EPx/TrainTalk Car Control Unit
FCC Certification Package

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1. INTRODUCTION

This document provides the information required for FCC certification of the intentional transmitters within the EPx/TrainTalk Car Control Unit (CCU). The document includes descriptions of the equipment and an overview of their intended operation. It describes the requirements to which the equipment has been certified and the laboratory test report. Design details including drawings and schematics are included within the appendices.

1.1 Description of Equipment

The EPx/TrainTalk system provides a wireless means to communicate between a locomotive and rail cars in order to control brake functions. An overview of the system is shown in Figure 1.1. The intentional transmitters are built from a radio module called the Intra-Train Communications Unit (ITCU). This ITCU is contained within the CCU.

The ITCU radio module is built using the Harris Semiconductor Prism chipset model HFA 3824A. More detail is provided in Exhibit B.

NOTE: The intended use of the CCU is not for the general public. It has been designed exclusively for industrial and commercial applications.

1.1.1 CCU Description

The Car Control Unit (CCU) receives the brake commands, manages the protocol and network link, controls the car brakes based on the brake commands received, and reports the health and status of the CCU. The CCU is installed on the car in place of the Service Pneumatic Control Valve, which is attached to the Pneumatic Pipe Bracket on pneumatic-only braking systems.

The CCU consists of a control and interface board called the Valve Interface Module (VIM) and a radio/processor board called the Intra-Train Communications Unit (ITCU). The VIM board provides unregulated 12 Vdc power to the ITCU; in turn the ITCU supplies regulated 5 Vdc to the VIM board. The CCU is a component of the Car Control Device (CCD), which comprises, in addition to the CCU, the antennas and an on-car power generation and storage subsystem.

The CCD, including the CCU, is professionally installed on a railcar by either trained GE-Harris personnel, or by trained and experienced support personnel provided by the customer.

This equipment is not offered for sale to the general public, and is only offered to commercial markets along with agreements that provide assurances that the equipment will be installed and utilized in accordance with all government and industry regulations and guidelines. In addition to the FCC, such agencies include, for example, the Federal Railroad Agency (FRA) and the Association of American Railroads.

As described in this document, the CCU is tested in conjunction with the antennas and cables supplied for installation of the unit. The power subsystem is installation-dependent, and the system is designed in such a way that the power subsystem is isolated and does not affect radio behavior, so it is not included in this test. All power subsystems will, however, include a Personality Module (a one-chip memory device), and that device has been included in the test configuration. Figure 1.1.1-1 illustrates the CCU configuration.

CCU on Rail Car

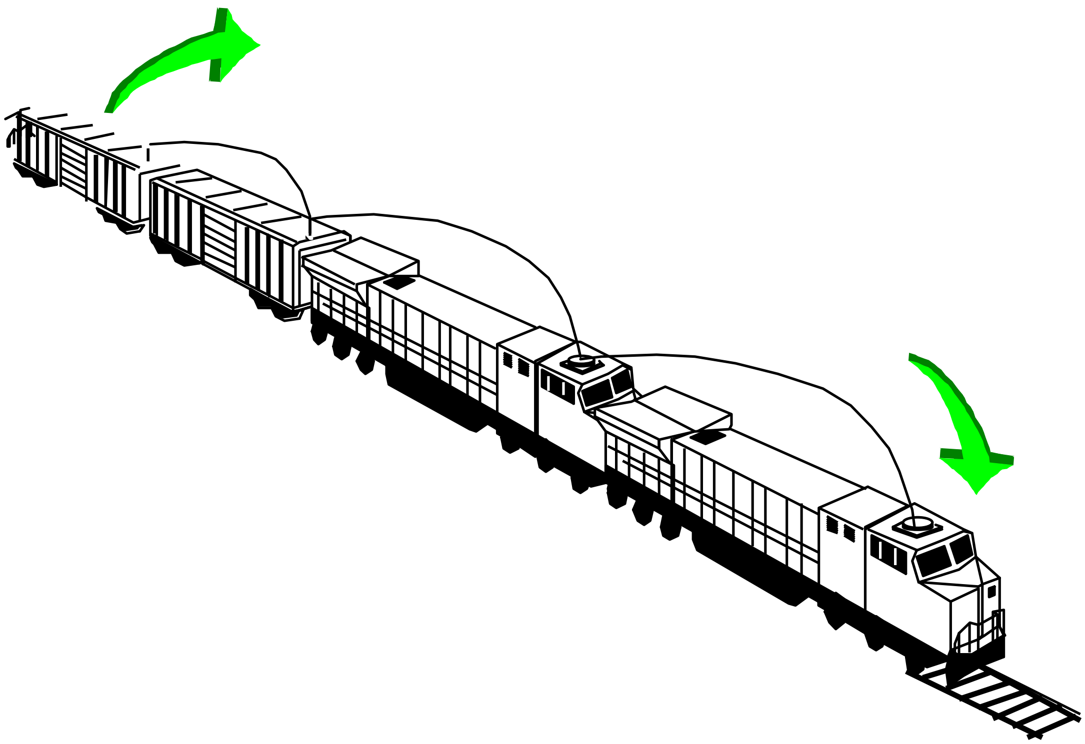

Figure 1.1. EPx/TrainTalk System Overview Diagram

Figure 1.1.1-1. CCU Configuration

1.1.2 Description of Communication Hardware and Protocol Software

The communications hardware, or Intra-Train Communication Unit (ITCU), is a single module that comprises two subfunctions: the Intra-Train Communication Radio (ITCR) and the Intra-Train Communication Engine (ITCE). The protocol is implemented primarily in the software residing in the ITCE.

1.1.2.1 Intra-Train Communication Engine (ITCE)

The ITCE is a microprocessor (Motorola 68360) along with the interface, memory, and support circuitry that is required for it to accomplish its functions. The reference oscillator for the entire ITCE is 20.48 MHz, which was chosen to minimize harmonic interference with the ITCR that would otherwise result in performance degradation and possible spurious emissions. The ITCU design features significant isolation between the ITCE and ITCU circuits to minimize the effects of ITCE digital signals on the ITCR RF / analog circuits. A significant design feature is the inclusion of a redundant watchdog circuit that is designed primarily to provide safe operation in the event of a processor hardware or software failure, but also serves to shut down the radio in such cases. This feature minimizes the probability of unwanted emissions from a failed unit. Also incorporated are multiple power supply circuits that provide highly-regulated and filtered voltages to the critical radio circuits.

1.1.2.2 Intra-Train Communication Radio (ITCR)

The radio is half-duplex (with transmit and receive capability but not simultaneously). The operational frequency is tuneable, with transmit and receive operations on the same frequency in any given radio configuration. The ITCR is designed around the Harris PRISM chipset, using a modified version of the reference chipset design. The up/down conversion is accomplished in two stages. The RF stage is tuneable, converting to/from the fixed 280 MHz IF. The IF stage converts between the 280 MHz IF and the I/Q baseband signals. Spreading, despreading, data modulation/demodulation, scrambling/descrambling, and acquisition are all performed in the Baseband Processor. The data is scrambled before transmission so that spectral lines are randomized in the event that the data being sent is not random. The ITCR also includes a PA watchdog circuit that turns off the PA in the event of a hardware or software failure that results in a “stuck on” transmitter. The watchdog function is implemented in a small microprocessor (PIC) that also provides the calibrated control of the level of the PA output power. The reference for all of the radio circuitry is the 22 MHz TCXO. It is used to generate the 11 MHz spreading, the 1 MHz data rate, the 280 MHz IF LO, and the tuneable RF LO. The synthesizer that is used for generating some of these references has a “Lock” indication to the software, which is designed to disable transmissions in the event of a failed synthesizer. This prevents spurious emissions that may result from an unlocked synthesizer.

1.1.2.3 Antenna Description

All installations of the TrainTalk radio utilize diversity antennas – a bi-directional antenna on each side of the railcar. The CCU has two antenna ports. The radio alternately tests each antenna port for the presence of a signal when in the receive mode, but does not “listen” to the ports simultaneously. It dwells on an antenna port that indicates the presence of a valid signal. When transmitting, the transmission is directed to only one of the antenna ports, with transmission on the other port only when no confirmation of the first transmission is received.

On the CCU (railcar installation), the shortest antenna cable is used in all testing, since this cable has the least attenuation, and thus attenuates any spurious emissions the least of any cable length. The maximum antenna gain in this configuration (in the 2.4 GHz band) has been measured by the test lab to be 4.0 dB.

The antennas and cables supplied with the CCU are the only configuration that is approved for installation. The installation method for each unique railcar type is designed, engineered, and tested by GE-Harris personnel. The approved configuration consists of the CCU and antenna mounting locations and methods, cable lengths, and the installation test procedure. Training is provided to professional installers by GE-Harris. Trained professional installers or trained railroad personnel will perform the installation.

During installation, the cables are firmly attached to the unit and the antenna, in order to prevent loosening of the hardware in a high-vibration environment, as well as to discourage tampering or modification.

The antenna unit has been designed such that no personnel will be near the antenna during normal operation, significantly farther than the minimum safe operating distance of 20cm. During maintenance operation, the unit is non-operational.

The installation manuals contain a statement to the effect that only the GEH-supplied antennas and antenna cables are to be used. Use of any components other than those supplied or authorized by GE-Harris (i.e., tested to meet FCC regulations with the TrainTalk system) is a violation of FCC regulations.

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1.1.2.4 Brief Description of Radio Protocol

The protocol used for TrainTalk is basically a token-forwarding protocol. A token is generated at the lead locomotive, no more that once every 300 msec. This token (a data packet) contains such sub-packets as braking commands and requests for information from the car or other locomotive on the train. A token contains as much as 567 bytes total, which results in a transmission lasting up to 4.536 msec. With two transmissions per token the worst-case duty cycle is thus (2*4.536)/300, or 3%.

The packet is handed-off down the train, hopping several cars at a time, with the cars in between "hearing" the data, but not relaying it. The designated relaying unit, in turn, passes the token further down the train. The last car on the train turns the packet around, and cars having data to send forward add that data to the token as it is relayed by the unit. The pattern of designated relaying units is rotated on each cycle in order to allow each car or locomotive an opportunity to relay its data to the lead locomotive. A transmitting unit always transmits first on the same antenna on which it "heard" the packet that it is relaying. In this way, the best-performing side of the train (e.g., the concave side of the train on a curved track, not the blocked convex side) is used primarily. A unit transmits on the opposite side of the train only if it does not receive a relaying response from the next designated relay unit.

1.2 Description of Intentional Emissions

The table below summarizes the characteristics of the intentional emissions of the system, as well as the design features pertinent to performance relative to FCC requirements:

Table 1.2 Intentional Emissions Characteristics

Emission Parameter/Feature	**Value/Characteristic**
Maximum transmitted power	+30 dBm (26 to 30 dBm, at antenna cable terminals, over all specified environments)
Antenna gain	+6 dBi maximum
Antenna design	Bidirectional horn or unidirectional horn
Diversity	Dual diversity (switched): Dual antennas (each bidirectional) or Quad antennas (each unidirectional, combined in pairs)
Frequency tuning range	2412 – 2467 MHz
Data Rate	1 Mbps
Data Modulation Type	DBPSK
Spread Rate	11 Mcps (11 chips per bit)
Processing Gain	10.4 dB
Scrambler	7-tap
Packet Length	1 to 5 msec
Typical transmitter Duty Cycle	< 0.5% (normal operational scenario on a train) 3% (Worst case operational scenario on a train)
Spread Sequence	11-chip Barker
Watchdog Failsafe circuits	PA stuck “on”, software failure, hardware failure, synthesizer lock failure
Mechanical design	High-isolation compartmented radio unit enclosure

2. CERTIFICATION REQUIREMENTS

2.1 FCC Section 15.247 Requirements

The FCC tests consist of conducted and radiated emissions tests to the requirements specified in section 15.247 for Direct Sequence Spread Spectrum Systems. These requirements are listed below. Note that neither equipment operates from AC power; therefore, the power line conducted tests are not required.

1. In any 100kHz bandwidth outside the frequency band in which the spread spectrum intentional radiator is operating, the radio frequency power that is produced by the intentional radiator shall be at least 20dB below that in the 100kHz bandwidth within the band that contains the highest level of the desired power, based on either an RF conducted or a radiated measurement.

2. Radiated emissions which fall in the restricted bands must comply with the radiated emission limits specified Table 2.1. Below 1 GHz, quasi-peak measurements shall be provided; above 1 GHz, both average and peak measurements shall be provided. The peak measurement limit is 20dB greater than the average limit shown in Table 2.1.

Table 2.1. Radiated Emissions Limits

Frequency (MHz)	Field Strength (µV/m)	Field Strength (dBµV/m)
30 - 88	100	40
88 – 216	150	43.5
216 – 960	200	46
960 – (10 x 2471)[1]	500	54

[1] Excludes f_c +/- 20 MHz.

3. For direct sequence systems, the peak power spectral density conducted from the intentional radiator to the antenna shall not be greater than 8 dBm in any 3kHz band during any time interval of continuous transmission.

4. The processing gain of a direct sequence system shall be at least 10 dB. The processing gain represents the improvement to the received signal-to-noise ratio, after filtering to the information bandwidth, from the spreading/despreading function. The processing gain may be determined using one of the following methods: (1) As measured at the demodulated

output of the receiver: (S/N w/ system spreading turned off)/(S/N w/ system spreading turned on) dB, or (2) CW jamming method.

3. BASIS FOR CERTIFICATION

This section documents the test requirements that were in place for the formal FCC qualification tests. These tests have been performed, and the results are documented within this application.

The CCU shall be certified to the FCC requirements as described in the following paragraphs. The CCU shall be tested in a configuration that includes all of the possible external connections and while operating in the peak power transmit mode. In order to evaluate the worst case intended emissions, spectrum analyzer measurements will be made at each of the following transmit channels: low (2412 MHz), middle (2442 MHz), and high (2471 MHz). Whichever channel produces the highest amplitude intentional emissions will be chosen to scan for the 30 MHz to 25 GHz spurious emissions test.

3.1 Power Meter Tests

A conducted test shall be performed by disconnecting the antenna cable and connecting the antenna port to a peak power meter. This data will be recorded for each of the three selected transmit channels. These measurements will be used to determine which channel produces the highest amplitude. The CCU will use a fully charged battery during its tests.

3.2 Conducted Emissions Tests

The conducted emissions tests shall be performed by disconnecting the antenna cable and connecting the antenna port to a spectrum analyzer through suitable attenuation. Initially, the analyzer will be set to the Peak Hold mode at the center frequency. A sweep will then be made from 750 kHz below the center frequency to 750 kHz above the center frequency to verify that the peak spectral density is not greater than 8dBm using a 3 kHz resolution bandwidth.

Following the power output measurement, the conducted Spurious Emissions tests will be performed by scanning up through the 10^{th} harmonic. Prior to performing the scan with the required bandwidth (100kHz), a preliminary scan using a larger bandwidth will be used to determine for which channel the emissions are strongest, and that channel will be used for the required bandwidth scan.

3.3 Radiated Emission Tests

The radiated emissions tests shall be performed at a 3 meter Open Area Test Site (OATS) as described in paragraph 4. Above 8 GHz, the measurements will be made within the shielded enclosure at a one meter antenna distance. Prior to performing the tests on the OATS, a preliminary scan will be made within a shielded enclosure and with the antenna dummy loaded to determine the frequencies of unintentional emissions from the chassis and cables. This preliminary scan will aid in distinguishing external environment signals when tested outside.

3.4 Processing Gain Certification

The processing gain test will be performed at the Prism test facility at Harris Semiconductor. This test will be based on the CW jamming margin method. The test consists of stepping a signal generator in 50kHz increments across the passband of the system. At each point, the generator level required to produce the required Bit Error Rate (BER) is recorded. This level is the jammer level. The output power of the transmitting unit is measured at the same point. The Jammer to Signal (J/S) ratio is then calculated and the worst 20% of the J/S points are discarded. The lowest remaining J/S ratio will then be used to calculate the Processing Gain using the following equation:

$$G_p = (S/N)_o + M_j + L_{sys}$$

G_p = Processing Gain

$(S/N)_o$ = Signal to Noise ratio

M_j = J/S ratio

L_{sys} = System losses = 2 dB, as allowed by FCC test instructions

4. TEST SETUPS

The CCU shall be tested at Rubicom Systems located in Melbourne, FL. The radiated tests shall be conducted at a 3 meter Open Area Test Site (OATS). These tests shall be performed on a turntable with the antenna positioned as described in CISPRR 22. Prior to performing the emissions tests on the open site, preliminary scans will be performed within a shielded enclosure to determine the highest emission frequencies and to aid in isolating external environment signals.

The equipment under test (EUT) shall be located on the non-conductive test bench standing on top of the turntable. The exercise equipment shall be isolated from the test area. The EUT shall include representative loads for each input and output signal that may be used in the actual installation. Detailed test setups are described in the following paragraphs.

4.1 CCU Test Setup

The CCU test setup shall be as shown in Figure 4.1-1. This configuration represents the worst case configuration for the CCU.

4.1.1 CCU Operation During Test

The CCU shall be operated in its peak power operating mode with the transmit frequency selected at the low, middle, and high channels. Prior to beginning the emissions scans, the CCU shall be placed into the transmit mode via commands over the RS-232 interface. The normal operating duty cycle of a CCU, in an operating train in which radio communication is active, is typically less than 0.5%, with worst case short-term peaks of less than 3%. For testing purposes, however, a special packet transmission test mode is included in the implementation, in which the duty cycle is approximately 60%. Also, continuous transmission modes are implemented to make measurements of the continuously-transmitted signal with random spread data, as well as a two-tone modulated non-spread signal. The following steps shall be followed to operate the CCU.

1. Place UUT in chamber
2. Connect antenna cables or terminations (as applicable)
3. Connect power cable to Power Supply (13 V) and to Load Box
4. Connect Maintenance Port to Load Box and PC Comm 1 port
5. Power-up CCU and the PC
6. Initiate application “MU 9-22-98” on PC (MU computer)
7. Menu selection: Tool/Radio Tests/Radio Test Screen
8. Click “Serial
9. Config.”On Port A, select Comm 1, 38400 buttons
10. On Radio Test Screen, click “Comm Test” if not already there
11. Verify “Send to Port B” is <u>not</u> checked *
12. To right of Module A Comm History, click “Clr” *
13. Click “Get Status”, verify string appears in Module A Comm History buffer *
14. Click “RM Packet Tx Test”
15. Note ITCU current approx. 380 mA
16. Perform EMI scan

Test terminates automatically after number of packets specified has been transmitted, displays “Test Complete” dialog box. To terminate early, click “Abort Test”.

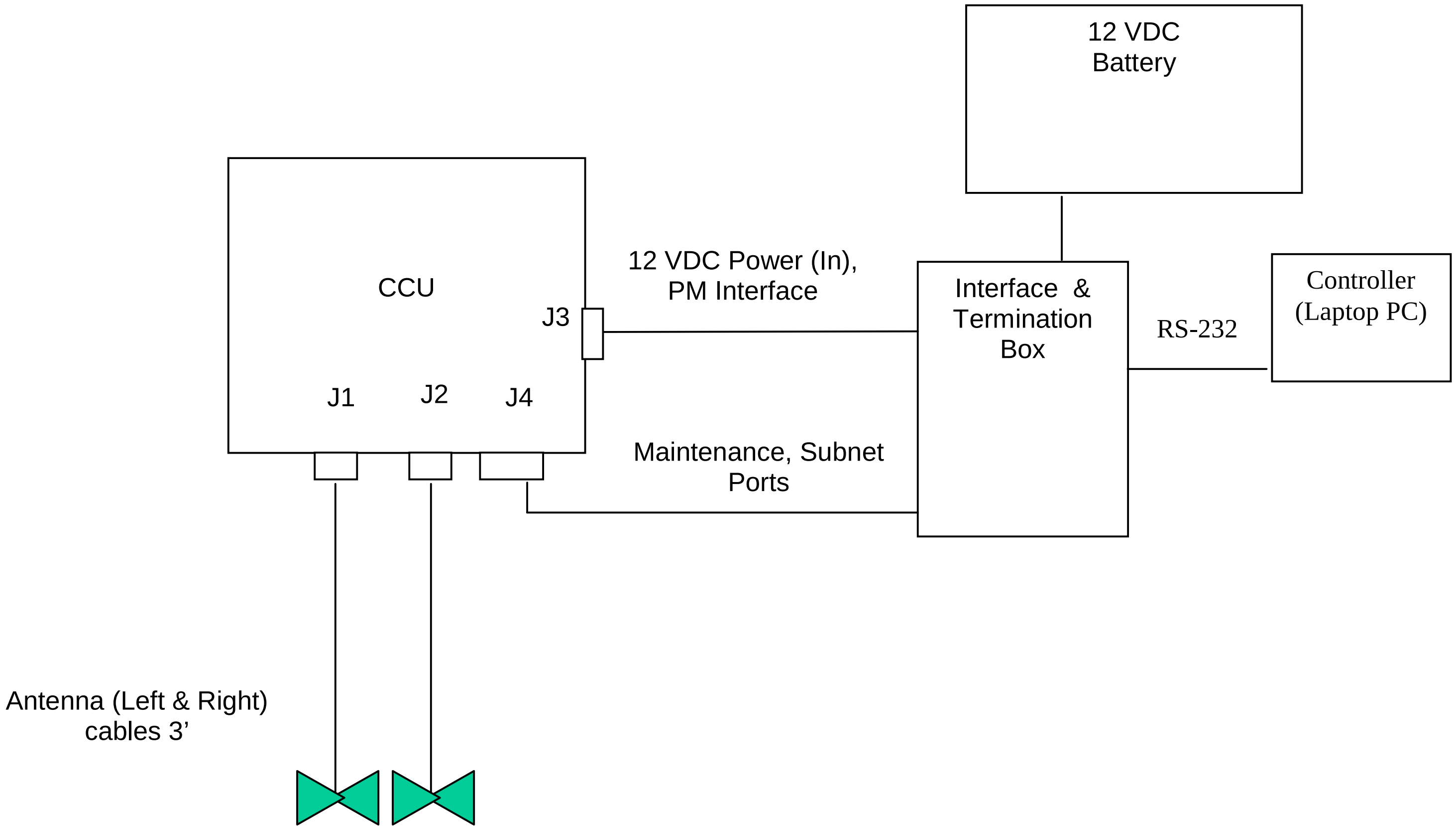

Figure 4.1-1. CCU Test Setup

5. PERSONNEL CONTACTS

The following personnel are involved in the FCC testing.

- Don Darby (GEHRE) – EPx/TrainTalk Project Engineer; responsible for coordinating hardware availability for testing
- Jeff Harris (GEHRE) – EPx/TrainTalk RF systems engineer
- Susan Beard (GEHRE) – EMI Engineer; responsible for generating test plan, test procedures, and summary report and for overseeing tests at Rubicom
- Michael Lipsky (GEHRE) – Test Engineer; responsible for running in-house stability tests and assembling Certification Package
- Joe Barbee (Rubicom) – performs testing at Rubicom's facility

6. PROGRAM SCHEDULE

FCC testing is scheduled as follows:

CCU: February 19 – 22, 1999

7. DOCUMENTATION

The following documents shall be produced during the process of planning, executing, and documenting these FCC tests.

- FCC Test Procedure – specifies the test requirements, limits, setups, and test modes for each of the UUT's
- FCC Test Report – documents the results in a format necessary to be submitted to the FCC for certification
- FCC Application – Form 731