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Technical Note



Radiating Cable (RCL/RCH)

Performance Test & Design Guidelines

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1 Introduction

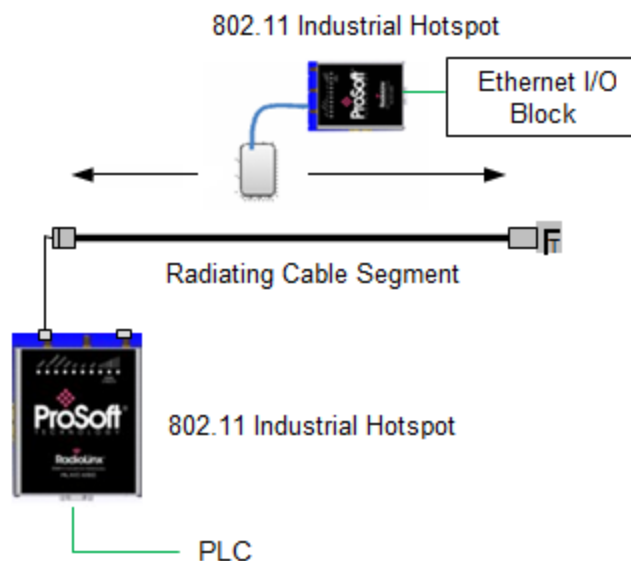
Radiating Cable (RC) is used for industrial wireless communications in situations where standard discrete antennas cannot be used effectively. Radiating cable may be used in wireless applications where antennas cannot reach due to obstructions such as tunnels or monorails. This document refers to applications and test results using ProSoft Technology Industrial Hotspots with Eupen-manufactured radiating cables.

Radiating cable (also known as "leaky feeder") has been applied for decades in low frequency radio applications. Highway and railway tunnels commonly use radiating cable for emergency radio communication and more recently, cellular phone connectivity. Radiating cable has also been installed in mines for voice radio communications.

The focus of this guide is applying 802.11 wireless technology over radiating cable for industrial control networking. ProSoft Technology specializes in wireless solutions for factory automation applications. These critical systems are complex to engineer. Partnering with a technology company with industrial networking knowledge and field application is crucial for success. While this guide contains valuable general information and suggested architectures, it is recommended to consult with our Wireless Support Engineers to ensure a successful project.

Basics

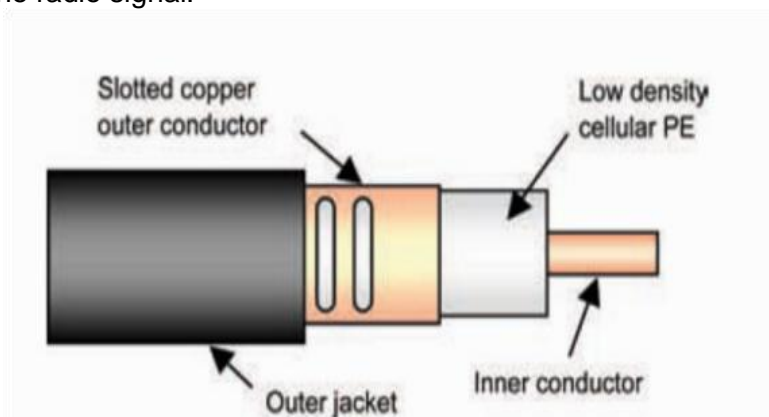
In some applications, radiating cable can be used instead of an antenna on one side of the radio frequency (RF) link.



Unlike antennas, radiating cable does not amplify the signal with gain. The RF energy is attenuated as it travels through the cable. This attenuation is called *longitudinal loss* and increases with the distance the signal travels through the cable.

There is also loss based on the air gap between the radiating cable and the antenna for the other radio in the link. This attenuation is called *coupling loss* and it increases with the gap. By using proper lengths of the cable and maintaining a consistent, short gap between the antenna and cable, a strong radio link can be maintained as the antenna travels along the cable.

Slots are cut in the shield part of the coax (underneath the insulation) to permit RF energy to propagate out of and be received into the cable. Sizing and spacing of these slots are based on the frequency of the radio signal.



Radiating Cable Construction (cutaway view)

The slots are arranged along one side of the cable and should face the antenna on the other side of the RF link, so cable orientation is critical for proper performance. To help installation, these slots are opposite to the ridge built into the outer jacket that runs the length of the cable.

Traditional discrete antennas are recommended over RC for most applications unless they are not capable of supporting reliable radio links due to confined spaces or line-of-sight challenges. The benefit of using RC lies in applications with moving equipment and machines that require a high quality RF connection as it travels along a track or through a tunnel.

Since RF radiates over several meters from RC cable, it is best practice to ensure no other Wi-Fi system uses the same or overlapping channels.

Proper mounting of RC is important to the success of a system. Please follow installation guidelines. Improperly mounting the cable will result in unwanted losses and poor performance. A terminator is required at the end of the cable to prevent RF reflection in the cable.

Cable

Radiating cable is 1/2" coaxial style cable. There are two basic types of Radiating Cable:

- RCL - Low Frequency (including 2.4 GHz band)
- RCH - High Frequency (5 GHz band)



The cable is available pre-terminated (N female connectors installed) or in bulk spools. Bulk cable must be properly terminated during installation.

Typical Cable Losses

RCH (5200GHz) = 19.1db/100m, 5.8db/100'

RCH (5800GHz) = 21.5db/100m, 6.5db/100'

RCL (2.4GHz) = 14.4db/100m, 4.47db/100'

Cable Installation Guidelines

The RF radiating characteristics of RC are such that proper installation is crucial to achieve expected wireless performance. This includes ensuring that the cable is installed far enough away from metal and concrete structures that may affect its RF characteristics. Plastic spacers with cable hangers (clamps) provide a practical way to install the RC. Because cable sags are undesirable, it is recommended to install hangers/clamps every meter. Plastic clamps can be used every meter. It is recommended that fire resistant clamps such as stainless steel be installed every 10th meter to better secure the cable (i.e. if there is a fire, the stainless steel clamps will ensure that the cable does not fall in a dangerous way).

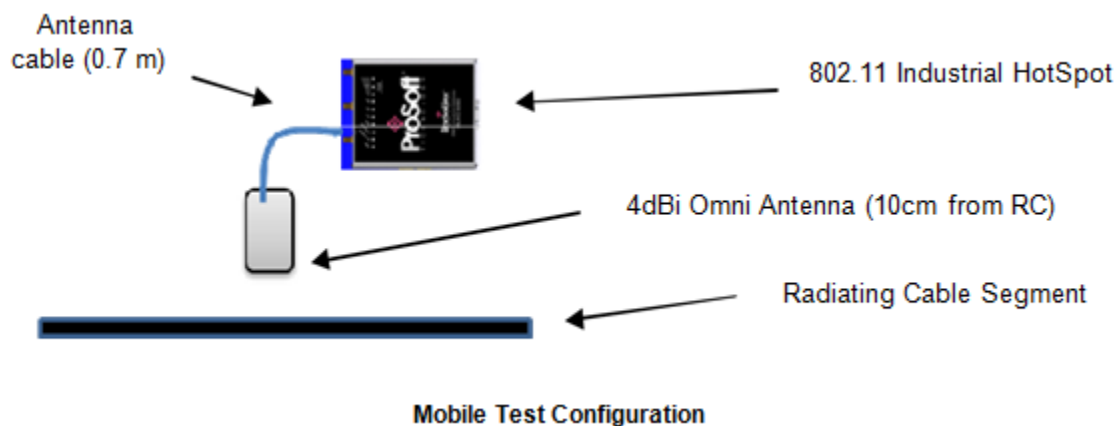
Once the hangers are installed, the terminated cable is then attached to the hanger clamps. The RC cable is clearly marked with a ridge indicating the opposite side of the RF propagation. The cable needs to be placed such that its RF signal is in the direction of the device/machine antenna.

2 Test Cases

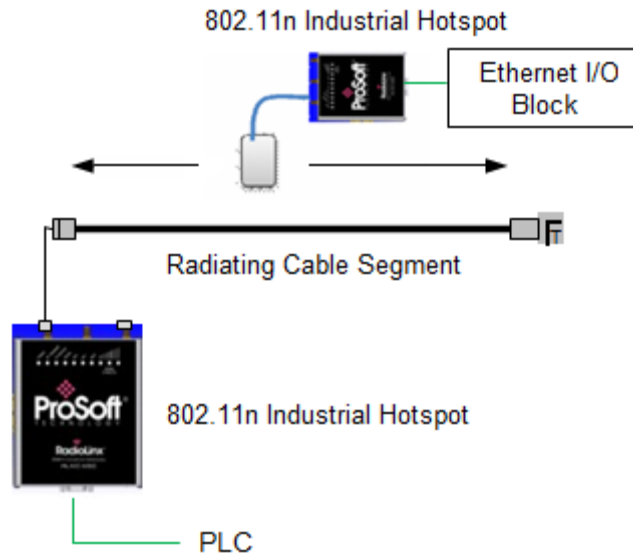
ProSoft Technology has performed extensive RC range and data rate performance testing using 802.11a, 802.11g and 802.11n wireless technologies. The tests were performed to gauge actual field performance, however installation environment and conditions can impact specific performance. Please consult with our Wireless Support Engineers for project assistance.

Test Conditions:

- ProSoft Technology Industrial Hotspots used for all tests.
- 802.11 clear channel (no other RF system in the same frequency range).
- 4dBi omni-directional antenna on the mobile device.
- The omni antenna was 10 cm (4") away from the RC segment (note that performance will decrease the further the antenna is away from the RC).
- EtherNet/IP controllers and I/O blocks used to generate high data rate.
- The test results are given for the connection requirements to maintain the fastest communication data rates for each tested Industrial Hotspot.



Test Case 1 - 802.11n Fast Industrial Hotspot (RLX2-IHNF) on Single RC Segment



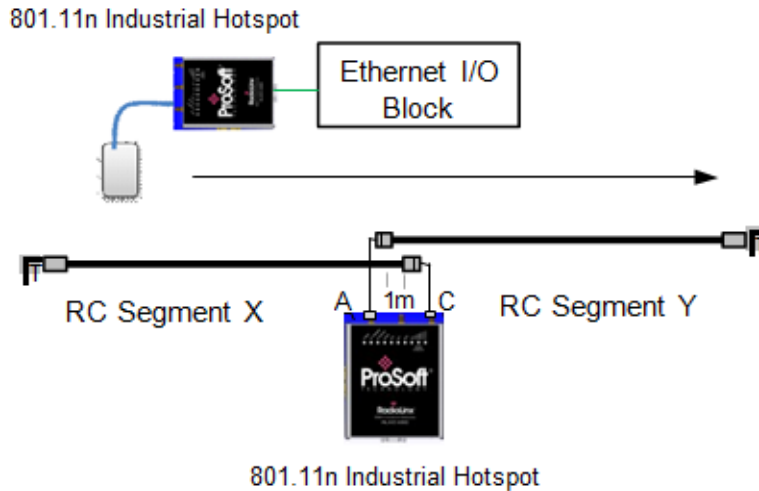
802.11n Test Case 1 System Architecture

Radiating Cable 802.11n Test Case 1 Results						
Cable Type	Frequency Band	Channel Width	RC Segment Distance Limit	Lowest RSSI	Max Data Rate Observed	Average EIP Packets/Sec
RCL	2.4 GHz	20 MHz	150 meters	-63 dB	65 Mbps	5,000
RCH	5 GHz	20 MHz	125 meters	-63 dB	65 Mbps	5,000
RCH	5 GHz	40 MHz (2 channels)	125 Meters	- 63 dB	150 Mbps	6,000

Test Notes:

- 802.11n rates up to MCS7 (single stream rates only)
- Omni antenna at 10 cm (4") from RC Segment
- Clear RF channel (no other RF systems present)

Test Case 2 - 802.11n Fast Industrial Hotspot (RLX2-IHNF) on 2 RC Segments



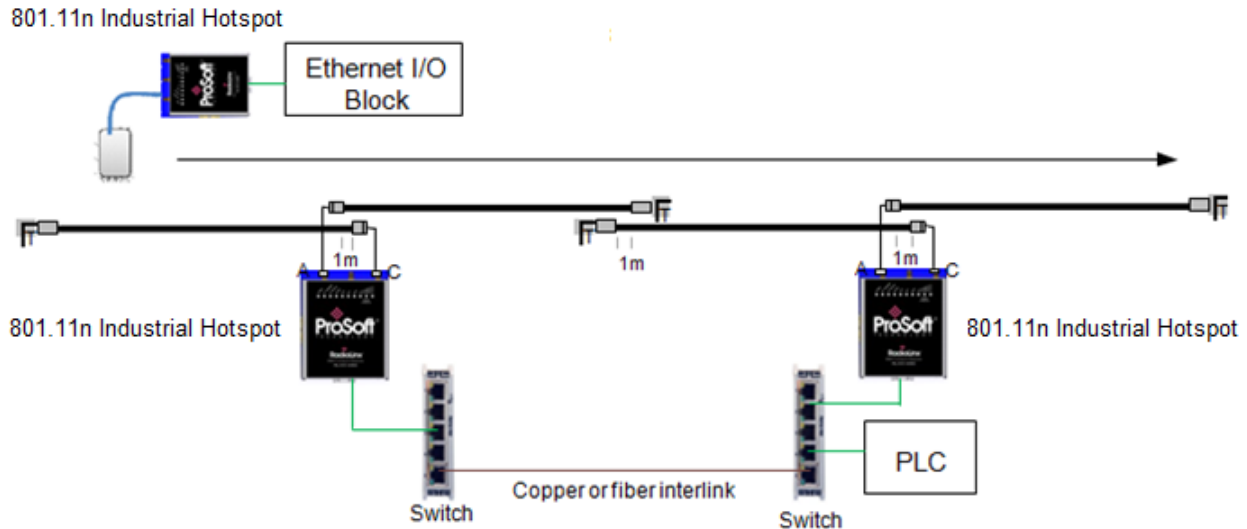
802.11n Test Case 2 System Architecture

Radiating Cable 802.11n Test Case 2 Results								
Cable Type	Frequency Band	Channel Width	Segment X	Segment Y	Total Effective Distance (X+Y-1m overlap)	Lowest RSSI	Max Data Rate Observed	Average EIP Packets/ Sec
RCL	2.4 GHz	20 MHz	150 m	150 m	299 m	-63 dB	65 Mbps	5,000
RCH	5 GHz	20 MHz	125 m	125 m	249 m	-63 dB	65 Mbps	5,000
RCH	5 GHz	40 MHz (2 channels)	125 M	125 M	249 m	- 63 dB	150 Mbps	6,000

Test Notes:

- RLX2-IHNF antenna ports A and C used
- 802.11n rates up to MCS7 (single stream rates only)
- Omni antenna at 10 cm (4") from RC Segment
- Segment X and Y overlap by 1 meter
- Clear RF channel (no other RF systems present)

Test Case 3 - Two (2) 802.11n Fast Industrial Hotspot (RLX2-IHNF) using Fast Roam



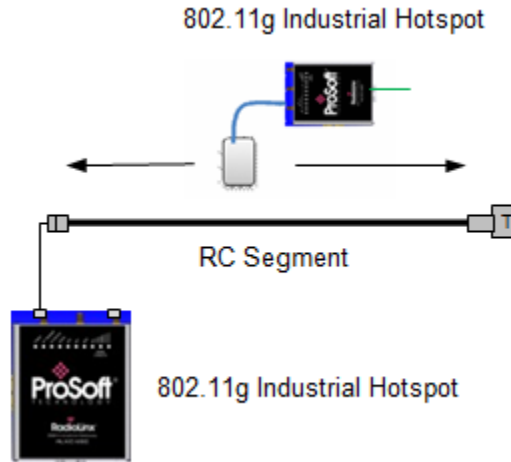
802.11n Test Case 3 System Architecture

Radiating Cable 802.11n Test Case 3 Results							
Cable Type	Frequency Band	Channel Width	Total Effective Distance (X+Y-1m overlap)	Roam Time	Lowest RSSI	Max Data Rate Observed	Average EIP Packets/Sec
RCL	2.4 GHz	20 MHz	299 m	< 40ms	-63 dB	65 Mbps	5,000
RCH	5 GHz	20 MHz	249 m	< 40ms	-63 dB	65 Mbps	5,000
RCH	5 GHz	40 MHz (2 channels)	249 m	< 40ms	- 63 dB	150 Mbps	6,000

Test Notes:

- Roam times of less than 40ms maintained PLC I/O connections - no faults
- 802.11n rates up to MCS7 (single stream rates only)
- Omni antenna at 10 cm (4") from RC Segment
- Segment X and Y overlap by 1 meter
- Clear RF channel (no other RF systems present)

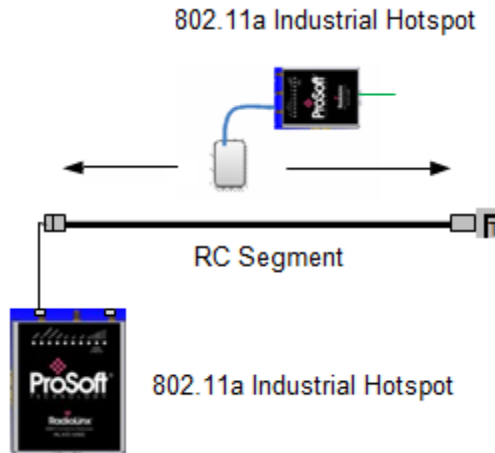
Test Case 4 - 802.11g High Power Industrial Hotspot (RLX2-IHG)



802.11g Test Case 4 System Architecture

Radiating Cable 802.11g Test Case 4 Results					
Cable Type	Frequency Band	RC Segment Distance Limit	Lowest RSSI	Max Data Rate Observed	Average EIP Packets/Sec
RCL	2.4 GHz	200 meters	-65 dB	58 Mbps	4,000

Test Case 5 - 802.11a High Power Industrial Hotspot (RLX2-IHA)



802.11a Test Case 5 System Architecture

Radiating Cable 802.11a Test Case 5 Results					
Cable Type	Frequency Band	RC Segment Distance Limit	Lowest RSSI	Max Data Rate Observed	Average EIP Packets/Sec
RCH	5 GHz	150 meters	-65 dB	58 Mbps	4,000

3 Test Conclusions & Best Practices

Radiating Cable (RC) is an effective way to support high speed automation systems using 802.11 wireless technologies. However, RC is much more complex and costly to install compared to traditional discrete antennas. RC should be used in situations where discrete antennas are not practical (confined spaces, large monorail systems and tunnels) where establishing line-of-sight is difficult.

RF performance with RC is very good at short distance from antenna to RC. However, the 802.11n speeds were slower compared to using MIMO (multiple-input and multiple-output), as dual streams is improbable with RC. If MIMOs can be used, it is preferable to RC.

Omni directional antennas showed the best performance for communicating to the RC segment. Directional (higher gain) antennas did not perform as well.

Radiating Cable is a good option for those applications where traditional antennas are not feasible. The wireless technology selection, cable design, and installation must be done precisely to assure good performance.