately 6 meters (20 feet) directly below eastbound rails – six-car train moving overhead	1.8 G / 180 µT
Approximately 10 meters (33 feet) directly below and between eastbound and westbound rails.	2.0 G / 200 µT [1]
Note: [1] Fairly constant field, with or without train movement overhead. *Source: Earth Tech, Inc., 2003.*	

fields that carry a greater possibility of health risks would not be associated with these environments, however. The field strengths of electrified rail systems would be low and below recommended exposure levels. Representative field measurements taken outside of existing BART stations are shown in Table 4.7-6.

Table 4.7-6: Vertical Field Peak and Range Measurements for Reference		
Location	**Range**	**Vertical Field Peak (in Gauss / µT)**
Church of Christ, Pleasanton parking lot	approximately 50 meters (164 feet) south of BART rails (with and without trains)	2.0 G / 200 µT
Church of Christ, Pleasanton parking lot	approximately 100 meters (329 feet) south of BART rails (with and without trains)	1.9 G / 190 µT
Background field measurement between Dublin and Livermore,	15 miles east of the end of BART tracks	1.3 – 1.7 G 130 µT – 170 µT
Background field measurement between Dublin and Livermore	15 miles east of the end of BART on farm	.8 – 1.4 G 80 µT – 140 µT
Source: Earth Tech, Inc., 2003.		

Measurements of DC magnetic fields were taken along the south wall of a substation at the Pleasanton Station where public exposure might occur. Additional measurements were taken at all three levels at the Lake Merritt Station. The values found at these BART stations are shown in Table 4.7-7.

Field strengths onboard BART trains, which contain major propulsion equipment below floor level, show measurements ranging from 1,600 to 2,000 mG total (USDOT et al. 2002). These values are equal to 160 to 200 µT, which is well within the ACGIH and ICNIRP guideline thresholds.

For the present analysis, a computer model was designed to calculate the worst-case static magnetic field strength that could occur as a result of BART vehicle operations. Two representative rail profiles were introduced into the model. The first is a typical rail layout for BART on an elevated structure with the

Table 4.7-7: Vertical Peak Measurements at Representative BART Stations	
Location	**Vertical Field Peak (in Gauss / µT)**
Between Pleasanton Station and BART rails, parking lot center – max. along south wall of substation	2.2 G / 220 µT
Lake Merritt Station – platform level between rail centers	1.3 G / 130 µT
Lake Merritt Station – Level 1, approximately 7 meters (23 feet) directly above southbound rails	1.7 G / 170 µT
Lake Merritt Station – Level 2, street level, approximately 15 meters (49 feet) directly above southbound rails	1.9 G / 190 µT
Source: Earth Tech, Inc., 2003.	

third rail located outside the running rails. The second rail profile is a typical BART rail layout at grade with the third rail located inside, or between, the running rails for each track. In each case modeled, a maximum third rail current of 12,000 amperes was used for simulation of a 10-car train under maximum load operation. This condition does not exist for extended operating periods, but typically only for short durations during maximum acceleration. Other moderating features typically employed by BART were omitted, such as multiple traction power substations and propulsion cross-bonding, which equalizes and distributes rail currents. This model is designed to illustrate the maximum potential field possible under normal operation. The earth's magnetic field of 50 µT, as it exists in the San Jose area, was used as a reference.

The results of the modeling showed that static magnetic field levels above 50 µT do not extend beyond 10.0 meters (32.8 feet) from the center of the two BART tracks at track level. This finding is based on two trains running in opposite directions on the two parallel tracks. Electric currents are assumed to be evenly distributed between the power rails (i.e., the third rails) and the running rails (i.e., the iron rails on which BART trains run), which return very low voltage current to electric power substations. Under conditions when electric currents are not evenly distributed (e.g., if only one of the third rails is supplying power to a train or return currents are not balanced among the running rails), static magnetic field levels above 50 µT can extend to approximately 15.0 meters (49.2 feet) from the center to the two BART tracks. At approximately 15.0 meters (49.2 feet), static magnetic field strength returns to the normal background level when there are no other sources of static electric currents present.

The existing MRI units at the San Jose Medical Center are set back from the proposed BART ROW by at least 30.0 meters (98.4 feet). Also, BART trains are running underground in two tunnels at this location. Therefore, the setback and underground tunnels are adequate to reduce possible EMF interference from BART operations, as demonstrated by the model discussed above.

The measurements and models presented in this section demonstrate that exposure levels for BART train passengers and operators, passengers and BART employees in a station, and other BART workers are well below the guidelines for preventing health effects. Therefore, the potential for non-users, businesses, and residences at ground level to experience EMF exposures from BART would be minimal, and present evidence suggests that there would be no demonstrable health risks from exposure to EMF with the BART Alternative, including the MOS Scenarios.

4.7.3.2 Design Requirements and Best Management Practices

Baseline Alternative

The Baseline Alternative would not introduce major new EMF generators into the study area environment; therefore, neither design requirements nor best management practices are necessary.

BART Alternative

The following design features and standards will be included for the BART Alternative and MOS Scenarios to minimize the potential for EMF and EMI effects:

- EMF issues will be included in the preliminary and final project design reviews to evaluate possible effects of the design with respect to DC and low frequency magnetic fields.
- An EMF Control and Test Plan will be included in the general contractor specifications to maintain awareness of the possible effects of the BART Alternative construction and operation, as well as provide field measurement for and confirmation of the final design. The plan will include EMF limits (based on ICNIRP and ACGIH guidelines) in the design and construction specifications and require testing and measurement of the final installed system.
- VTA will alert the Office of Radiology at the San Jose Medical Center of any intent to begin construction within approximately 300 meters (approximately 1,000 feet) of their facility. However, no interruption of their operations is anticipated.

4.7.3.3 Mitigation Measures

No-Action and Baseline Alternatives

The No-Action and Baseline alternatives would not introduce major new EMF generators into the study area environment; therefore, no mitigation measures are necessary.

BART Alternative

Because EMF intensities and exposures from BART operations are below thresholds indicating potential health risks, no mitigation measures are required for the BART Alternative or MOS Scenarios.