

Antenna Basics

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Contents

Antenna Basics	3
What Do Antennas Do?	3
Anatomy of an Antenna	3
Antenna Gain	5
Line of Sight	5
Omni-Directional Antennas	6
Directional (Yagi) Antennas	7
Path Loss, or Link Loss, Calculations	8
Antenna Installation	11
Weatherproofing Remote Antenna Installations	11
Mounting an RP-SMA Antenna Directly to the Cabinet	12
Mounting an RP-SMA Antenna Remotely	13
Mounting N-Type Antennas Remotely	15

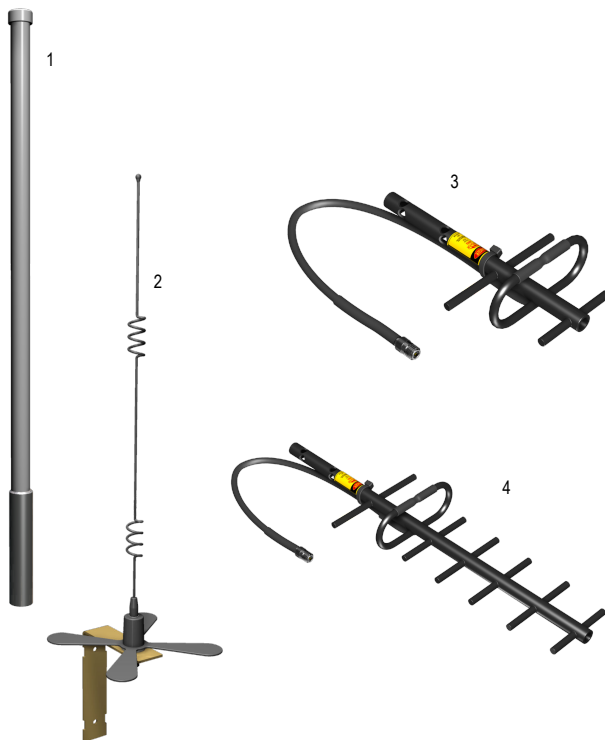
Antenna Basics

This Antenna Basics reference guide includes basic information about antenna types, how antennas work, gain, and some installation examples.

What Do Antennas Do?

Antennas transmit radio signals by converting radio frequency electrical currents into electromagnetic waves. Antennas receive the signals by converting the electromagnetic waves back into radio frequency electrical currents.

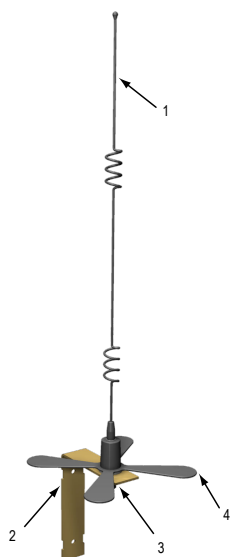
Because electromagnetic waves do not require a medium in which to travel, antennas can function in air, space, under water or other liquid, and even through solid matter for limited distances. Every antenna has specific characteristics that determine the signal's range and radiation pattern or shape.



1. Omni antenna with radome
2. Omni antenna with ground plane
3. Low-gain Yagi antenna
4. High-gain Yagi antenna

Anatomy of an Antenna

There are many components to an antenna system, including the parts of the antenna and the cabling used to connect the antenna to the radio.



- 1. Antenna element
- 2. Mounting bracket
- 3. N-type connector
- 4. Ground plane



Antenna extension cable with an SMA connector at one end and an N-type male connector at the other end. This cable typically connects between the SureCross® device and the antenna or another extension cable.



Antenna extension cable with an N-type male connector at one end and an N-type female connector at the other end. This extension cable connects between another cable and a surge protector or antenna.



Surge suppressors mount between the antenna and the radio system to protect the electrical equipment from damage during a lightning strike or other electrical surge. No surge suppressor can absorb all lightning strikes. Do not touch any radio device or any equipment connected to the radio device during a thunderstorm.

Always install and properly ground a qualified surge suppressor when installing a remote antenna system. Remote antenna configurations installed without surge suppressors invalidate the Banner Engineering Corp. warranty. Always keep the ground wire as short as possible and make all ground connections to a single-point ground system to ensure no ground loops are created.

Antenna Gain

The antenna's gain, measured in decibels, relates directly to the radio signal's radiation pattern and range.

Adding gain to a radio system does not amplify the signal. Antennas with greater gain only focus the signal. A low-gain antenna transmits (and receives) the radio signal equally in all directions. A high-gain antenna transmits its signal farther in one direction than the low-gain system.

Decibels

Mathematical equations indicate that for every 3 dB increase in the gain, the effective transmission power doubles. Experimentation indicates that for every 6 dB increase in the gain, the radio signal range doubles. Therefore, if a 0 dB antenna (unity gain) transmits three miles, a 6 dB antenna on the same radio transmits the signal six miles.

To simplify conversions between dBi, dBm, dBd, use the following approximation: $\text{dBm} = \text{dBi} = \text{dBd} + 2.15$, where dBm refers to a ratio of the measured power referenced to 1 milliWatt, dBi is a measurement of an antenna's gain compared to a mathematically ideal isotropic antenna, and dBd is a ratio of the antenna's forward gain to a half-wave dipole antenna.

Why Do You Need Gain?

According to rules set by the FCC, radio systems like the SureCross® radio device may not exceed 30 dBm Effective Isotropic Radiated Power (EIRP), or approximately 1 Watt. Because the 900 MHz SureCross radio system has a conducted power of 21 dBm (150 mW), the maximum system gain that may be used with the Banner system is 9 dBm. Using these higher gain antennas allows users to focus the signal both for transmission and for reception.

For systems requiring cables and connectors, the losses from the cables and connectors add up to reduce the effective transmission power of a radio network. What starts out as a 9 dB antenna may only have an effective gain of 5 dB once losses are totaled. Because the 9 dB limit applies to the radio system, including connectors and cables, using a higher gain antenna may be necessary to transmit the required distance and would still comply with FCC regulations.

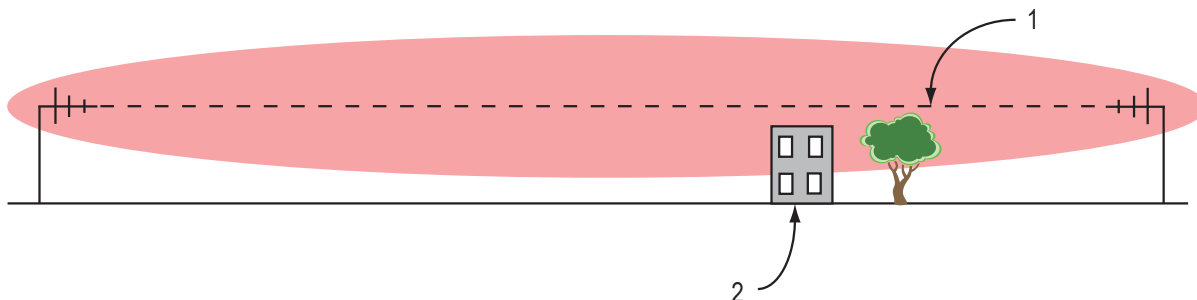
In addition to increasing the range, adding gain changes the radiation pattern. How the radiation pattern changes depends on the type of antenna: omni-directional or directional.

Line of Sight

Accurate radio transmission depends on a clear path between radio antennas known as the line of sight.

If any obstructions, including buildings, trees, or terrain, interrupt the visual path between antennas, the obstructions will also interfere with the radio signal transmission, resulting in multi-path fade or increased signal attenuation.

Multi-path fade is the result of radio signals reaching the receiver via two or more paths. In industrial settings, a received signal may include the line of sight signal in addition to signals reflected off buildings, equipment, trees, or outdoor terrain. Signal attenuation is the decrease in signal strength as a result of travel through the medium, in this case the air.



1. Line of sight
2. Obstruction in the "lobe" (Fresnel zone) of the radio signal.

Despite a clear line of sight, obstructions in the Fresnel zone, a three-dimensional ellipsoid formed with the two antennas as the foci, will still interfere with the radio signal and cause multi-path fade. Raise the antennas high enough to clear any obstructions. Ideally there should be no obstructions anywhere in the Fresnel zone, even if line of sight is preserved.

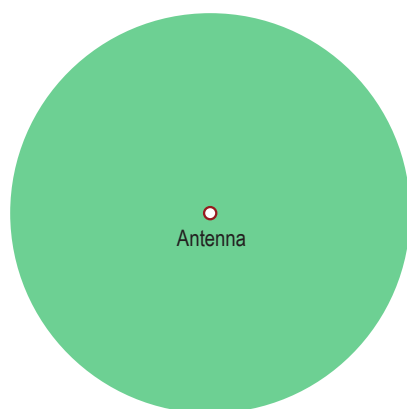
If a radio network site is spread over a large area with multiple obstructions or a variety of terrain, conduct a site survey to determine optimum antenna locations, antenna mounting heights, and recommended gains for reliable performance.

Omni-Directional Antennas

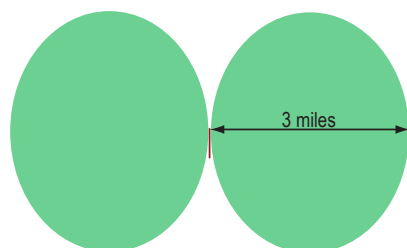
Omni-directional antennas mount vertically and transmit and receive equally in all directions within the horizontal plane.

Omni-directional antennas are used with the SureCross® Gateway, because the Gateway is usually at the center of the star topology radio network.

An omni-directional, or omni, antenna transmits and receives radio signals in the 'doughnut' pattern shown. Note the lack of a signal very close to the antenna. Most dipole omni antennas have a minimum distance for optimum signal reception. From the top view, the signal radiates equally in all directions from the antenna. For this reason, omni-directional antennas are best used for the device in the center of a star topology network.



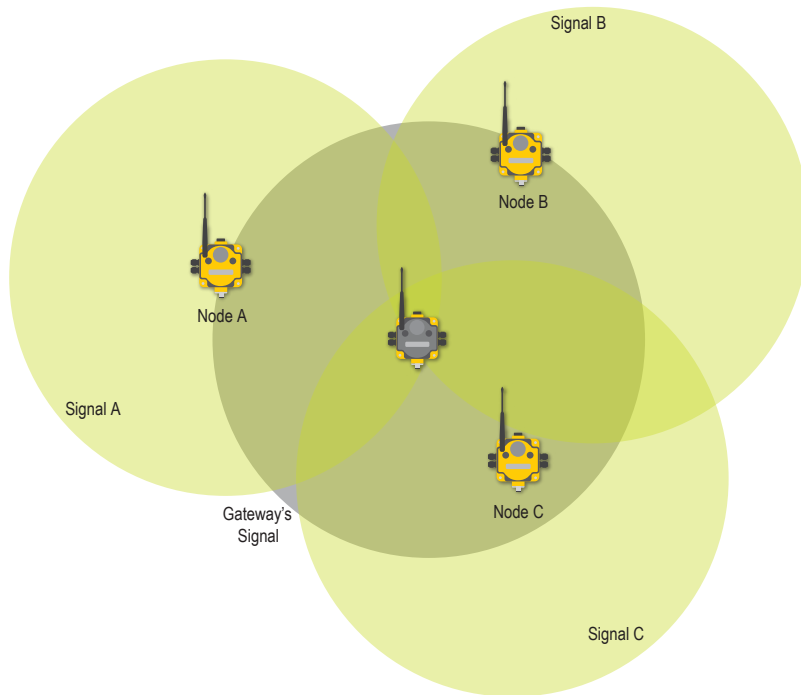
Viewed from the side, however, the radiation pattern of an omni-directional antenna is doughnut shaped.



With the star topology network, using the omni-directional antenna on the Gateway ensures that all Nodes fall within the antenna radiation pattern.

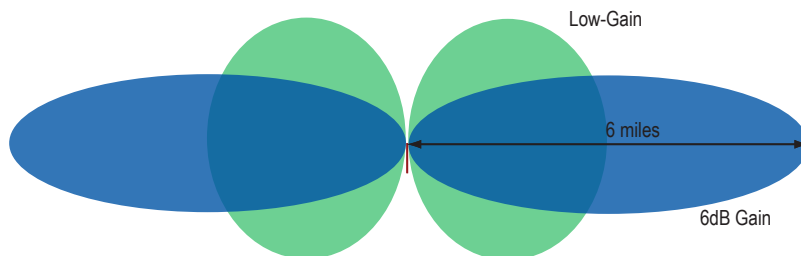
Low Gain Omni Antennas

Low-gain omni-directional antennas work well in multipath industrial environments, such as inside metal buildings. High-gain antennas work well in line-of-sight conditions. Using an omni-directional antenna in the center of a star topology ensures all radio devices receive a signal.



High Gain Omni Antennas

A high gain omni antenna with increased gain also has a circular radiation pattern when viewed from the top. From the side view, however, the decreased energy sent vertically increases the energy transmitted horizontally. The radiation pattern stretches to extend the range, focusing the signal along a horizontal plane. This makes higher gain omni antennas more sensitive to changes in elevation between the Gateway and its Nodes.



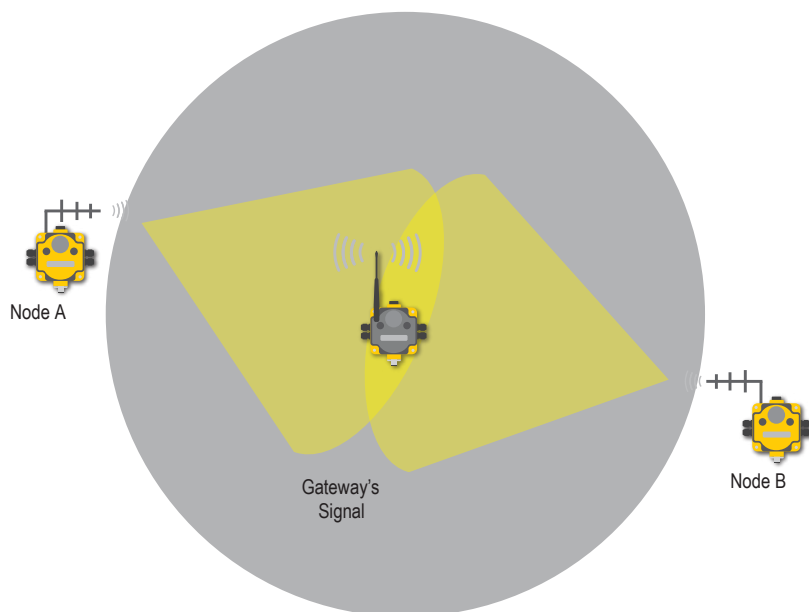
Increasing the gain of omni-directional antennas results in less energy sent vertically and more energy sent horizontally, extending the range.

Directional (Yagi) Antennas

A directional, or Yagi, antenna focuses the radio signal in one specific direction.

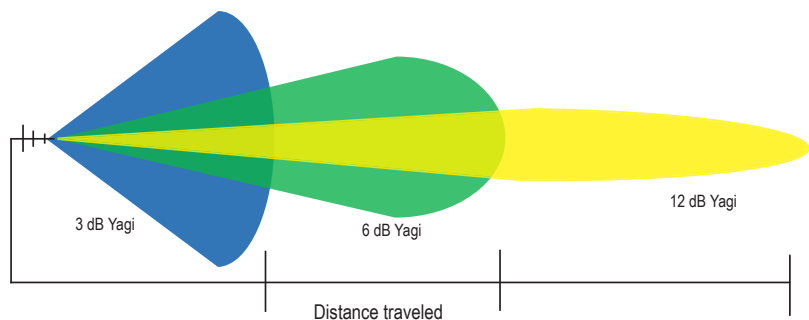
If you compare antenna radiation patterns to light, an omni antenna radiates a radio signal like a light bulb — evenly in a spherical pattern. A directional antenna radiates similar to a flashlight — focusing the signal only in one direction. The higher the gain, the more focused the beam becomes.

Yagi antennas are best used in line-of-sight radio systems because Yagis focus the radio signal in a specific direction. In the following example, the Gateway uses an omni antenna to receive radio signals from multiple directions but the Nodes use Yagi antennas aimed directly at the Gateway to send and receive the radio signal.



High-Gain Yagis

Because Yagi antennas yield narrower radiation patterns, accurately aiming a high-gain Yagi is important when setting up a radio network. The higher the gain of the antenna, the more the signal is focused along a specific plane. High-gain antennas should only be used for line-of-sight applications.



High-gain Yagi antennas are sensitive to mechanical mounting problems like wind, causing the antennas to become misaligned.

Path Loss, or Link Loss, Calculations

Path loss, or link loss, calculations determine the exact capabilities of a radio system by calculating the total gain (or loss) of a radio system.

System Total Gain = Transmitter gain + Free space loss + Receiver gain

The transmitter and receiver gains are typically positive numbers while the free space loss is a larger negative number. The total gain for any radio system should be negative. Compare this total gain value to the receiver sensitivity of the Banner SureCross® radios listed below.

Radio Receivers	Rated Sensitivity
900 MHz	-104 dBm
2.4 GHz	-100 dBm

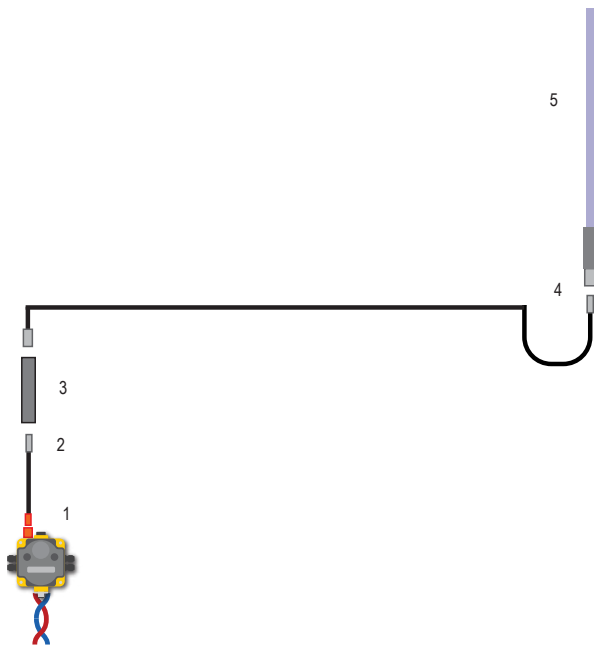
Path loss calculations must include all components of a radio system because any item connected to a radio system has a specific loss associated with it. Common items used within a radio network are cables, connectors, and surge suppressors. Cabling loss is usually measured per foot while losses for connectors and other items are specific to the component. When calculating the total gain of a radio system, include losses from all components of the system in your link budget calculations.

Item	Estimated Loss (dB)
Surge suppressor	1 dB
N-type connectors (per pair)	0.5 dB
SMA connector	0.5 dB
LMR400 coax cable	3.9 dB per 100 ft (0.039 dB per ft)
	0.128 dB per meter (1.28 dB per 10 meters)

Example Calculation - Transmitter System

To calculate the loss of the transmitter system shown below, include the losses from each connector pair, the surge suppressor, and the cable.

Radio's Power Output	DX70 or DX80 radio	21 dBm
Gains (+) or Losses (-)	Connector pairs	-1.0 dB
	Surge suppressor	-1.0 dB
	Cable (50 ft length)	-1.95 dB
	Omni antenna*	+8.15 dBi
Effective output of radio system		25.2 dBm



1. RP-SMA connection (-0.5 dB)
2. N-type male connection
3. Surge suppressor (N-type female to N-type male) (-1.0 dB)
4. N-type male connection (cable) to N-type female (antenna) (-0.5 dB)
5. Omni-directional antenna (6 dBd/8.15 dBi)

Losses:

- 0.5 dB per connection
- 1.0 dB per surge suppressor

-3.9 per 100 feet of cable for LMR400 coax

* Varies based on the antenna. Please refer to the technical specifications for the specific antenna used in the radio system.

Example Calculations - Free Space Loss

In addition to losses from cabling, connectors, and surge suppressors, radio signals also experience loss when traveling through the air. The equations for free space loss are:

$FSL_{900MHz} = 31.5 + 20 \text{ Log } d$ (where d is in meters)

$FSL_{2.4GHz} = 40 + 20 \text{ Log } d$ (where d is in meters)

For a 900 MHz radio system transmitting three miles, the free space loss is:

$FSL_{900MHz} = 31.5 + 20 \text{ Log } (3 \times 5280/3.28)$

$FSL_{900MHz} = 31.5 + 20 \text{ Log } (4829.27)$

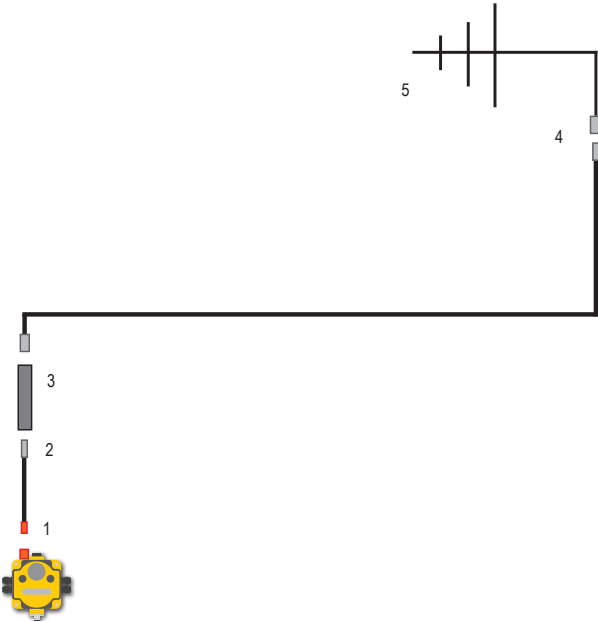
$FSL_{900MHz} = 31.5 + 73.68 = 105.18 \text{ dB}$

Because this is a loss calculation, free space loss is a negative number.

Example Calculations - Receiver System

To calculate the link loss of the receiver system shown below, include the losses from each connector pair, the surge suppressor, and the cable.

Radio's Power Output	DX70 or DX80 radio	N/A
Gains (+) or Losses (-)	Connector pairs	-1.0 dB
	Surge suppressor	-1.0 dB
	Cable (50 ft length)	-1.95 dB
	Yagi antenna*	+8.15 dBi
Effective gain of receiving antenna system		4.2 dBm



- 1. RP-SMA connection (-0.5 dB)
- 2. N-type male connection
- 3. Surge suppressor (N-type female to N-type male) (-1.0 dB)

4. N-type male (cable) to N-type female (antenna) connection (-0.5 dB)

5. Yagi antenna (6 dBd/8.15 dBi)

Losses:

-0.5 dB per connection

-1.0 dB per surge suppressor

-3.9 per 100 feet of cable for LMR400 coax

* Varies based on the antenna. Please refer to the technical specifications for the specific antenna used in the radio system.

Example Calculation - Complete System

The total losses for the entire system are:

Effective output of radio system	25.20 dBm
Free space loss	-105.18 dB
Effective gain of receiving antenna system	4.20 dBi
Total received power	-75.78 dBm

Compare the total received power to the sensitivity of the radio receiver to determine if the signal will be reliably received by subtracting the receive sensitivity of the radio from the total received power: $-75.78 \text{ dBm} - (-104 \text{ dBm}) = 28.22$

If the result is greater than 10 dB, the receiver should reliably receive the radio signal.

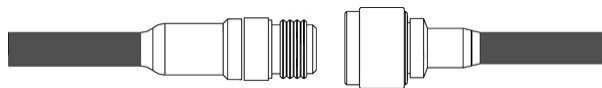
Antenna Installation

Always install and properly ground a qualified surge suppressor when installing a remote antenna system. Remote antenna configurations installed without surge suppressors invalidate the manufacturer's warranty.

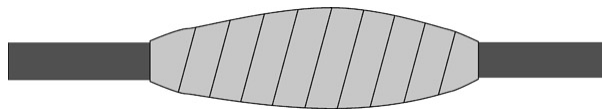
Always keep the ground wire as short as possible and make all ground connections to a single-point ground system to ensure no ground loops are created. No surge suppressor can absorb all lightning strikes. Do not touch the SureCross™ device or any equipment connected to the SureCross device during a thunderstorm.

Weatherproofing Remote Antenna Installations

Prevent water damage to the cable and connections by sealing the connections with rubber splicing tape and electrical tape.



Step 1: Verify both connections are clean and dry before connecting the antenna cable to the antenna or other cable and hand-tightening.



Step 2: Tightly wrap the entire connection with rubber splicing tape.

Begin wrapping the rubber splicing tape one inch away from the connection and continue wrapping until you are one inch past the other end of the connection. Each new round of tape should overlap about half the previous round.

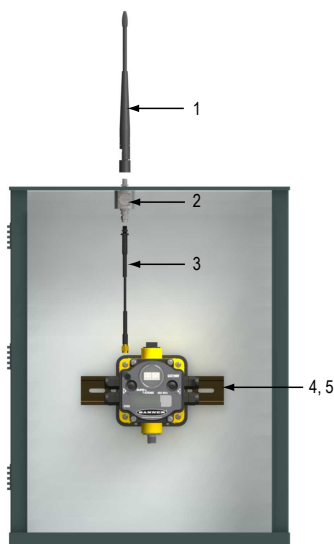


Step 3: Protect the rubber splicing tape from UV damage by tightly wrapping electrical tape on top of the rubber splicing tape. The electrical tape should completely cover the rubber splicing tape and overlap the rubber tape by one inch on each side of the connection.

Mounting an RP-SMA Antenna Directly to the Cabinet

This antenna mounts directly to the outside of the box, with the SureCross device mounted inside the box.

This situation may be used either inside or outside the building.

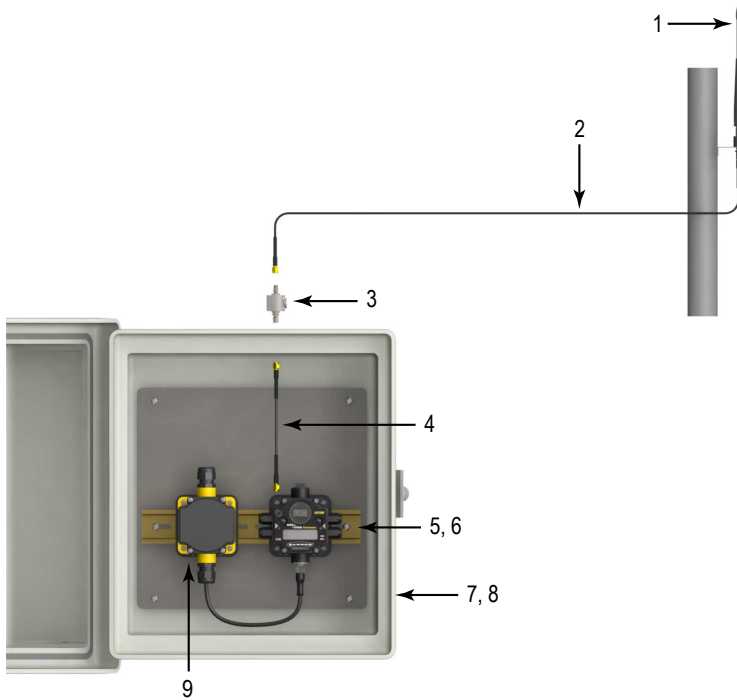


	Model Number	Description
1	BWA-902-C	Antenna, Omni, 902-928 MHz, 2 dBd, Rubber Swivel, RP-SMA MALE
	BWA-202-C	Antenna, Omni, 2.4 GHz, 2 dBd, Rubber Swivel, RP-SMA MALE
	BWA-205-C	Antenna, Omni, 2.4 GHz, 5 dBd, Rubber Swivel, RP-SMA MALE
	BWA-207-C	Antenna, Omni, 2.4 GHz, 7 dBd, Rubber Swivel, RP-SMA MALE
2	BWC-LMRSFRPB	Surge Suppressor, Bulkhead, RP-SMA Type, 900 MHz/2.4 GHz
3	BWC-1MRSFRSB02	RG58 Cable, RP-SMA TO RP-SMA Female Bulkhead, 0.2 m
	BWC-1MRSFRSB1	RG58 Cable, RP-SMA TO RP-SMA Female Bulkhead, 1 m
	BWC-1MRSFRSB2	RG58 Cable, RP-SMA TO RP-SMA Female Bulkhead, 2 m
	BWC-1MRSFRSB4	RG58 Cable, RP-SMA TO RP-SMA Female, Bulkhead, 4 m
4	DIN-35-105	DIN Rail section, 105 mm long, 35 mm design
5	SMBDX80DIN	DIN Rail Bracket Assembly for DX70 and DX80 models.

Mounting an RP-SMA Antenna Remotely

This antenna mounts remotely from the box, with the SureCross device mounted inside the box.

This situation may be used either inside or outside the building, though a Yagi antenna is usually used in outdoors applications while an omni-directional antenna may be used either inside a building or outside.



	Model Number	Description
1	BWA-902-C	Antenna, Omni, 902-928 MHz, 2 dBd, Rubber Swivel, RP-SMA MALE
	BWA-905-C	Antenna, Omni, 902-928 MHz, 5 dBd, Rubber Swivel, RP-SMA MALE
	BWA-202-C	Antenna, Omni, 2.4 GHz, 2 dBd, Rubber Swivel, RP-SMA MALE
	BWA-205-C	Antenna, Omni, 2.4 GHz, 5 dBd, Rubber Swivel, RP-SMA MALE
	BWA-207-C	Antenna, Omni, 2.4 GHz, 7 dBd, Rubber Swivel, RP-SMA MALE
2	BWC-1MRSFRSB02	RG58 Cable, RP-SMA TO RP-SMA Female Bulkhead, 0.2 m
	BWC-1MRSFRSB1	RG58 Cable, RP-SMA TO RP-SMA Female Bulkhead, 1 m
	BWC-1MRSFRSB2	RG58 Cable, RP-SMA TO RP-SMA Female Bulkhead, 2 m
	BWC-1MRSFRSB4	RG58 Cable, RP-SMA TO RP-SMA Female, Bulkhead, 4 m
3	BWC-LMRSFRPB	Surge Suppressor, Bulkhead, RP-SMA Type, 900 MHz/2.4 GHz
4	BWC-1MRSFRSB02	RG58 Cable, RP-SMA TO RP-SMA Female Bulkhead, 0.2 m
	BWC-1MRSFRSB1	RG58 Cable, RP-SMA TO RP-SMA Female Bulkhead, 1 m
	BWC-1MRSFRSB2	RG58 Cable, RP-SMA TO RP-SMA Female Bulkhead, 2 m
	BWC-1MRSFRSB4	RG58 Cable, RP-SMA TO RP-SMA Female, Bulkhead, 4 m
5	DIN-35-105	DIN Rail section, 105 mm long, 35 mm design

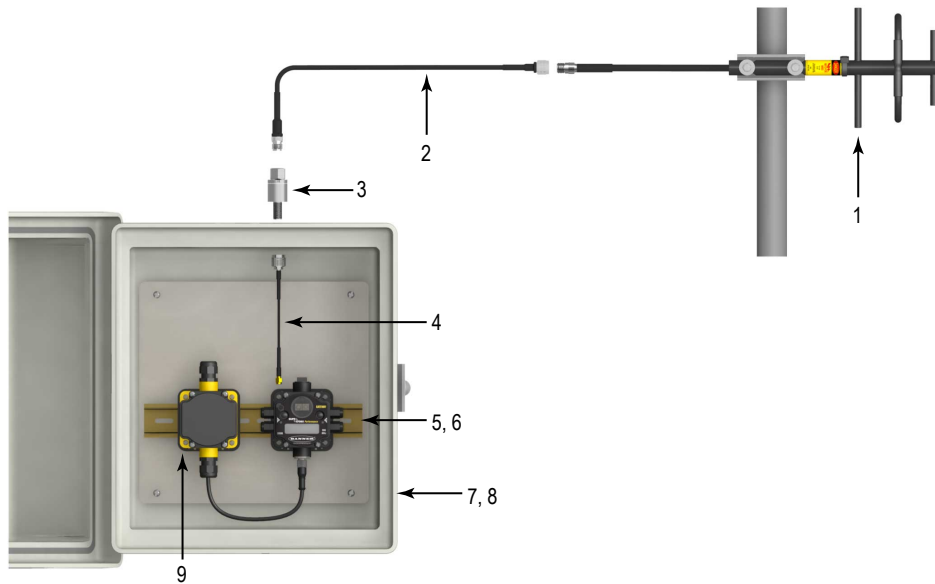
	Model Number	Description
6	SMBDX80DIN	Bracket Assembly, DIN Rail, for DX80
7	BWA-EF14128	Fiberglass enclosure, 14" x 12" x 8"
8	BWA-PA1412	Internal panel, 14" x 12"
9 *	DX81	DX81 FlexPower Battery Supply Module
	DX81P6	DX81P6 FlexPower Battery Supply 6-Pack

* This example image depicts a DX80 radio with a 10-30V dc power supply. The example installation may also work with the DX70 radios or MultiHop radios. However, the DX81 and DX81P6 FlexPower Battery Supply Modules can only power FlexPower devices. The battery supply modules cannot be used with any 10-30V dc-only powered devices and cannot be used with the DX70 radios.

Mounting N-Type Antennas Remotely

This antenna mounts remotely from the box, with the SureCross device mounted inside the box.

This situation may be used either inside or outside the building, though a Yagi antenna is usually used in outdoors applications while an omni-directional antenna may be used either inside a building or outside.



	Model Number	Description
1	BWA-9Y6-A	Antenna, Yagi, 900 MHz, 6.5 dBd, N Female
	BWA-9Y10-A	Antenna, Yagi, 900 MHz, 10 dBd, N Female
	BWA-9O6-A	Antenna, Omni, 900 MHz, 6 dBd, Fiberglass, N Female
	BWA-9O5-B	Antenna, Omni, 900 MHz, 5 dBd/7.2 dBi, With ground plane, N Female
	BWA-2O8-A	Antenna, Omni, 2.4 GHz, 8.5 dBi, N Female, Fiberglass 24"
	BWA-2O6-A	Antenna, Omni, 2.4 GHz, 6 dBi, N Female, Fiberglass 16"
2	BWC-4MNFN3	LMR400 Cable, N-Male to N-Female, 3 Meters
	BWC-4MNFN6	LMR400 Cable, N-Male to N-Female, 6 Meters
	BWC-4MNFN15	LMR400 Cable, N-Male to N-Female, 15 Meters
	BWC-4MNFN30	LMR400 Cable, N-Male to N-Female, 30 Meters
3	BWC-LFNBMN-DC	Surge Suppressor, Bulkhead, N-Type, 900 MHz/2.4 GHz, dc-Blocking
4	BWC-1MRSMN05	LMR200 Cable, RP-SMA to N-Male, 0.5 Meters
	BWC-1MRSMN2	LMR200 Cable, RP-SMA to N-Male, 2 Meters
5	DIN-35-105	DIN Rail section, 105 mm long, 35 mm design
6	SMBDX80DIN	Bracket Assembly, DIN Rail, for DX80
7	BWA-EF14128	Fiberglass enclosure, 14"x 12" x 8"
8	BWA-PA1412	Internal panel, 14" x 12"

Model Number		Description
9 *	DX81	DX81 FlexPower Battery Supply Module
	DX81P6	DX81P6 FlexPower Battery Supply 6-Pack

* This example image depicts a DX80 radio with a 10-30V dc power supply. The example installation may also work with the DX70 radios or MultiHop radios. However, the DX81 and DX81P6 FlexPower Battery Supply Modules can only power FlexPower devices. They battery supply modules cannot be used with any 10-30V dc-only powered devices and cannot be used with the DX70 radios.

Index

A

- antenna
 - dipole 6, 7
 - direct installation 12
 - directional 7
 - extension cable 3
 - gain 5
 - omni 6, 7
 - remote installation 13–15
 - Yagi 7
 - antenna
 - surge suppressor 3
- antenna installation
 - warning 11
 - weatherproofing 11
- attenuation 5

C

- cable loss 5

D

- decibel 5
- directional antenna 7

E

- Effective Isotropic Radiation Power 5
- EIRP 5
- electrical tape 12

F

- free space loss 8–11
- Fresnel zone 5

G

- gain 5
- ground loop 3
- ground wire 3, 11

L

- lightning arrestor 3
- line of sight 5
- link loss 8–11
- loss
 - cable 5
 - free space 8–11
 - path 8–11
 - receiver system 8–11
 - system 8–11
 - transmitter system 8–11

M

- multi-path fade 5

P

- path loss 8–11

R

- rubber splicing tape 12

S

- single-point ground 11
- site survey 5
- star topology 6, 7
- surge suppressor 3

T

- topology
 - star 6, 7

Y

- Yagi antenna 7