Attachment A. Electromagnetic Interference White Paper

ELECTROMAGNETIC INTERFERENCE IMPLICATIONS OF AUSTIN LIGHT RAIL TRANSIT SYSTEM

1. Introduction

Operation of Austin Light Rail Transit (LRT) system (a DC light rail system with 1500 VDC system voltage) will produce transient magnetic fields that would perturb the static background magnetic environment—which is primarily the geomagnetic field—in proximity to the alignment.

The magnetic fields are produced by the flow of electric currents on the DC traction system conductors, namely supply currents flowing to LRT vehicles on the overhead contact system (OCS) and returning to traction power substations (TPSS) via the rails. LRT vehicles draw electric power from the OCS via pantographs and provide a return path to the rails via the wheels.

In general, magnetic fields from currents on the DC traction system depend on details of the system layout along with train operations and are proportional to the magnitude of the currents flowing on the various sections of the traction system. As such, the largest magnetic fields occur when the largest currents are drawn by the operating vehicles, e.g. with two trains accelerating simultaneously, and because currents flow from each TPSS to the LRT vehicles, these magnetic fields occur along the entire sections of the alignment over which the currents flow; these magnetic fields are not exclusively at a train location. Furthermore, because the currents are continuously varying with train operations, the magnetic fields are continuously varying as well.

This magnetic field source is transient in nature, and produces changes, or shifts in the background DC magnetic field environment along the alignment, with characteristic timescales typically ranging from a fraction of a second to tens of seconds. Light rail magnetic fields add to the background geomagnetic field as vectors, and as such are not always additive (vectors in opposite directions subtract); the resulting magnetic field will change in direction and it can decrease or increase in magnitude. In general, the magnetic field impacts are strongest near the alignment, and decrease rapidly moving away from the tracks.

Magnetic fields from light rail are generally specified in units of magnetic flux density. The milligauss (mG) unit is commonly used in the United States, but the SI unit of microtesla (µT) or nanotesla (nT) is also used. For reference, 1 mG = 0.1 µT = 100 nT.

Most electronic equipment is unaffected by typical light rail magnetic field transients, even relatively close to the alignment. This can be attributed to the generalization that light rail magnetic field transients are small on a relative basis (compared to systems that intentionally create magnetic fields) and quite slow (quasi-DC), which means induction via time-varying flux is inefficient on a relative basis.

However, there are a number of specialized measurement, imaging, and research systems that require a very stable magnetic field environment for proper operation. At sufficiently strong levels, transient or time-varying magnetic field disturbances can interfere with proper operation of magnetically sensitive equipment, causing electromagnetic interference (EMI). The sensitivity of various instruments varies widely, so an EMI evaluation requires estimates of magnetic field transients produced by the light rail system (quantifying the source), and identification of potentially sensitive instrumentation or equipment in proximity to the alignment. Comparing expected light rail magnetic field transients with the magnetic field limits of potentially sensitive equipment provides a measure of the likelihood for interference to occur.

2 Magnetic Field Modeling

As discussed above, the predominant magnetic field impact from light rail is due to the large traction currents that power train operations—supply currents on the OCS and return currents on the rails, as shown in the double-track cross-section of Figure 1.

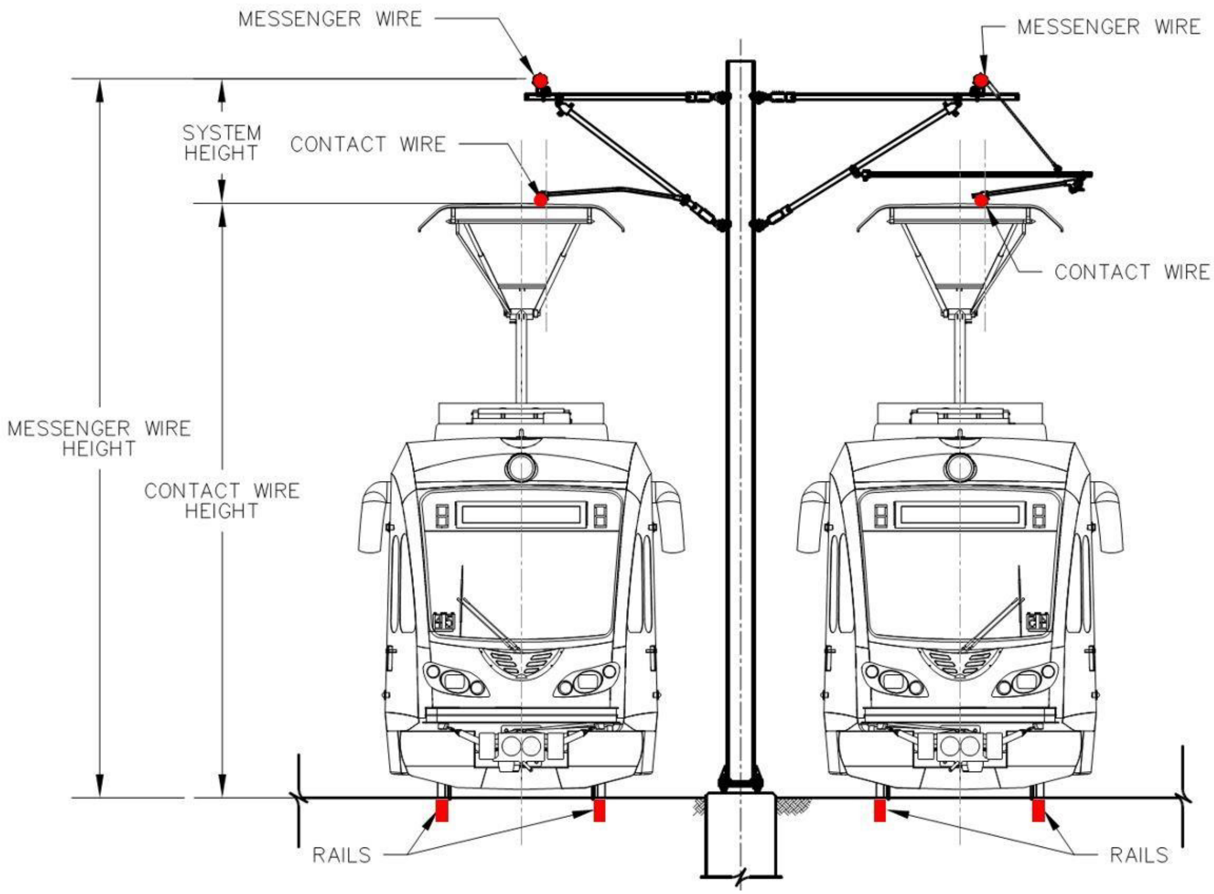


Figure 1. Two-track cross-section showing main electric traction system conductors.

Looking at a single track, the supply current in one direction on the OCS and returning on the rails in the opposite direction forms a dipole loop of current with magnetic fields (flux lines are only an approximation in figure) per Figure 2. Magnetic fields circulate around the currents and fields are lateral to the tracks. Positive current coming out of the page at the top figure, corresponding to the OCS, and negative current into the page at bottom figure, corresponding to the rails.

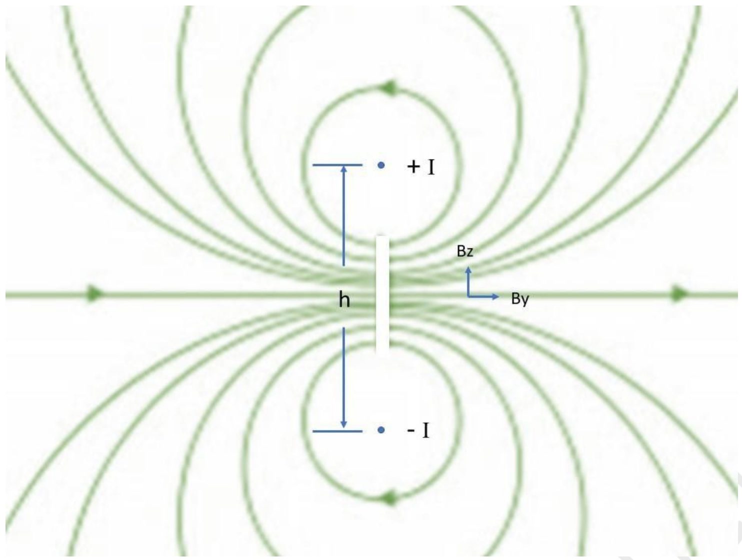


Figure 2. Long straight section of OCS and rail currents can be approximated as a simple two-dimensional dipole.

The magnetic field magnitude in units of milligauss (mG) from a two-dimensional dipole is given by:

$$B\ (mG) = 2\ I\ h\ /\ r^2 \qquad (1)$$

Where I is the current in amperes (A), h is the height in meters, and r is the distance in meters from the center of the dipole. From this equation, one can see three basic concepts. First, magnetic fields are proportional to the current flowing to a train. Second, magnetic fields are proportional to the height of the OCS above the rails. And third, magnetic fields decrease rapidly with distance, as the inverse square of the distance from tracks.

The Equation (1) can be used to estimate magnetic fields from the trains making some realistic assumptions. At this stage of design, the LRT alignment, the operations plan, and the vehicle type are still tentative. In addition, locations of EMI susceptible equipment and the extent of present level EMI caused by other systems in the vicinity of the LRT alignment (the Base Case scenario) is still not known. Accordingly, a high level of EMI assessment has been made with following input data/assumptions:

- The most conservative estimate of OCS of a single-track drawing maximum current is assumed.
- The OCS has been simplified (messenger and contact wire combined) as a single conductor at 22 feet (6.7 m) above top of rails.
- 13 main line TPSS are being planned for the LRT system for Phase 1 plus Priority Extensions. The loading on each TPSS will be different and the maximum power drawn from these TPSS is estimated to vary between 1753 kW and 607 kW.

The magnetic flux density has been calculated at distances of 100' and 500' from the track center and it varies from 16.87 mG to 5.84 mG at 100' and from 0.67 mG to 0.23 mG at 500', as shown in the Table 1 below:

Table 1. Simplified magnetic field estimates from dipole equation (1)

Magnetic Flux Density (mG)		
Distance from Track Center (feet)	Power Draw (kW)	
	Maximum	Minimum
	1753	**607**
100	16.87	5.84
500	0.67	0.23

The two-dimensional dipole is an extreme oversimplification, only valid for long straight segments of balanced currents, but it is useful as a conservative and quick rule-of-thumb evaluation.

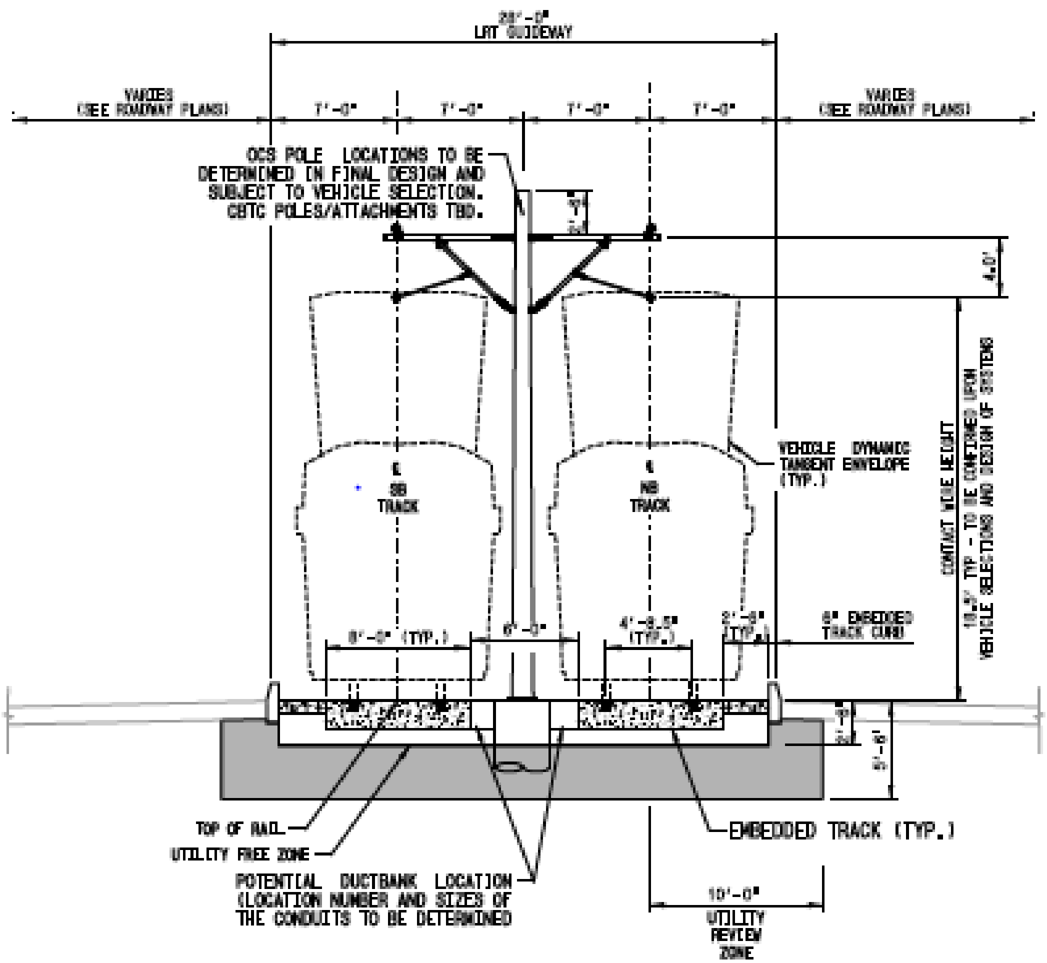
Actual current flow on the traction system is more complex and inherently three-dimensional:

- At a train, currents flow vertically from the OCS to the vehicle and down to the rails.
- Also, current flow to a train comes from both directions on the OCS and returns in both directions on the rails.
- A two-track system has two sets of OCS and rails, allowing for simultaneous operation of trains in both directions, eastbound (EB) and westbound (WB). Cross-bonds on the rails join EB and WB rails allowing return currents to distribute across all four rails in flowing back to a TPSS. Similarly, a common positive bus connection inside each TPSS allows supply currents to utilize both sides of the OCS. Thus, OCS and rail currents are not necessarily balanced on each track.

To estimate magnetic fields more realistically, detailed three-dimensional modeling of the traction system was performed using OT_OPN modeling software. 1000 A current was assumed flowing in a double track OCS as shown in Figure 3. A sample of the output is presented in Figure 4. This result represents an estimate of the maximum magnetic flux density on a specific point on the alignment taken within 10 meters of the most heavily loaded TPSS connection point. Magnetic flux density varies along the alignment and should be measured at the location of potential impacts to sensitive medical imaging equipment and other equipment sensitive to EMI.

This model shows a magnetic flux density 1 μT at a distance of 51m from the centerline of two tracks, that is 48.86m from the center line of the outer track.

The comparable figures using the formula given in Equation (1) gives a result of 5.62 mG or 0.562 μT.



TYPICAL EMBEDDED TRACK SECTION

Figure 3: Austin LRT Alignment - OCS Cross-section

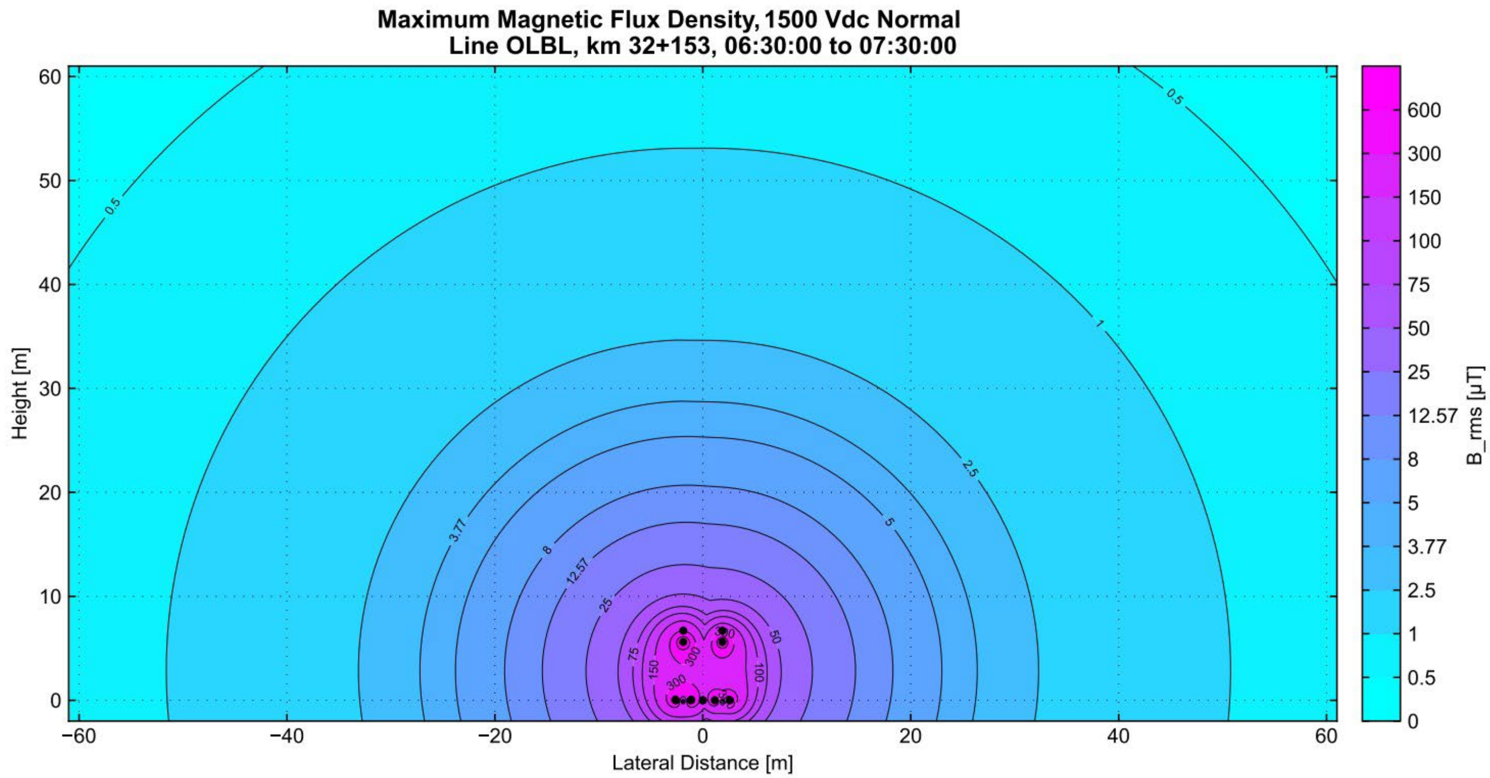


Figure 4: Flux Density Spread Perpendicular to Alignment

3 Conclusion

Operation of the Austin Light Rail Transit (LRT) traction power system could result in EMI impact to medical imaging equipment and other sensitive equipment exposed to the range of 1 µT to 0.1 µT absent any installed magnetic shielding. Magnetic flux density varies along the alignment and should be measured at the location of potentially impacted equipment. Maximum results show magnetic flux density decrease to 1 µT at 51 meters perpendicular to the alignment. Actual locations of equipment perpendicular to the alignment and the equipment's sensitivity to EMI should be identified to estimate exposure.