



# ITCR Locomotive Radio User's Manual and Installation Instructions

Applicable Model: 63020

## Revision History

Revision	Date	Summary of Changes
0.1		Initial Draft
0.2	8/29/2011	Add notices to user and general editing for FCC/IC Submission
0.3	9/27/2011	Expand Section 1, Rewrite Section 2, insert new Section 3.
2	4/30/2013	Update frequency range.

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## 1. Overview

This document provides information required for the operation and verification of the Meteorcomm Interoperable Train Control Radio Network (ITCR) Locomotive radio.

### 1.1 Applicable Radio Models and Identifiers

This document applies to the Locomotive radio model listed below along with its regulatory identifiers.

Model: 63020 FCC ID: BIB63020 IC: 1300A-63020
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### 1.2 General Description

The Locomotive radios are designed to satisfy the industry standard Positive Train Control (PTC) requirements as an integrated 220 MHz radio network. The Base radio, Locomotive radio, and Wayside radio form the transportation backbone on which a messaging application provides communication capabilities between railroad assets and their back offices. The ITCR is designed to provide communication in an interoperable fashion enabling messaging to occur across railroad boundaries.

The Locomotive radio is a packet data radio that is part of a mobile station. It is half duplex, i.e., it alternately transmits or receives. It is mounted in a designated equipment area inside the locomotive. Its power source is the on-board 74Vdc bus. It is connected by coax to a 220 MHz band antenna on the cab roof. It has an ethernet connection to the on-board Train Management Computer (TMC) and serves the TMC as a wireless off-board communication path. Its primary mission is to receive data packets from Wayside radio stations about the track conditions ahead of its intended path on the rails. This information is passed to the TMC which in turn routes display information to the engineer's console. The TMC also detects and can independently react to potentially unsafe conditions. The Locomotive radio also wirelessly communicates on 220 MHz with a nearby base station. The base station backhauls the locomotive messages for various monitoring and control purposes at the railroad central office. The Locomotive radio can also receive relayed Wayside transmissions from any of several nearby base stations on different frequencies that it can monitor simultaneously when not transmitting.

## 1.3 Chassis

Locomotive radios are housed in electrically sealed metal cases. The Locomotive radio is LSI-rack compatible and its height is less than 6xMCUs. It weighs less than 22 lbs.

All input/output ports are grounded and/or shielded. In addition, best engineering practices have been employed with respect to internal shielding, unit assembly and PCB design in an effort to minimize potential sources of unwanted radiated emissions.

## 1.4 Ports and Ethernet Connectors

The Locomotive radio provides two 8-pole, female, M12, D coded connectors for Ethernet LAN plus a Maintenance port.

## 1.5 Power Connectors

The Locomotive radio provides a MS 3102 A18-4P connector for nominal 74 Vdc power.

## 1.6 Antenna Connector

The Locomotive radio is provided with two N-type connectors for the narrowband RF antennas. One antenna jack is used for the primary receive and transmit antenna cable. The other is used only for diversity reception.

# 2. Important Information for the User

## 2.1 Transmitter Warm-Up Period

The Locomotive transmitter uses a temperature compensated crystal oscillator (TCXO) to achieve frequency accuracy and stability. No warm-up period is required beyond the built-in radio startup delays.



## 2.2 Limiting RF Exposure



**Please refer to the RF Energy Exposure Guide packed with each radio for specific information regarding safe distances that must be maintained between personnel and energized transmitting antennas.**

The information in the RF Energy Exposure Guide is determined from FCC and Industry Canada rules that when followed, limit human exposure to radio frequency energy to acceptable levels. Note that the RF Energy Exposure Guide calculates the larger lateral safe distances for an uncontrolled environment. Obeying these limits will protect both railroad employees and the general public.

This radio is intended for use by railroad employees who have full knowledge of their exposure and can exercise control over their exposure to meet FCC and IC limits. This radio device is not intended for use by consumers or the general population.

This transmitter is intended to be operated with a mobile antenna in an Occupational/Controlled Exposure environment per FCC OET 65 or Controlled Use Environment per IC RSS-102. To protect the safety of employees and the general public, application of the Maximum Permitted Exposure (MPE) limit for devices in the presence of the general public in the 100-300 MHz range,  $0.2 \text{ mW/cm}^2 = 2 \text{ W/m}^2$ , is recommended.

Table 1 in the RF Energy Exposure Guide lists the calculated lateral distance to be maintained between the general public and an operational locomotive transmitter antenna mounted on the cab roof of a locomotive.

The licensee, installer, maintainer and locomotive operators must take into account all transmitting antennas on the locomotive with regard to potential RF exposure. In general, it is recommended that *all* locomotive transmitters with cab top antennas be disabled before accessing the cab top area.

## 2.3 Antenna Guidelines

This section contains antenna information and additional notes regarding methods to limit RF exposure.

- The licensee is required to comply with all limits imposed by the station license including frequency of operation, antenna location, power and effective

antenna height per 47CFR §90.701 et. seq., or Industry Canada SRSP-512 §6.3 as applicable.

Mobile antenna installations must adhere to the (general public) lateral separation distances in the RF Energy Exposure Guide supplied with each radio.

- Install antennas in accordance with the manufacturer's instructions.
- Disable the transmitter when installing or servicing its antenna or transmission line.
- Refer to the RF Energy Exposure Guide for specific guidelines regarding the siting and installation of mobile and fixed antennas.
- Acceptable mobile and fixed antenna types are listed in the tables in the RF Energy Exposure Guide.
- Unauthorized antennas, equipment modifications or attachments could invalidate any equipment warranty or authority to transmit. Modification could damage the radio and may violate FCC or IC regulations. Contact Meteorcomm before using other antennas.
- Maintain a safe distance from energized transmitting antennas. See above.

## 2.4 RF Interference to Residential Receivers (Part 15)

**NOTICE TO USER:** This device complies with part 15 of the FCC Rules. Operation is subject to the condition that this device does not cause harmful interference.

**NOTE:** This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to Part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more the following measures:

- Reorient or relocation the receiving antenna.
- Increase the separation between the equipment and receiver.
- Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.
- Consult the dealer or an experienced radio/TV technician for help.

## 2.5 Equipment Modifications



**Caution:** Any changes or modifications to this equipment not expressly approved by the party responsible for compliance (in the respective country of use) could void the user's authority to operate the equipment.

## 3. Locomotive Transmitter Operation

It is the responsibility of the licensee to operate this radio transmitter in compliance with the terms of the license and FCC or Industry Canada service rules for 220-222 MHz, i.e., FCC Rules Part 90T and Industry Canada SRSP-512, or in the U.S. only, operation on 217.6-218 and 219-220 MHz frequencies is subject to FCC Rules Part 80.

### 3.1 Locomotive radio channelization and frequency range

The Locomotive radio can be licensed and configured to transmit on any one of 80 selectable 25-kHz spaced channels ranging from 220.0125 to 221.9875 MHz inclusive in the 220-222 MHz Radio Service defined by Part 90 Subpart T. The spectrum included corresponds to all 5-kHz wide FCC channels numbered from 1 at 220.0025 MHz to 400 at 221.9975 MHz. Each Locomotive radio transmission occupies five of the FCC-defined 5-kHz channels. The lowest Locomotive radio channel center frequency is in the center of FCC channel 3 and the next is FCC channel 8, then 13, 18, and so on, up to the highest in the center of channel 398.

In the USA only, the radio can be licensed and configured to operate on 56 additional (Part 80) frequencies in the ranges 217.6125 to 217.9875 MHz and 219.0125 to 219.9875 MHz.

### 3.2 Locomotive channel restrictions

Section 90.715 of the FCC Rules lists the authorized frequencies of the 400 total 5-kHz-wide channels. According to §90.733(d), these can be aggregated into larger channel widths with the exception of FCC channels 161-170 and 181-185. Therefore, the Locomotive radio may not transmit on those channels or their 221 MHz counterparts, 361-370 and 381-385. This corresponds to Locomotive radio frequencies 220.8125, 220.8375, 220.9125, 221.8125, 221.8375, and 221.9125 MHz.

Please refer to Part 90 Subpart T and SRSP-512 for additional frequency use restrictions in Canadian and Mexican border areas.

### 3.3 Locomotive radiated power limits



It is the responsibility of the licensee to comply with the effective radiated power limits based on operating frequency, geographic location, and effective antenna height set out in 47CFR Parts 80 and 90 or Industry Canada SRSP-512 §6.3, as applicable.

**Important:** The following supplementary antenna system information discusses means for the licensee to calculate effective radiated power (ERP) and how to comply with regulatory power limits.

Licensees should note that mobile radios operating in the 220-222 MHz frequency range including Locomotive radios must limit effective radiated power (ERP) to 50W or  $10 \cdot \log(50) + 30 = 47\text{dBm}$  PEP referenced to the 2.15 dBi gain of a dipole unless operating under a waiver of FCC rule §90.729(b) or IC SRSP512 §6.3.1.4 as applicable. The EIRP for this case is 49.15 dBm. Also note that the maximum ERP on FCC/IC channels 196-200 at 220.975 to 221.000 MHz is 2 watts.

Antennas designed for locomotives at 220 MHz generally use a rugged cast aluminum body and are top-loaded vertically polarized requiring a metal cab roof for a ground plane. They are necessarily electrically shorter than one fourth wavelength due to vertical space limitations. Maximum practical antenna gain when installed properly on a locomotive cab roof is expected to be 0 dBd = 2.15 dBi.

Assuming no other losses between transmitter and antenna, the maximum allowed transmitter output for 0 dBd gain antenna is  $(47-0) = 47\text{ dBm PEP} = 50\text{W PEP}$ . In this case, if the measured transmitter output power exceeds 50W PEP, its power must be adjusted down to 50W PEP. Locomotive radio output power can be adjusted as described later in the manual.

The Locomotive transmitter should not be adjusted to greater than 50W PEP output. In a practical installation, the feedline and filter losses between transmitter and antenna are taken into account. If the Locomotive transmitter output is 50W PEP =

47 dBm PEP and the minimum feasible feedline loss is 0.3 dB, then the radiated power is 46.7 dBm = 46.8 W ERP.

Most if not all Locomotive installations will include an in-line 220 MHz band pass filter that adds 0.7 dB loss for a total loss of 1.0 dB. This filter prevents generation of intermodulation products in the Locomotive radio power amplifier by other cab top RF power sources, e.g., the 160 MHz voice radio transmitting antenna. The actual ERP in this case is therefore  $47 - 1.0 = 46$  dBm = 39.8 watts. The transmitter installation cannot be operated on FCC channels numbered 196-200 due to the 2W limitation.

Other power limits apply to U.S. operation in the frequency ranges 217.6125 MHz to 217.9875 MHz and 219.0125 MHz to 219.9875 MHz. In any case, transmitter power and antenna heights must comply with the applicable FCC rules, the station license, and any applicable waivers.

## 4. Setup and Configuration for the Locomotive Radio

Set up physical connections with the following:

- DC power
- Ethernet
- RF output termination

The sections below identify each of the physical connections.

### 4.1 Power Supply

Locomotive radios operate at 74V. Table 1 describes the power supply requirements for the Locomotive radio.



**Caution:** Applying an incorrect voltage to a Locomotive radio can cause damage. Confirm the voltage rating of the radio and its power supply before applying power.



**Caution:** The power supply voltage of this radio presents a potential electrical shock hazard. Disconnect all power supply sources before

installation or maintenance begins.

**Table 1 Locomotive Radio Power Parameters**

Parameter	Locomotive Radio
Nominal DC Power Input Voltage	74VDC
Operational Range	45-100Vdc
Damage limit	120VDC
Current Drain (while transmitting rated power)	7A peak max while transmitting into 50 ohm load 2.5A for max average operating current

## 4.2 Ethernet Connection

Locomotive radios use a non-standard Ethernet cable (MCC P/N 14001627-01) to connect between a PC and the maintenance port of the radio. Configure the PC network card with a fixed IP address of 10.10.1.254.

You will use XtermW, a Meteorcomm terminal emulation program, to connect with and control the radio via commands issued at command prompts.

## 4.3 RF Output Termination

The Loco radio is rated for 50W PEP. Sufficient termination is required to protect test equipment. Locomotive radios have a single TX/RX port with two additional ports for receiving only. For transmitter testing, connect the test equipment to the port labeled "TX/RX."

## 5. Tuning the Locomotive Radio

There are three parameters to test and potentially tune before/during RF testing:

- Master reference crystal oscillator frequency
- RF output power
- RF output channel

Factory technicians tune the master reference crystal oscillator and set the RF gain for maximum rated output power. You may have to adjust the three parameters

before or during RF testing by entering commands using XtermW or another terminal emulation program.

## 5.1 Equipment Required

1. 10A DC power supply at rated voltage of Locomotive radio, nominally 74 VDC.
2. Personal computer with ethernet network adapter and Meteorcomm XtermW or equivalent terminal program installed.
3. 30 dB 50W RF power attenuator.
4. Vector spectrum analyzer for power and frequency measurements.
5. Optional 8+ digit frequency counter for frequency measurements.
6. High stability time base accurate to 0.1 ppm. Can be internal to items 4 and 5.

## 5.2 Set up the Radio for Testing

1. Connect a cable that has CAT5 ethernet connector on one end and an 8-pin M12 cable connector on the other end (MCC P/N 14001627-01). Connect the M12 connector to the radio port labeled MAINT. Connect the other end to a computer network card. The default radio IP address is 10.10.1.254. Set the IP address of the computer network card to a compatible fixed address such as 10.10.1.1. The computer should have Meteorcomm XtermW or a similar terminal emulation program installed.
2. Adjust a 10A DC power supply to 74 VDC and then disable it temporarily. Connect the Locomotive power cable to the radio and then observing polarity markings connect the cable to the power supply terminals.
3. Apply power to the radio. Wait 30 seconds to open an XtermW session. Use the Edit/Configure Port window to set Port Type = TCP/IP, Protocol = Stream, TCP/IP Settings Host = 10.10.1.254, Port 4000. Select Device Type = MCC 6100 SDR (which also applies to ITC radios). Return Character = CR, Data Format = ASCII.
4. Attach a 50W 30 dB RF attenuator to the TX/RX1 N-type antenna connector. Attach an (e.g., Agilent MXA or PXA) vector spectrum analyzer or similar to the transmitter port for power and frequency measurements. The VSA should contain either a precision stability reference oscillator or attach an external rubidium reference to the VSA external reference input.

## 5.3 Measure and Calibrate Reference Crystal Oscillator Frequency

The instructions below allow you to change the factory calibration settings for the master reference oscillator crystal.

### To check the master reference crystal oscillator frequency calibration:

1. Open an XtermW session.
2. Put the radio into test mode by typing:  

```
dsp, watchdog, off  
dsp_mode, test
```
3. Reduce output power to approximately 2W by typing:  

```
cal, set, igain, -1000  
cal, set, qgain, -1000
```
4. Begin transmitting a test tone offset +8kHz from the carrier:  

```
dsp_mode, idle  
dsp_mode, test  
ll_test, stop  
ll_test, set, txmod, cw  
ll_test, set, txfreq, 220012500  
ll_test, start, tx
```
5. Use the frequency counter or frequency counting marker on the VSA to measure the output frequency. The measured value is exactly 8 kHz greater than the actual carrier frequency. The carrier frequency is normally well within 352 Hz (1.5 ppm) of the carrier frequency.
6. Alternate to the test tone: Substitute the following  $\pi/4$ -DQPSK modulation command for the fourth line in step 4.  

```
ll_test, set, txmod, dqpsk
```
7. Set the VSA to the center frequency of the channel and set it to demodulate the 16 ksym/second  $\pi/4$ -DQPSK emission and measure the error frequency which is referenced to the VSA center frequency.
- 8.



**To adjust the master crystal reference oscillator parameters:**

1. First, check the factory default setting for the crystal reference parameter by typing

```
cal
```

2. Note the value for “xo” in the cal factors table that is displayed.
3. At the XtermW command line, type:

```
cal , set , xo , xx
```

where xx is some value close to the original factory set value.

4. Use trial and error to determine the set point for the xo value to achieve the desired carrier frequency accuracy.

**To reset the XO tuning parameter to the factory setting:**

Power cycle the radio.

## 5.4 Measure and Adjust Output Power



**Caution:** Avoid unnecessary adjustments. Exercise caution when setting I and Q gain values as damage to the radio can occur if gains are set too high.

The Locomotive radio is rated for 50W PEP. To achieve this power radios are pre-calibrated at the factory. If additional tuning is required, use an appropriate method to determine PEP for a  $\pi/4$ -DQPSK signal. The CCDF function on the VSA is recommended for peak power measurement. Slowly increase/decrease I and Q gain levels from their nominal set point, as determined by issuing the command ‘cal’.

A step of 100 points (for example, -250 to -150) is approximately equivalent to an increase of 2dB in power.

**To measure and adjust output power:**

1. At the XtermW command line, begin transmitting a  $\pi/4$ -DQPSK signal by typing:

```
dsp_mode , idle
```

```
dsp , watchdog , off
```

```
dsp_mode , test  
  
l1_test , stop  
l1_test , set , txmod , dqpsk  
l1_test , start , tx
```

2. View the calibration settings by typing:

```
cal
```

3. Note the values for igain and qgain. They are normally matched.
4. Increase the output level by entering larger matched values or reduce output level using smaller matched values. Use cal command in between to verify the new settings.

```
cal , set , igain , xxxx  
  
cal , set , qgain , xxxx
```

5. Tune the VSA to the center of the channel frequency and use the CCDF function to measure the peak envelope power, average power and peak to average ratio. Do not set peak envelope power greater than 50W.

## 5.5 Check and Adjust RF Output Channel

You can adjust the RF output channel by stopping transmission, setting transmission frequency, and then starting transmission again.

### To adjust RF output channel:

1. Tune the radio to the bottom channel (220.0125MHz) by typing:

```
l1_test , stop  
l1_test , set , txfreq , 220012500  
l1_test , start , tx
```

2. Tune the radio to the mid-channel (221.0125MHz) by typing:

```
l1_test , stop ,  
l1_test , set , txfreq , 221012500  
l1_test , start , tx
```

3. Tune the radio to the high channel (221.9875MHz) by typing:

```
l1_test , stop  
l1_test , set , txfreq , 221987500  
l1_test , start , tx
```

## 6. Operations

This section provides commands used during normal operation of the Locomotive radio.

### 6.1 Restore Factory Settings

**To restore factory settings without cycling the radio:**

- At the XtermW command prompt, type:

```
factory
```

### 6.2 Display Software and Firmware Revision Numbers

**To display what software and firmware versions are installed on your radio:**

- At the XtermW command prompt, type:

```
rev
```

### 6.3 Display Radio Identification Information

This section provides you with commands to display serial number and identification information.

**To display serial number information:**

- At the XtermW command prompt, type:

```
serialnumber
```

**To show current ID setting:**

- At the XtermW command prompt, type:

```
ID
```