METROLINX

Radio Equipment Installation Standard for Coverage Enhancements Inside Buildings and Tunnels

MX-STC-STD-005

Revision 00
November 2024

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Publication Date: November 2024

Metrolinx,

an Agency of the Government of Ontario

Preface

This is the first edition of the Metrolinx *Radio Equipment Installation Standard for Coverage Enhancements Inside Buildings and Tunnels* (MX-STC-STD-005).

This document is for use by designers, consultants and contractors, and all others involved in the installation of radio equipment that will provide radio coverage inside buildings. It is intended for suitably qualified professionals that are familiar with the subject matter. This document is not a substitute for all applicable local codes, standards and manuals.

The technical content of the Metrolinx *Radio Equipment Installation Standard for Coverage Enhancements Inside Buildings and Tunnels* (MX-STC-STD-005) was developed by the Metrolinx Radio Systems office within the Asset Management and Maintenance Division.

Suggestions for revision or improvements can be sent to Metrolinx Radio Systems, Attention: Senior Manager, Radio Systems, who will introduce the proposed changes to Metrolinx Radio Systems. The Senior Manager, Radio Systems, ultimately authorizes the changes. A description of the proposed change shall be included along with information on the background of the application and any other useful rationale or justification. Proposals for revisions or improvements shall include your name, company affiliation (if applicable), e-mail address, and phone number.

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1. Introduction

1.1 General

1.1.1 Metrolinx Corporate UHF Radio System provides communications for operating groups, including Bus, Rail and Station Operations, Customer Protective Services, and the Network Operations Centre. This standard describes the installation of P25 Phase 2 UHF radio equipment operating in the 410 – 420 MHz frequency band.

1.1.2 In planning, installing, or modifying any antenna site, the need to comply with regulations and standards concerning human exposure to RF energy must be considered. Factors to be considered include the following:

a) The location, direction, transmission power, frequency, physical characteristics, and design of all antennas and other equipment at the site, in light of the existing or possible human occupation or usage of the adjacent areas;

b) Any necessary and appropriate steps to limit or control human access to adjacent areas, including limited-access doors, fencing, signs, and training;

c) Appropriate operational procedures to ensure ongoing compliance with radio frequency (RF) energy exposure regulations and standards when the antenna site is operational.

1.1.3 Metrolinx, as a provincial agency, is requiring that all contractors or employees follow all federal regulations or acts, including the Innovation, Science and Economic Development (ISED) Radio Communications Act and operate only Commercial/Professional Radios with licensed channels for any radio equipment installation.

1.1.4 This standard is mandatory adoption to ensure that the appropriate equipment is installed correctly in the new and existing buildings and tunnels where radio service is required.

2. Definitions, Abbreviations, Codes, and Standards

2.1 Definitions

2.1.1 Capitalized terms used in this standard shall have the meanings prescribed in Table 1.

Table 1: List of Definitions

Term	Definition
Amplifier	An electronic device that boosts the amplitude of an electrical signal.
Antenna	A device that converts electrical signals into electromagnetic waves and vice versa. It is used to transmit and receive radio frequency signals.
Channel	A communication path through which information can be transmitted, such as a frequency band used for radio or television broadcasts, or a digital pathway used for data transmission over the internet.
Coaxial Cable	A type of electrical cable consisting of a central conductor surrounded by a concentric layer of insulation and a grounded shield. It is commonly used to transmit high-frequency signals with low loss, such as for cable television and radio communication.
Donor Antenna	External antenna, usually mounted on the roof or a side of the structure, where a clear line-of-sight path exists to the distant radio tower. The distant site is also known as the "donor site."
Facility	A place, building, or tunnel used by Metrolinx. For example, rail or bus stations, maintenance or office buildings, tunnels for vehicles or pedestrians, rail layovers, etc.
Grounding	Known as earthing, it is the process of connecting electrical equipment or structures to the earth or a ground plane. It is used to prevent electric shock and protect equipment from damage due to static electricity or lightning strikes.

Term	Definition
Grounding Bar	A metal bar is used to connect two or more metallic objects together to create a common ground. It is commonly used in electrical systems to ensure that all metallic components are at the same electrical potential, thereby reducing the risk of electrical shock or damage to equipment.
Metrolinx	Means Metrolinx, a non-share capital corporation, continued under the Metrolinx Act, S.O. 2006, c.16 and a Crown Agency in accordance with the Crown Agency Act, R.S.O. 1990, c.48 and includes all operating divisions.
Metrolinx Radio Systems	Metrolinx Radio Systems department
N-Connector	A type of coaxial connector used for high-frequency applications. It features a threaded coupling mechanism and is designed to offer low-loss and high-power handling capabilities. N-connectors are commonly used in RF systems, such as in antennas, amplifiers, and transceivers.
P25 Phase 2	Project 25 is a suite of digital radio communication standards used in public safety and emergency response applications. It is designed to ensure interoperability and compatibility between different radio systems, allowing first responders to communicate effectively during emergency situations. Phase 2 is using Time Division Multiplexing to fit two traffic channels into one frequency channel for increased spectrum efficiency,
Power Supply	An electronic device that converts AC or DC electrical power from a source to the correct voltage, current, and frequency needed to power other electronic devices or systems.
Radio Frequency	It is the number of radio waves per second.
R56	Standards and Guidelines for Communication Sites.
RF Safety Code 6	A Canadian standard that sets limits on human exposure to radiofrequency (RF) electromagnetic energy in the frequency range of 3 kHz to 300 GHz, providing guidelines for the safe use of RF emitting devices and equipment. It includes regulations for the measurement and assessment of RF exposure, as well as mitigation strategies to minimize potential health risks.
Single-Mode Fiber	A type of optical fibre designed to carry a single ray of light with very high bandwidth over long distances.

2.2 Abbreviations

2.2.1 The abbreviations used in this standard shall have the meaning prescribed in Table 2.

Table 2: List of Abbreviations

Abbreviation	Definition
BDA	Bi-Directional Amplifier
DAS	Distributed Antenna System is a network of spatially separated antenna nodes connected to a common source via a transport medium that provides wireless service within a structure.
DAQ	Delivered Audio Quality is a measure of audio quality over a transmission medium. This metric is commonly used to quantify the quality of audio heard over a radio system.
dB	The decibel (dB) is a relative unit of measurement equal to one-tenth of a bel (B). It expresses the ratio of two values of power on a logarithmic scale.
dBm	dBm is a unit of measurement of power level expressed in dB (decibels), using one milliwatt as the reference point. One milliwatt of power equals 0dBm.
IEC	International Electrotechnical Commission. It creates Standards for electrical and electronic technologies.
ISED	Innovation, Science and Economic Development Canada, (formerly IC – Industry Canada). It is the government agency responsible for licensing of the radio spectrum.

Abbreviation	Definition
OHSA	Occupational Health and Safety Act of Ontario sets out the rights and duties of workers, supervisors, and employers in provincially regulated workplaces.
PPE	Personal Protective Equipment refers to equipment and clothing designed to protect individuals from hazards that may cause injury or illness in the workplace or other settings.
RF	Radio Frequency
RSSI	Received Signal Strength Indicator is the numeric value of the RF signal level measured by the receiving device.
UHF	Ultra-High Frequency is the designation for radio frequencies in the range between 300 megahertz (MHz) and 3 gigahertz (GHz).
UPS	An Uninterruptible Power Supply is a device that provides backup power to electrical equipment in case of a power outage or other power disruptions.

2.3 Codes, Standards, and Reference Documents

2.3.1 All systems, equipment and materials required for work relating to this standard shall be provided by Metrolinx in accordance with the most current edition of applicable federal, provincial, municipal, and industry codes, standards, and guidelines (collectively, "Standards and Guidelines") including the following:

a) R56 Standards and Guidelines for Communication Sites;

b) Canadian Centre for Occupational Health and Safety;

c) Canadian Standards Association (CSA);

d) Metrolinx standards and specifications.

3. Planning an In-Building Radio System

3.1 Facility Design Phase

3.1.1 Metrolinx Radio Systems department shall be contacted and engaged at 30% design phase and stay involved until 100% completion of the design review of new facilities. At the design phase location of radio equipment, including antennas, cables, and amplifiers, shall be determined and shown on the drawings.

3.1.2 Architectural design might require low profile or hidden antennas to be used inside and outside of the facility. Proper solution shall be found at the design phase to address esthetical aspects without compromising radio system performance.

3.1.3 Antennas, cables, and other equipment shall be installed in places where they cannot be damaged or vandalized and are out of the reach of the general public for security reasons and hidden, if possible.

3.1.4 Metrolinx Radio Systems department might experience additional challenges and costs with the installation of new equipment when facilities and tunnels are designed without consideration and provisions for in-building coverage, to the point that installation of radio equipment may not be possible.

3.2 Facility Construction Phase

3.2.1 Metrolinx Radio Systems department shall stay involved through the facility construction phase and shall be invited for related meetings and site visits. All requests for Design Change during construction that can affect radio equipment shall be submitted for review by the Metrolinx Radio System department.

3.2.2 Construction progress shall be monitored to ensure that all provisions for radio antennas, cables, conduits, and other equipment are provided in accordance with design drawings. If facilities and tunnels are built without provisions for in-building coverage, additional challenges and costs may be experienced later.

3.3 Site Survey

3.3.1 When construction is finished, or if radio coverage in the existing facility needs to be improved, the Metrolinx Radio Systems department shall organize a site survey. For the new facilities, the design plans shall be verified and confirmed. For the existing facilities site walk is required to plan for radio equipment locations.

3.3.2 For both new facilities and existing facilities, a site survey shall be conducted by Metrolinx Radio Systems to determine radio signal levels in the areas of interest. Before starting a site walk, it is advisable to obtain floor plans. While on the site survey, it is recommended to take the on-site information and correlate it with the floor plans.

3.3.3 Radio signal levels and the quality of radio communications shall be measured. Two persons with portable radios can conduct a simple radio survey and determine DAQ and RSSI. Both parties shall verify that the received audio is at least DAQ 3 based on the DAQ.

Table 3: Delivered Audio Quality (DAQ)

DAQ	Description
1	Unreadable. Speech present but not understandable.
2	Barely readable. Requires frequent repetition due to noise or distortion.
3	Speech understandable with some effort. Requires occasional repetition due to noise or distortion.
3.5	Speech understandable without repetition. Some noise or distortion present.
4	Speech easily understandable. Little noise or distortion.
4.5	Speech easily understandable. Rare noise or distortion.
5	Perfect. No distortion or noise discernible.

3.3.4 Two portable radios calibrated in dBm can be used to measure UHF signal levels and conduct test calls. The signal levels higher than -100 dBm are typically sufficient for good communications.

3.3.5 If areas of unacceptable coverage are discovered, the Radio Systems department shall consult with business departments that operate in the building and confirm if radio coverage improvements are required. Upon confirmation, the Radio Systems department shall proceed with planning for radio equipment locations.

3.4 Planning for Radio Equipment Location

3.4.1 It is essential to find a suitable location and mount for the donor antenna. Ideally, the donor antenna should provide the highest signal level received from the system radio site. A clear line of sight to the donor site is recommended. However, the signal levels outside of the building are typically high enough to allow the signal to be amplified by the in-building RF system to improve indoor coverage. Existing penetrations and conduits on the roof should be utilized to minimize the potential for water leaks. If there are no conduits and mounts on the roof, a roofing contractor may need to be engaged to install conduit and mount. The outdoor antenna, antenna mount and conduit must be grounded. Grounding and lightning protection of the antennas and support structures shall comply with Motorola R56 standards.

3.4.2 When the cable entrance point is defined, the location for BDA should be determined as well. Any suitable room like communications, electrical, mechanical or operations room can be considered for BDA installation. Electric power receptacle fed from UPS should be within a 1 m cable distance from the BDA equipment. If UPS power is unavailable at the facility, local power backup (UPS or backup batteries) shall be provisioned.

3.4.3 Locations for internal antennas should be selected to provide radio coverage in the areas where measured signal levels were low. If possible, existing conduits and cable trays should be considered for running cables connecting BDA with outdoor and indoor antennas. If there are no existing conduits, then new conduits shall be provisioned.

3.4.4 A walk through of the facility should help to determine proper locations for radio equipment and verify that all requirements for radio equipment installation could be met.

4. In-Building Radio System

4.1 In-Building Radio System for Small Facilities

4.1.1 Most of the existing in-building radio systems owned by Metrolinx belong to this category. Facilities, including buildings and tunnels with dimensions of 100 m or less, are considered undersized for the purposes of this standard. Losses in coaxial cables limit the size of such systems; usually, the cable length is less than 100 m. Basic in-building radio systems for small facilities typically include the following components.

a) Donor antenna - external antenna, usually mounted on the roof or a side of the structure, where a clear line-of-sight path exists to the distant radio tower. The distant site is also known as the "donor site.";

b) Lightning protection device shall be installed between the external antenna and BDA to prevent damaging equipment caused by high-voltage lightning surges;

c) BDA (Bi-Directional Amplifier). A specialized RF amplifier that selects the frequencies are to be amplified in the downlink and uplink paths. The downlink path is from the radio site to the user radio. The uplink path is from the user radio to the radio site;

d) The RF distribution network typically includes 50-ohm coaxial RF cables and splitters;

e) The coaxial cables can be standard (non-radiating) and radiating. Standard (Non-radiating) coaxial cables route RF signals to multiple indoor antennas placed in areas where radio operation is needed. Most of our existing installations use standard coaxial cables. The standard coaxial fire-rated cables shall be installed in conduits and in places where they cannot be damaged or vandalized, and hidden for esthetical reasons, if possible;

f) Radiating coaxial cables have holes in the shield to allow low-level RF signals to leak in and out of the cable; and

g) Indoor antennas are placed where radio coverage is required and connected to the BDA via coaxial cables and signal splitters. This method is called Distributed Antenna System or "DAS".

4.2 In-Building Radio System for Larger Facilities

4.2.1 Facilities, including buildings and tunnels with dimensions of more than 100 m, are considered large for the purposes of this standard. For larger facilities where the cable length may exceed 100 m, losses in coaxial cables may become prohibitive. For such cases, more advanced and expensive in-building radio systems using fibre optic cables can be designed and installed. Examples of such systems owned by Metrolinx include the East Rail Maintenance Facility in Whitby and the Union Station

Bus Terminal. The large in-building radio system contains elements similar to the basic system, with the addition of fibre optic interfaces and cables.

4.2.2 Donor antenna - an external antenna, the same basic antenna or specific for application, can be used.

4.2.3 Single or multiple BDAs can be installed. Typically, those are more advanced BDAs with multi-channel digital filters and fibre optic interfaces.

4.2.4 One or many Distributed Antenna Systems (DAS), including coaxial RF cables, splitters, and indoor antennas, can be designed and installed.

4.3 BDA Specifications

4.3.1 BDA specifications shall be determined in the design phase. Recommended main specifications are listed here:

- Downlink bandwidth 410 - 414 MHz
- Uplink bandwidth 415 – 419 MHz
- Minimum guard band 1 MHz
- Pass Bandwidth 4 MHz
- Maximum Gain 80 dB
- Gain adjustment 0 – 30 dB in 1 dB steps
- Maximum Input Level 0 dBm
- Output Power +24 dBm (single carrier)
- Noise Figure (without attenuation) 6.5 dB maximum
- Operating Temperature Range -30^{O} to +50^{O} C
- Nominal Impedance 50 ohms
- VSWR <1.5:1
- Input/Output Connectors N Female
- AC Input Power 100-240 VAC; 50-60 Hz

5. DAS Equipment Installation

5.1 Preparation for the Installation

5.1.1 Rooms and locations identified in the planning and design phases should be prepared and ready before installation shall commence. The construction works should be finished, and conduits, cables and electric power shall be installed as per design drawings. Metrolinx Radio Systems shall be notified about the completion of the construction. Upon receiving such notification, Metrolinx Radio Systems shall conduct the site visit to determine if the site is ready for installation and provide a report.

5.1.2 Metrolinx Radio Systems shall procure all equipment identified in the design phase, such as antennas, cables, BDA, and other miscellaneous devices.

5.1.3 Metrolinx Radio Systems shall acquire the necessary materials to implement the radio system. This may include coaxial cables, ethernet cables, single-mode (SM) fibre, power cords, and other devices, as well as tools and test equipment for installation.

5.2 Radio Equipment Installation

5.2.1 Metrolinx Radio Systems shall install equipment as described in the design documentation and follow the "R56 Standards and guidelines for communication sites", the manufacturer's instructions and all relevant safety guidelines.

5.2.2 All installation procedures shall be performed in accordance with recognized safety standards and guidelines, including those published by the Occupational Health and Safety Act of Ontario (OHSA) and other regulatory agencies.

5.2.3 During the installation process, Metrolinx Radio Systems personnel, visitors, and contractors shall follow all safety procedures and guidelines, use personal protective equipment (PPE) such as hard hats, safety glasses, and boots, and adhere to site-specific safety protocols.

5.2.4 All cables shall be properly installed and tested. Then cables shall be connected and labelled as per design documentation.

5.2.5 All equipment must be properly installed and grounded to prevent electrical hazards. Electrical connections shall be securely terminated and tested for proper voltage and grounding.

5.3 Radio Equipment Configuration and Testing

5.3.1 Metrolinx Radio Systems personnel shall configure and test installed equipment to ensure optimal performance, reliability, and compliance with industry regulations.

The configuration process includes setting up the frequency parameters, amplifier gain and power levels.

5.3.2 Radio communication equipment shall be tested for output power using a calibrated power meter. The testing process involves measuring the signal strength, range, and quality to ensure that the equipment is performing as expected. This testing is crucial to ensure that the equipment is secure and reliable and that it meets the necessary regulations for safe and effective communication.

5.3.3 Coverage provided by the in-building radio system shall be tested for inbound and outbound radio communications using portable radios.

5.4 Documentation and Maintenance

5.4.1 Installation and maintenance activities, including equipment specifications, installation procedures, and any modifications, shall be properly documented by Metrolinx Radio Systems.

5.4.2 Accurate records of all installation details, including equipment specifications, test results, and compliance with regulatory requirements, shall be kept by Metrolinx Radio Systems.

5.4.3 Maintenance includes routine inspections, cleaning, and repairs. Proper site documentation and maintenance are crucial to ensure the long-term performance and safety of radio communication equipment.

5.4.4 All Metrolinx radio installations shall comply with regulatory requirements and industry standards.

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