EMI/RFI Generation from Light Rail Transit Systems
Los Angeles Metro Crenshaw/LAX Transit Corridor

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Executive Summary

The Los Angeles County Metropolitan Transportation Authority (Metro) is designing and building a new light rail transit line (Crenshaw/LAX) in South Los Angeles that includes a segment of alignment that is immediately adjacent to the ends of the runways at Los Angeles International Airport (LAX). During the project Preliminary Engineering phase of the Crenshaw project, the Federal Aviation Administration (FAA) and Los Angeles World Airports (LAWA) raised concerns that the electric powered light rail trains may cause interference with flight operations and navigational aid systems due to radio-frequency interference (RFI) and electromagnetic interference (EMI) emissions from the trains and the associated overhead contact system (OCS).

Due to the unique configuration of this air-rail interface it was recommended to conduct a study including field test simulations. This study would ensure public safety, and facilitate the design of the Crenshaw/LAX project. The early coordination and cooperation between Metro, the FAA and the Los Angeles World Airports (LAWA) was found to be the key to the success of preparing test procedures, conducting efficient field testing and providing mutually conclusive findings.

The field analysis required the gathering of accurate measurements of actual train produced electromagnetic and radio frequency signals. The test procedures specified exposing specialized, highly sensitive aviation navigation and communications instruments to the RF environment near existing operational Metro light rail lines (the FAA provided the appropriate instrumentation and participated in all field testing). The field analysis also included direct observation and the recording of potential EMI/RFI issues.

The communications systems tests and FAA field simulations (NAVAID) revealed no interference due to LRT operations at all locations where the testing and simulations were staged. Further post-test analyses by the FAA have not revealed any interference issues. Additionally since communications receivers did not break squelch it was concluded that signals received were rejected as a background condition. The study team was confident that the Crenshaw/LAX Line would not pose undue risk of interference to airport operations and communications.

Although other air-rail interfaces may appear similar, the study team has recommended that due to the uniqueness of each project configuration, field testing and verification should be performed in all cases. Project stakeholders should be involved at the early stages of project development to foster an understanding of issues, and develop an environment of mutual problem solving. It is important to utilize highly qualified, experienced professionals noting that stakeholder participation in the development of procedures and performance of field tests is extremely beneficial. With the advance of digital communications, interference by analog signals may become a moot issue.

The following paper provides additional information in development of the study team, test procedures, field simulations and conclusions reached from the test results.

1 Crenshaw/LAX – Project Description (See Appendix A).
EMI/RFI Generation from LRT Systems

Introduction
The Los Angeles County Metropolitan Transportation Authority (Metro) is designing and building a new light rail transit line (Crenshaw/LAX) in South Los Angeles that includes a segment of alignment that is immediately adjacent to the ends of the runways at Los Angeles International Airport (LAX). During the Preliminary Engineering phase, the FAA raised concerns that the electric powered light rail trains might cause interference with flight operations and navigational aid systems due to radio-frequency (RF) and electromagnetic (EM) emissions from the trains and overhead contact system.

Hatch Mott McDonald (HMM) and its specialist sub-consultants are providing Metro with a wide range of engineering design services for this project. One assigned task, undertaken in January of 2011, included performing a detailed analysis of the potential impacts that light rail trains may pose to flight operations at LAX, including RF and EM interference.

This unique task required the cooperation and coordination with a number of key stakeholders. The early coordination between Metro, the FAA and the Los Angeles World Airports (LAWA) was found to be the key to the success of conducting efficient testing and mutually conclusive findings.

The analysis would require the gathering of accurate measurements of train produced electromagnetic and radio frequencies. The plan to gather the data included exposing actual aircraft navigation and communications instruments to the RF environment near operational Metro light rail lines, allowing direct observation, and recording potential EMI/RFI issues.

This paper will discuss the analysis process, the excellent stakeholder cooperation in studying this important topic, and the conclusions reached from the test results.

Project Location
The southern end of the Crenshaw project alignment parallels Aviation Boulevard on an existing Metro rail corridor (former BNSF), immediately adjacent to the east end of runways 25L and 25R at Los Angeles International Airport (LAX). A portion of this segment, within the runway protection zone (RPZ), will be constructed as a depressed trench, with the entire system below grade (See figure 1). Both LAWA and the FAA are extremely concerned about the impact that the electrified system and LRT operations may have to airport communications and navigation aids.
Project Stakeholders

Metro is the local agency responsible for the Crenshaw LRT project and has environmentally cleared the project through the NEPA/CEQA process. Metro has contracted HMM to conduct preliminary engineering to support the procurement of a final design-build contractor who will complete the design and construct the system. Metro Management has embraced a methodology of early stakeholder and community involvement at all stages of project development.

As the regulators of the LAX airport, the FAA\(^2\) has been very keen on understanding the Crenshaw project from both a constructability and operations sense. With vital navigational aids installed in proximity to the proposed LRT, the FAA was keenly interested in determining any impacts the LRT system would have on vital navigational aids. As such the FAA was actively involved with preparing the test procedures and conducting the actual field tests.

As the operators of the LAX airport, LAWA\(^2\) is also very interested in determining the impacts that the LRT system may have to other airport operational systems. Metro and LAWA have worked closely to develop a construction plan that minimizes or eliminates airport operational impacts.

\(^2\) FAA and LAWA Responsibilities (See Appendix B).
Metro has coordinated project reviews with both LAWA and the FAA to facilitate the project approvals required for construction and operations of the Crenshaw transit system.

**Radio Frequency & Electromagnetic Emissions and Interference**

All communications and navigation systems rely on the accurate transmission and reception of signals. Those intentional signals exist in a sea of unwanted noise. Broadly speaking, “electromagnetic interference” (EMI) occurs when unwanted noise disrupts the accurate transmission/reception of those intended signals. When interference happens at the high frequencies used in radio (and other communications) applications, it is often referred to as “radio frequency interference” (RFI).

Importantly, intentional signals from one system (say, broadcast television) might look like interfering signals to another system (say, radio communications). This is why “channels” exist: different frequency bands are dedicated to different uses so as to minimize interference between different systems. Even though purposeful transmissions are regulated by government bodies to minimize interference, all electrical systems emit some incidental signals, as well. Interference caused by these incidental emissions is more difficult to address via regulation, and in some cases unique studies must be conducted to determine electromagnetic compatibility (EMC). One such study for the Metro Crenshaw/LAX Transit Corridor project, examined the compatibility with aircraft operations at LAX.

Like other environmental parameters, EMI and EMC boil down to the emissions from a given source and the susceptibilities of sensitive receptors. For this project, new LRT infrastructure and vehicles are expected to emit both low-frequency magnetic fields and high-frequency (radio-frequency, RF) electromagnetic fields. Nearby sensitive receptors include ground-based and airplane-based transmitters/receivers for radio communications and navigation. This study focuses on the radio-frequency emissions, especially in those parts of the spectrum dedicated to airport communications and navigation.

**Radio Frequency Interference**

The LRT operations generate radio-frequency emissions primarily via three sources: 1) on-board and wayside communications systems; 2) train power systems; and 3) arcing between the pantograph and overhead contact system. The intentional emissions from communications systems are more-or-less continuous and are assumed to exist at discrete frequencies. Our understanding is that communications systems for Metro operate at 160MHz and 800MHz, with provision for frequencies used by emergency agencies. Similarly, the unintended emissions from power systems are expected to be continuous signals at discrete (but lower) frequencies with associated harmonics. On the other hand, the unintended emissions due to arcing are expected to be highly transient and spread out across the frequency spectrum.

**Electromagnetic Interference**

Operation of a light rail transit system produces a range of electromagnetic fields from the traction power system and the light rail vehicles (LRVs). A typical DC traction system with overhead catenary produces both electric and magnetic fields as power is provided from substations to operating LRVs. DC electric fields are produced by the voltage on the overhead contact system and transient magnetic fields are produced by currents flowing to LRVs on the OCS and returning on the rails. Also, intermittent arcing between the LRV pantographs and contact wire due to contact bounce produces impulses of higher-frequency electromagnetic noise.
The shape of the arcing signal is expected to exhibit broad energy content, perhaps with a few narrowband components related to “ringing” of current in the electrical system and emitted as the OCS wires act as a large antenna. Our primary assumption is that RF emissions due to arcing constitute the greatest unknown threat for electromagnetic interference. This is because we assume that signal levels due to power systems are small and already designed for electromagnetic compatibility with other LRT systems; and also because signal levels due to LRT system communications are already designed for compatibility with other LRT and external systems (as regulated by FCC).

Onboard the LRVs, control systems and power electronics drive traction motors for propulsion while communications systems transmit and receive narrow-band signals at specific operating frequencies, an intentional source of radio-frequency (RF) fields. The power electronics create localized magnetic fields at frequencies used to drive the traction motors, and this includes the associated harmonics. The frequencies associated with the propulsion are significantly lower than the operating frequencies of the LRV communication systems that are intentional sources of radio-frequency fields (RF). In addition to these power-frequency and RF emissions, passing LRVs also cause relatively slow disturbances to the local background geomagnetic field due to a focusing effect from magnetization in the steel structure of the LRVs.

The most common form of interference caused by light rail operations is due to the magnetic fields from propulsion currents that flow on the overhead catenary from traction substations to the train and back on the rails, essentially forming long current loops that throw off magnetic fields in proportion to the currents being drawn by trains. Magnetic fields produced by light rail propulsion currents are relatively slow (compared to RF), with typical time-scales ranging from a fraction of a second to tens of seconds. These slow transient magnetic field variations generally don’t cause interference with commonly used systems. For example light rail magnetic fields do not affect wireless systems, cellular telephone, first-responder communications, data centers, computer systems, or magnetic media storage. However, light rail magnetic fields do cause interference with highly specialized instrumentation—electron microscopes, electron-beam lithography, nuclear magnetic resonance, MRI, and CT scanners—found at university research laboratories, medical imaging, or high-technology facilities (e.g. semiconductor, nanotechnology, biotechnology). The instruments potentially impacted by light rail magnetic fields are so sensitive that local sources of magnetic field variation such as elevators, passing trucks, opening of a steel door, or even walking into the laboratory with a cell phone, are problematic.

An airport would not be expected to have the specialized instrumentation sensitive to the light rail magnetic fields and of course, electric transportation systems are commonplace at or near airport facilities. For typical magnetic field levels from light rail operations, even operation of an aircraft’s magnetic compass would hardly be affected, if at all, near a light rail alignment. This turns the focus of potential interference to the critical airport functions of navigation and communication which rely on systems operating at RF frequencies. As noted above, RF emissions from the light rail operations are the arcing of the overhead contact system due to contact bounce, and intentional RF from light rail communication systems. Light rail communications systems for MTA operate at 160MHz and 800MHz, with provision for frequencies used by emergency agencies. The intentional emissions from communications systems are more-or-less continuous and are assumed to exist at discrete frequencies. On the other hand, the unintended emissions due to arcing are expected to be highly transient and spread out across the frequency spectrum. On the airport side, nearby sensitive
receptors include ground-based and airplane-based transmitters/receivers for radio communications and navigation. This study focuses on the radio-frequency emissions, especially in those parts of the spectrum dedicated to airport communications and navigation.

**Preliminary EMI Testing**

When we first engaged the EMI component of the project, no explicit direction had been given by LAWA (operator of LAX) or FAA regarding acceptable parameters for electromagnetic interference. Searches of the FAA Regulatory and Guidance Library (RGL, accessible online at http://rgl.faa.gov) revealed no documents related to electromagnetic emissions from nearby city infrastructure. The search terms “EMI”, “EMC”, and “RFI” appear in many documents discussing aircraft engines and onboard systems and in documents related to airport-installed signaling and communications. However, no guidance regarding interference thresholds or significance levels related to off-airport systems was found.

In the absence of explicit interference thresholds, a test procedure was developed by Metro, approved by FAA and preliminary testing was conducted to characterize the emissions from the LRT system. Since light rail vehicles (similar to those proposed for Crenshaw) currently operate on many parts of the Metro rail network, it was easy to find test settings where emissions could be measured directly. We then measured existing signal levels around LAX to compare against the LRT-emitted levels.

The test procedure for these measurements was based generally on the US Department of Transportation document UMTA-MA-06-0153-85-11, *Radiated Interference in Rapid Transit Systems, Volume II: Suggested Test Procedures*. The procedure describes characterization of broadband RF emissions from transit systems via testing of radiated electric field strengths from 0.140~400MHz, and the measurements are made with antenna and spectrum analyzer. The testing consisted of recording the electric field strength at the antenna with the spectrum analyzer operating in peak-hold mode during each train pass. Comparing multiple train pass results at locations where arcing at the pantograph was visible with ambient measurements when no trains were present gave a general indication of RF noise strengths from passing trains as a function of frequency.

The effect of LRT pass-bys, including arc-induced emissions, could be seen in the data (see Figure 2). As expected, the impact varied with frequency, and significant (but not necessarily interfering) signals were seen at frequencies relevant to airport operations. This comparison was presented to LAWA and FAA and helped catalyze a focused set of tests by FAA and their partners, tailored to the critical airport functions.
Advanced Level Testing

While the FAA Regulatory & Guidance Library does not include any documents regarding EMC with respect to off-airport infrastructure, FAA personnel do have tools to evaluate and judge interference. Unlike our preliminary (comparative) testing of emissions and signal levels, the FAA chose to conduct in-situ simulations, which prompted the development of a specialized test procedure.

During these new tests, FAA personnel exposed real-life navigation and communications instruments to the RF environment near operational Metro light rail lines, allowing direct observation of interference, if present (see Figure 2). Therefore, no explicit definition of interference threshold was established; rather, FAA observed instrument operations during train pass-by and judged interference.

Test Locations

Testing was performed at three locations - one was under controlled conditions at a maintenance yard while the other two were along operational sections of track. The maintenance yard (Hawthorne Yard) site was chosen because it presented a controlled test environment in which operators could repeatedly accelerate a vehicle through an electrical isolator (deliberately causing large arcs).
The two other sites represent a live operating condition: a site near the intersection of 11th and Flower Streets in downtown Los Angeles allowed examination of emissions where the rail transitions from the surface to a tunnel section; and a test site on the Broadway Bridge in North LA allowed examination of emissions from an elevated position. In all three cases, the LRT vehicle is the same as to be used on the Crenshaw Line. In all cases some minimal contact arcing was observed; a short video illustrating the arcing at the Hawthorne Yard test site is online at: http://www.youtube.com/watch?v=ShGLO8vHG4M.

**Instruments and Data Collection**

The FAA technicians used three sets of instruments during the testing: a transmitter/receiver pair intended to simulate NAVAID receiver performance; a generic signal analyzer; and several radio communications receivers. The NAVAID simulation sought to expose simulated navigation instruments to the emitted RF field while monitoring signal quality. Quantitative data were recorded and post-test processed to determine interference. In parallel, the communications equipment and signal analyzers were used to observe signal levels and establish qualitative impressions of interference with communications.

Interestingly, the NAVAID simulation required low-level transmission of a real navigation signal. During testing, a low-level (local) signal was transmitted for reception by the NAVAID receiver antenna stationed near the rail alignment. The receiver was programmed to record signal quality metrics in 1-millisecond intervals during train passes, therefore allowing examination of signal degradation due to train RF emissions. While the NAVAID simulation provided quantitative data regarding interference, the signal analyzer and radio communication instruments were observed for qualitative signs of interference. The instrument list provided by FAA is shown in Table 1 below.
Table 1. Test Instrument List

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Model No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Motorola VHF Receiver</td>
<td>CM-200</td>
</tr>
<tr>
<td>Portable Emergency Transceiver</td>
<td>PET-2000</td>
</tr>
<tr>
<td>Universal Radio, Inc. AOR Receiver</td>
<td>AR8200</td>
</tr>
<tr>
<td>Yupiteru Receiver</td>
<td>MVT-7100</td>
</tr>
<tr>
<td>Radar Engineers Ultrasonic Detector</td>
<td>Model 250</td>
</tr>
<tr>
<td>Radar Engineers Line Sniffer</td>
<td>Model 247-B</td>
</tr>
<tr>
<td>Rohde &amp; Schwarz Handheld Spectrum Analyzer</td>
<td>FSH3</td>
</tr>
<tr>
<td>AH Systems Antenna Kit</td>
<td>AK-18G</td>
</tr>
<tr>
<td>Radio Communications Test Set</td>
<td>2955B</td>
</tr>
<tr>
<td>AeroFlex Avionics Signal Generator</td>
<td>NAV-750C</td>
</tr>
<tr>
<td>Rohde &amp; Schwarz ILS/VOR Analyzer</td>
<td>EVS300</td>
</tr>
</tbody>
</table>

Test Findings

- The NAVAID simulation revealed no interference due to LRT operations at both of the locations where the simulation was staged. In the field, no obvious problems were observed. Additionally, the post-test processed signal-quality data exposed no deeper concerns.
- During field testing, the NAVAID transmitter signal level was varied over a significant range. At the Broadway Bridge test location, for example, the NAVAID signal level (as measured by the receiver) started at -52dBm (a signal level similar to NAVAID signal levels measured at LAX) and was lowered from there. Data were collected at weaker navigation signal levels as low as -88dBm (far below the levels measured at LAX). It is important to note that no interference was observed, even at the lowest signal levels. Since interference is more likely when the intentional navigation signal is weaker, the fact that no problems were reported even at -88dBm offers confidence in the conclusion that no significant interference occurred.
- The communications systems tests indicated no interference due to LRT operations at all three locations where the instruments were deployed. Signals related to train passes were observed on the spectrum analyzer and the voice receivers (on open squelch); however, the signal levels and transient characteristics were considered to be less-than-significant sources of interference.
- Metro and the FAA jointly conducted the testing and collected the following communications systems observations:
### Table 2. Test Notes

<table>
<thead>
<tr>
<th>Location</th>
<th>Instrument/System</th>
<th>Performance Notes and Assessments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hawthorne Yard</td>
<td>PET-2000 Transceiver</td>
<td>Squelch not broken; squelch level defined as -98dBm</td>
</tr>
<tr>
<td></td>
<td>R&amp;S FSH3 Spectrum</td>
<td>No obvious LRT signal; however, noise from nearby power lines observed</td>
</tr>
<tr>
<td></td>
<td>Analyzer</td>
<td></td>
</tr>
<tr>
<td></td>
<td>CM-200 Ground Voice</td>
<td>Squelch not broken, but some background noise increase on open squelch</td>
</tr>
<tr>
<td></td>
<td>Receiver</td>
<td></td>
</tr>
<tr>
<td>11th &amp; Flower</td>
<td>Motorola Handheld Radio</td>
<td>Squelch not broken, but some background noise increase on open squelch</td>
</tr>
<tr>
<td></td>
<td>R&amp;S FSH3 Spectrum</td>
<td>Elevated background noise observed, some noise increase observed during train passes</td>
</tr>
<tr>
<td></td>
<td>Analyzer</td>
<td></td>
</tr>
<tr>
<td>Broadway Bridge</td>
<td>Yupiteru MVT-700</td>
<td>Squelch not broken, no significant increase in background noise during train passes</td>
</tr>
<tr>
<td></td>
<td>R&amp;S FSH3 Spectrum</td>
<td>Some noise increase observed during train passes, assumed due to arcing</td>
</tr>
<tr>
<td></td>
<td>Analyzer</td>
<td></td>
</tr>
</tbody>
</table>

Note: The fact that the communications receivers never “broke squelch” is important. Squelch is a circuit that attempts to differentiate between background noise and intentional communications. When the signal level falls below a presumed communications level, the squelch circuit mutes the channel because it is assumed that no true communications are being received.

### Conclusions

The project schedule was maintained by introducing the perceived project issues to the FAA and LAWA very early in the design development stage. This early involvement of project stakeholders fostered an environment of mutual problem solving, decision making, and trust that will last through project design, construction and operations.

FAA and LAWA involvement in the development of the test procedure and participation in field testing provided an overall team confidence of the results observed.

The FAA field simulations (NAVAID) revealed no interference due to LRT operations at all locations where the simulation was staged. Further post-test analyses by the FAA has not revealed any interference issues.

The communications systems tests indicated no interference due to LRT operations at all locations where the instruments were deployed. Communications receivers did not break squelch – signals received were rejected as a background condition. This, along with the fact that the NAVAID simulation did not reveal any problems, provided us the confidence that the Crenshaw/LAX Line would not pose undue risk of interference.
Recommendations

- Discussions with the FAA and airport operators cannot begin early enough. Create a study team with key stakeholders. This provides a forum for efficient issue resolution and effective study participation. Stakeholder coordination and cooperation is essential to facilitating the project design development.

- The Crenshaw project configuration near LAX is very unique. The tests results for Crenshaw should not be considered generic for similar air-rail situations. Field testing and simulations should be considered essential in confirming potential EMI/RFI interference at each unique location.

- Highly qualified, experienced individuals should conduct the field testing. A great benefit is received when FAA/Airport instrumentation is utilized during the testing.

- It is important to review local airport capabilities as newer digital communications systems may not be impacted by analog LRT signal transmission.
APPENDIX A

Crenshaw/LAX Transit Corridor

The Los Angeles County Metropolitan Transportation Authority (Metro) is building a new light rail line in the Crenshaw/LAX Transit Corridor (Project). This north-south running line will greatly enhance the connectivity of West Los Angeles County by providing a connection between the existing Metro Green Line and Metro Exposition Line.

The proposed Crenshaw/LAX Transit Corridor Project alignment is shown in Figure A1 – Crenshaw/LAX Transit Corridor Alignment. The proposed alignment extends approximately 8.5 miles, from the Exposition LRT line at the intersection of Crenshaw and Exposition Boulevards to the Metro Green Line Aviation/LAX Station. The alignment is comprised of a double-tracked right-of-way (ROW) consisting of at-grade, aerial, and below-grade guideway sections.

The proposed LRT alignment’s northern terminus is located at the proposed Crenshaw/Exposition Station, where the Crenshaw/LAX Corridor will provide a pedestrian at-grade link to the Exposition Line, currently under construction. From the Crenshaw/Exposition Station, the LRT alignment extends south along Crenshaw Boulevard for 3.25 miles to the Harbor Subdivision of the BNSF Railroad. At this point, the alignment turns to the southwest and continues along the Harbor Subdivision for approximately 3.15 miles to Aviation Boulevard. Then the alignment continues south on the Harbor Subdivision alongside Aviation Boulevard for 2.15 miles to a connection to the Metro Green Line near the Green Line Aviation/LAX Station.

New stations under consideration at the following locations: Crenshaw/Exposition, Crenshaw/Martin Luther King Jr., Crenshaw/Vernon (optional), Crenshaw/Slauson, Florence/West, Florence/La Brea, Florence/Hindry (optional), and Aviation/Century.

The LRT alignment features crossings at a number of heavily trafficked roadways and highways, and is in proximity to the south runways of LAX. To avoid traffic delays, grade separations are currently being considered at some roadway crossings and locations: Century Boulevard, Manchester Avenue, La Cienega Boulevard, I-405, La Brea Avenue, Victoria Avenue to 60th Street, 48th to 39th Streets. The Crenshaw/LAX Transit Corridor Project, as described above and shown in Figure 1A, was adopted as the Locally Preferred Alternative (LPA) at the meeting of the Metro Board of Directors on December 10, 2009.

Metro has advanced the engineering design to an approximate 30% level, in order to complete the environmental clearance and prepare documents to solicit proposals from Design – Build (DB) contractors who will complete the design and construct the project. Metro is currently evaluating the proposals and expected to make a contract award in the summer of 2013.

The Crenshaw Project is funded under the Measure R Los Angeles County Sales Tax, supported by a Federal TIFIA loan, and by other local and state funds.
Figure A1 – Crenshaw/LAX Alignment
**Additional Design Information – LAX Proximity**

The design of a light rail system in proximity to the third largest airport in the US does not advance without an understanding of airport operational constraints and the compatibility of systems for rail and aviation. LA Metro recognized the importance of involving LAWA and the FAA very early in the design development stage to confront any issues of significance that would impact project cost or schedule. Early discussions with LAWA/FAA revealed a number of concerns that Metro needed to include in the project design development:

There are a number of factors that influence the vertical and horizontal alignment in proximity to the Los Angeles International Airport (LAX) including:

- The existing at-grade freight corridor adjacent to LAX runways 25L & 25R running parallel to Aviation Boulevard.
- FAA agreement to a fully depressed alignment within the LAX Runway Protection Zone
- Compliance with LAWA/FAA guidelines for RPZ encroachment during construction
- LRT Alignment requirement to pass under the I105 Freeway and above Imperial Highway.
- LAWA requirement to grade separate both 111th and 104th Streets
- Metro Design Criteria – maximum gradients, vertical curve lengths, tangent length between vertical curves, edict to maximize train speeds.

Although the Metro design criteria accepts an at-grade running alignment adjacent to the LAX property, both LAWA and the FAA contended that this does not comply with standards in place to protect airport operations and the public. Although the preponderance of all LAX take-offs and landings are from east to west, in the event of an aborted takeoff in the reverse flow direction (west to east) Metro agreed to depress the LRT alignment throughout the RPZ and cover at the end of both runways. Metro’s light rail alignment design is to construct a 2500’ double track concrete trench extending through the limits of the RPZ’s for runways 25L & 25R. The trench will include two 500’ reinforced concrete roof covers designed for aircraft loading centered on each of runways 25L and 25R.
APPENDIX B

Project Stakeholders
The success of any infrastructure project is due in large part to the early identification and collaboration between the various project stakeholders. The Crenshaw project stakeholders include the typical local County and City agencies and third party utility owners, however also includes specific agencies related to the proximity of the LAX airport. LA Metro identified these stakeholders to be critical to development of the final design and construction documents.

Los Angeles International Airport (LAX) is the sixth busiest airport in the world and third busiest in the United States, and ranks 13th in the world in the amount of air cargo handled. The central complex features nine passenger terminals connected by a U-shaped two-level roadway. Curbside baggage check-in is available on the upper departure level. Baggage claim is on the lower level. Brand-named and ethnic-styled restaurants, cocktail lounges, gift shops, newsstands, duty free shops for international flights, restrooms, public telephones and business centers offer convenient services for the traveling public.

Other amenities include a first aid station in the Tom Bradley International Terminal and special telephones connected to area hotels/motels, bus/limousine services and car rental firms serving most Southland communities. Free shuttle service is provided between all terminals and remote parking lots.

The major organizations involved in operating a major airport such as LAX include the Airport Operator – Los Angeles World Airports (LAWA), the Federal Agencies having jurisdiction over different aspects of airport operations, and the commercial carriers.

LAWA
Los Angeles World Airports (LAWA) is the City of Los Angeles department that owns and operates a system of three airports: Los Angeles International (LAX), LA/Ontario International (ONT) and Van Nuys (VNY). Each plays an integral role in helping to meet the Southern California regional demand for passenger, cargo and general aviation service. Each airport makes a distinct contribution to the strength of the system as it provides a high level of safety, security and service for its customers, communities and stakeholders.

Los Angeles World Airports is a self-supporting department of the City of Los Angeles, governed by a seven-member Board of Airport Commissioners. The Board is comprised of public-spirited business and civic leaders appointed by the mayor and approved by the City Council.
Policies of the commission are carried out by a professional administrative staff of nearly 3,500 employees who are responsible for operations and maintenance of the three airports.

LAWA is responsible for the physical elements of the airport including runways, fueling facilities, passenger terminals, and ground transportation facilities. As the Crenshaw project will impact LAX airspace, early discussions with LAWA will very important to determine project construction constraints.

Federal Agencies

Federal agencies that have jurisdiction over different aspects of airport operations include the: U.S. Department of Homeland Security, U.S. Department of Transportation, U.S. Customs and Border Protection and Transportation, the Federal Aviation Administration (FAA) and the Transportation Security Administration.

- FAA – The FAA is the operator of the nation’s airways and has the authority to regulate and oversee all aspects of civil aviation in the US. This agency of the U.S. Department of Transportation is responsible for creating and enforcing the rules, regulations and standards that apply to all aspects of civil aviation. In the context of the Crenshaw project the FAA is responsible for the licensing of LAX to operate (considering such factors as site, runways, crash equipment and other aspects for safe operations). The FAA and LAWA have been instrumental in defining both the final Metro light rail alignment and construction staging. The FAA has been very cooperative in working with Metro to examine the potential for EMI and RFI exhibited as a result of the LRT operations.

- TSA - This agency, within the U.S. Department of Homeland Security, protects the nation’s transportation systems and infrastructure to ensure freedom of movement for people and commerce. It determines airport and aircraft security procedures; screens passengers; and controls access to aircraft and boarding areas. The TSA also ensures airport operators monitors compliance and enforces the airport’s security plan.

Commercial Air Carriers

Commercial air carriers are private companies licensed by the FAA to operate aircraft between destinations to carry passengers and freight for profit. Their operating procedures are closely regulated by the FAA to ensure public safety. As a consideration, LA Metro has contacted the Airline Pilots Association to make them aware of the Crenshaw project and to better understand any impacts the project may have on carrier operation at LAX.

Los Angeles County Metropolitan Transportation Authority (Metro)

Metro is responsible for the rapid transit rail system in Los Angeles County. The Crenshaw/LAX project is being planned, environmentally cleared, designed and constructed by Metro. The rail corridor adjacent to LAX and parallel to Aviation Boulevard is owned by Metro (former BNSF Harbor Subdivision), and is being designed to accommodate the Crenshaw line. Although Metro has the
authority to build an LRT system on the rail corridor, they must abide by FAA airspace regulations and LAX operations.

As the project sponsor and owner, Metro understands the importance of early stakeholder collaboration.

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- Nico Nguyen

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- Michael Harris-Gifford Executive Officer, Wayside Systems  
- Frank Castro  
- Leon Bukhin  
- Tony Tirtilly  
- Bob Fischer  
- Daniel Lindstrom

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- Gordon Head  
- Arkady Bernshteyn  (HMM employee at the time of testing)  
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APPENDIX C

Los Angeles County Metropolitan Transportation Authority

Test Procedure

For

Crenshaw – LAX EMI/RFI Measurements

Revision 0.3.A

January 25, 2011
1.0 Preface to Test Procedure

This test procedure will test and verify the operation of the actual Federal Aviation Administration navigational aid also known as NAVAID and communication receivers in conjunction with the light rail vehicle and overhead contact system.

There is a significant interest in the determination of the level of electromagnetic disturbances caused by the moving train line-pantograph system and overall RF (in VHF and UHF frequency bands where FAA operates) emission from the train in open trench, in order to determine if RF interferences exist and if necessary, design the correct shielding to protect FAA NAVAID and communication receivers.

2.0 Scope

This test procedure defines field testing of FAA specified NAVAID and communication receivers (operating in specified by FAA frequency bands) which shall be performed in conjunction with light rail vehicle (LRV) RF emission tests across the operating frequencies of the FAA systems, at multiple distances from the rail alignment. The objective of these tests is to provide a system-specific assessment of the potential for RF interference from light rail operations associated with the extension of LA Metro Green Line along the east edge of LAX runways. LRV RF emissions tests will also be performed for a representative trenched location to provide an assessment of attenuation provided by below-grade operation.

2.1 FAA Equipment and Radio Bands to be tested

Localizer 25L 109.9MHz (VHF)

Glide Slope 25L 333.8MHz (UHF)

VHF Communication (40 ILS channels between the carrier frequency range 108.10MHz and 111.95MHz)

UHF Communication (carrier frequency between 329.15 and 335MHz)

Receiver frequencies and Threshold values are as follows:

<table>
<thead>
<tr>
<th>Facility</th>
<th>Frequency</th>
<th>Threshold</th>
<th>Band</th>
</tr>
</thead>
<tbody>
<tr>
<td>25L Localizer</td>
<td>109.9 MHz</td>
<td>-108 dBm</td>
<td>108-118 MHz</td>
</tr>
<tr>
<td>25L Glide Slope</td>
<td>333.8 MHz</td>
<td>-107 dBm</td>
<td>328.6-335.4 MHz</td>
</tr>
<tr>
<td>25L VHF Comm</td>
<td>120.95 MHz</td>
<td>-104 dBm</td>
<td>118-137 MHz</td>
</tr>
<tr>
<td>UHF Comm</td>
<td>239.3 MHz</td>
<td>-104 dBm</td>
<td>225-328.6, 335.4-380 MHz</td>
</tr>
</tbody>
</table>

2.2 Tests to be performed

Each test will generally consist of two main parts (as practical). The first part involves characterization of LRV RF emissions across the FAA system frequency bands as listed in Section 2.1, and the second part involves an RF interference/degradation evaluation using FAA-provided equipment. The following tests will be performed and monitored at the open-air right of way and above trench structures as appropriate using existing Metro trains.
Characterization of LRV RF emissions and their attenuation will be performed by recording electric field strength transient waveforms using a broadband antenna connected to an FFT spectrum analyzer, or digital storage oscilloscope with FFT capability. If a time-domain spectrum analyzer is not used, a frequency domain sweep spectrum analyzer should be utilized with peak-hold detection and large resolution bandwidth for fast sweeps (in VHF-UHF bands). Note: the bandwidths to be measured are to be specified by FAA.

It is anticipated that measurements will be conducted at distances of not to exceed 150’ from the track centerline to characterize attenuation, with the antenna oriented in the vertical direction. Distances can be extended if EMI signals are not attenuating sufficiently within the initially specified distances. A minimum of three waveforms (readings) should be recorded for each configuration. Each measurement will be recorded during a train pass. Up to 6 train pass measurements will be recorded at each location. A background measurement should be made immediately after each train pass to provide comparable RF ambient noise level readings. If practical, one set of measurements will be recorded directly above the overhead catenary, e.g. at an overpass, or using a non-conducting mast/support for the antenna.

2.2.1 Open Air Tests
   A. A test site that will allow EMI measurements of passing revenue LA Metro trains at the specified lateral distances will be utilized for characterizing LRV RF emissions. The selected sites will be simulating an operational airport to allow for Navaid receiver operation/monitoring during multiple train passes. Receive antennas will be set at comparable distances at approximately 150’, relative to the track centerline, corresponding to the antenna used for EMI characterization. Any degradation or misoperation of NAVAID receivers will be noted accordingly on test sheets immediately after each train pass. FAA EVS system will be used if applicable to characterize receiver operation during train passes. Also, communication receiver systems will be evaluated/monitored during train passes to determine if interference is significant.
   B. A test site will be selected to allow for EMI characterization directly above the track centerline, e.g. at an overpass. The measurement antenna will be deployed with sufficient distance from nearby objects.
   C. A test site at a Metro Rail Yard Facility will be selected to allow for worst-case EMI measurements, i.e. where significant known arcing occurs at non-bridged gaps.

2.2.2 Trench Structures
To characterize the attenuation provided by below-grade operations, comparable in-trench sites will be selected for comparison with the open-air tests described in the preceding section. The measurements should be repeated at appropriate distances to allow for direct comparison.

2.2.3 (Optional) Bench Testing
If no RF interference or degradation of NAVAID and communication receivers is noted during revenue or yard testing described above, then bench tests can be set up to determine field strength thresholds at which interference occurs in the FAA supplied receiver systems. This will require an appropriate RF generator with amplifier that can emulate recorded by spectrum analyzer pantograph arcing transients, and performance specifications (to define when interference occurs) developed with input from FAA system experts.

2.3 Test Organization
2.3.1 Test Preparation
Each test or set of tests activity shall be administered by the following personnel:

Test Manager;

Test Conductors

Test Witnesses

Other personnel involved in the test will include:

Representative of the FAA, LAWA, Metro and HMM for the purpose of witnessing the test and recording of the test results

Two teams – a roving team and fixed team

2.3.2 Test Support
The nature of these tests dictates that suitably qualified personnel be assigned to the supervision and operation of related peripheral equipment and systems to support certain tests delineated in this test procedure. This support includes:

a) The FAA/LAWA designated personnel who is suitably trained on the interface to and operation of the NAVAID and communication receivers;

b) Metro designated personnel who is suitably trained on the interface to and operation of the radio testing equipment to initiate signal and monitor indications as required by this test procedures;

c) Qualified personnel who are suitably trained on the interface to and record of the testing equipment and monitor indications as required by this test procedures;

2.3.3 Outside Equipment
Radio and/or cell phone communications will be required. During the testing Metro will provide portable radios to test personnel to communicate on R5 – Maintenance channel.

Note: cell phone usage on the Right-of-Way (i.e. within the fence-line) is prohibited.

FAA will provide NASE package for use to simulate the aircraft localizer receiver and aircraft Communication receivers to simulate the aircraft Communication equipment.

2.3.3.1 Test Schedule and Locations
2.3.3.2 Test Schedule
The tests will be conducted at times mutually agreeable to all parties concerned. All parties will be notified accordingly as to the schedule for testing.

2.3.3.3 Tests Locations
a. Hawthorne yard, Green Line.
b. 11th & Flower streets, MBL
c. Broadway Bridge MGL (test pantograph under section insulator);
2.4 Criteria for Acceptance
The test shall be considered successful when each FAA system has been operated without any adverse impacts during each of the six measured revenue train passes for each test location.

2.4.1 Test Data Sheets
The test data will be recorded on the test data sheets provided in the appendix A. There is a data sheet for each test to be conducted.

If a test does not apply to a specific condition, location or other situation, the test data sheet will be filled with N/A

2.5 Test Set-up Configuration
2.5.1 Proposed Test Equipment List:
1. Rohde & Schwarz FSH3 Handheld Spectrum Analyzer.
5. Yupiteru MVT-7100 Receiver.
6. Radar Engineers Model 250 Ultrasonic Detector.
7. Radar Engineers Model 247-B Line Sniffer.
8. AH Systems Inc. AK-18G Antenna Kit.
9. Radio Communications Test Set 2955B.
10. IFR NAVAIDS Signal Generator.
11. Coaxial cables with N-type connectors, adapters as required.
12. Mounting hardware to allow for vertical polarization measurements.
13. Non-conducting tripods or masts for the antennas.
14. NASE package for use to simulate the aircraft localizer receiver.
15. Aircraft Communication receivers to simulate the aircraft Communication equipment.
16. Transmitter equipment required to provide on-site operational signals (to provide localizer, glide-slope, and comm. Signals for FAA receivers).
17. Laptop computers or USB memory sticks to download/backup test data for further analysis.

The test equipment used during the test, along with calibration information will be prepared for each test date.
2.5.2 Test Set up Diagrams
Test set-up diagrams for each of the required tests are provided in Appendix B of this test procedure.

2.5.3 Test Reports
A full test report will be submitted for review by FAA within 30 days. The report shall contain the following:

1. Copy of the test results sheets;
2. Test organization;
3. Individual test procedures for each test location;
4. Recommendation of the test group and conclusion summary.
Appendix A – Test Data Sheets

<table>
<thead>
<tr>
<th>Item</th>
<th>Frequency under Test</th>
<th>Measured Level (dBm)</th>
<th>Sensitivity Level Specification (dBm)</th>
<th>Notes</th>
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Appendix B – Test Set-up Diagram

![Test Set-up Diagram](image-url)
EMI/RFI Generation from LRT Systems

CRENSHAW LRT - LAX
RAILROAD PROTECTIVE ZONE
RUNWAYS 25L & 25R

3 DEGREE GLIDE SLOPE

RUNWAY 25L THRESHOLD POINT

RUNWAY 26L THRESHOLD Q

CRENSHAW LRT Q

AVIATION BLVD.

PANTOGRAPH WIRE

BNSF Q
CR ENSHA W- LA X
EMI/RF I
TEST SITES