Cisco Multi-element, 9-in-1, LTE/Wi-Fi/GNSS antenna (5G-ANTM-0-4-B)

This chapter contains the following:

Overview

This section describes the technical specifications and installation instructions for the Cisco Multi-element, 9-in-1, LTE/Wi-Fi/GNSS antenna (5G-ANTM-0-4-B), hereafter referred to as the antenna. The antenna meets or exceeds a variety of environmental ruggedization specifications for transportation applications.

Antenna Features

The antenna features:

- Wideband coverage: 4G LTE, 5G - FR1 and dual-band 802.11ac (Wi-Fi 5) coverage in a single, low-profile housing
- Superior out-of-band rejection: Proprietary filtering design allows wideband coverage for all GNSS frequencies
- Metal 1-inch stud mount with slotted jam nut provides single cable exit for easier installation and/or antenna replacement.
- IP67 compliant design provides maximum protection against water or dust ingress under severe environmental conditions (when installed on sealed surface)

- Proprietary high rejection filtering allows wide-band coverage while achieving superior out-of-band rejection for all GNSS frequencies
- Meets EN 50155:2007 and AAR certification requirements for rail applications

The antenna may require RF extension cables. A shorter 2 foot cable length was selected on LTE WAN and WiFi WLAN to allow you to optimize LTE WAN and WiFi WLAN RF performance and wireless range. If you require a cable length longer than 2 feet with the antenna, you will need to select RF extension cables of appropriate length and type. Thicker RF cables, such as LMR-600, LMR-400, or LMR-240 result in lower loss, higher RF performance and longer range of wireless network than thinner cables such as LMR-195, LMR-200. The trade-off is that thicker cables are more difficult to bend and route. For optimal performance, the length of thin cables needs to be kept as short as possible.

For example, 2 foot and 10 foot lengths of LMR-195 cable at 2700 MHz frequency would have losses of 0.5dB and 2.3dB respectively. In this example at 2700 MHz the area covered by the wireless system with the 10 foot cable is reduced by 34% compared to the 2 foot cable. Radius of communication is degraded by 20% in 10 foot vs. the 2 foot case. At 5825 MHz WiFi frequency, 2 foot and 10 foot lengths of LMR-195 would have losses of 0.8dB and 3.4dB respectively. In this example at 5825 MHz, the area covered by the wireless system with the 10 foot cable is reduced by 45% compared to the 2 foot cable. Radius of communication is degraded by 26% in the 10 foot vs. the 2 foot case.

Note Loss of the 17 foot GNSS cable is compensated by the gain of the active GNSS antenna, and has little impact on GNSS performance.

Antenna Assembly

Figure 1: Cisco 5G-ANTM-0-4-B Antenna

Figure 2: Antenna Mechanical View (Side and Top)

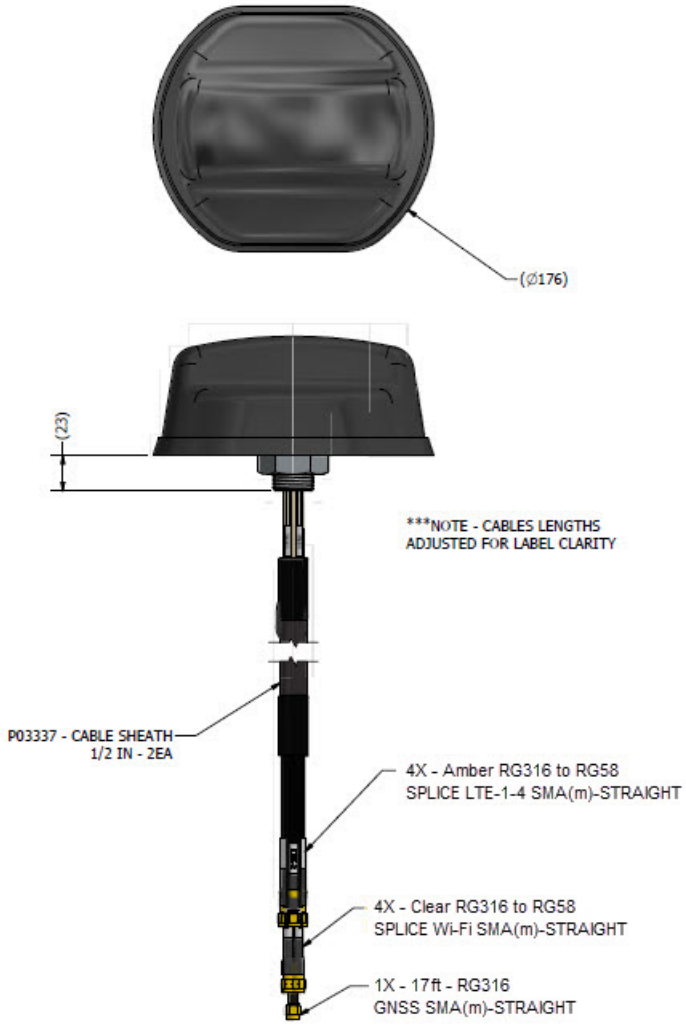
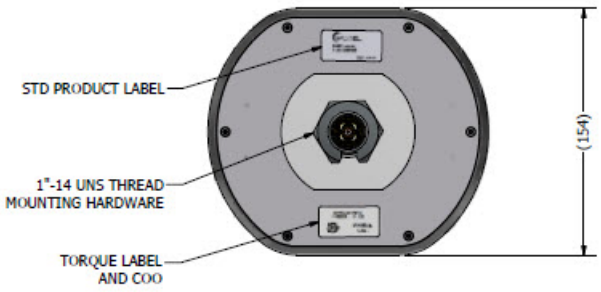


Figure 3: Antenna Mechanical View (Bottom)

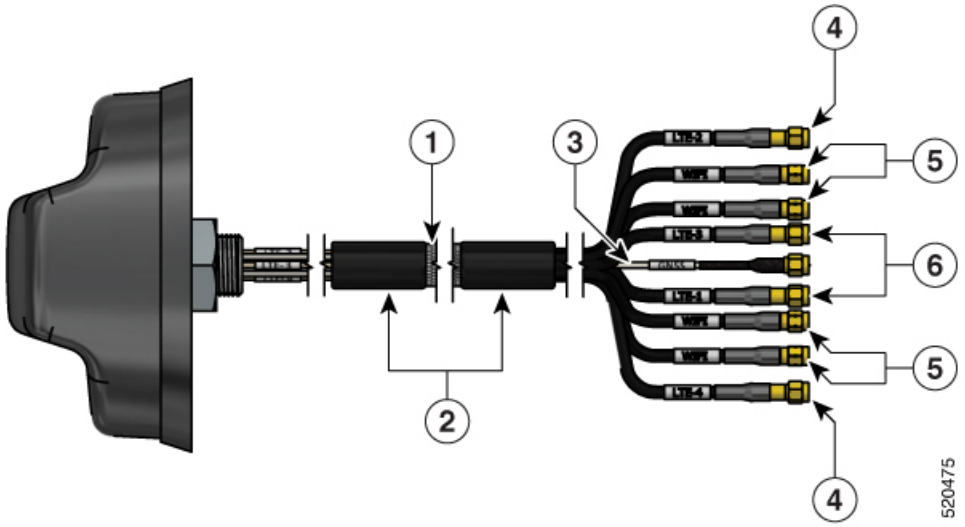


Note All dimensions are in millimeters [inches] unless explicitly stated otherwise in the drawing.

Antenna Cable Details

The following figure shows the details and labels of the antenna cables.

Figure 4: Cable Details



1	Cable sheathing
2	HS TUBING, 2EA LTE-ID LABEL 2EA
3	RG316 GNSS MSMA STRAIGHT
4	LTE SECONDARY (DIVERSITY) – LTE2 (DIV0) and LTE4 (DIV1) AMBER RG316 - RG58 CABLE, SPLICE, MSMA-STRAIGHT
5	4X WIFI CLEAR RG316 - RG58 CABLE SPLICE, RPSMA-STRAIGHT
6	LTE PRIMARY (MAIN) – LTE1 (MAIN0) and LTE3 (MAIN1) AMBER RG316 - RG58 CABLE, SPLICE, MSMA-STRAIGHT

Technical Specifications

This section contains mechanical, electrical, environmental, and operational specifications.

Mechanical Specifications

The following table shows the details for the antenna cables.

Table 1: Antenna Cable Details

Elements	Cable	Connectors	Mounting Method
LTE (All Ports)	Four-17 feet (2-ft RG-316/15-ft Pro-Flex™ Plus 195)	SMA Plug (Male)	1-inch OD, 3/4-inch long (.75”) zinc stud mount with jam nut
Wi-Fi (All Ports)	Four-17 feet (2-ft RG-316/15-ft Pro-Flex™ Plus 195)	Reverse Polarity SMA Plug (Male)	
GNSS	One-17 feet RG-316	SMA Plug (Male)	

The following table shows the details for the antenna body.

Table 2: Antenna Body Details

Dimensions (L x W x H)	Weight (9 ports)	Housing Material	Gasket Design & Construction
6.93 x 6.09 x 3.01 in (176.0 x 154.8 x 76.5 mm)	4.8 lbs (2.2 kg)	UV-Stable Rugged Thermoplastics	Contour matching, conformable, thermoplastic-elastomer gasket designed to seal between radome and baseplate. Gasket flexes and conforms to contoured surfaces. Baseplate has a 3M™ VHB mounting pad for anti-rotation.

Electrical Specifications

The following tables provide Radio Frequency specifications:

Table 3: LTE Primary (1 and 3)

F1 (MHz)	F2 (MHz)	VSWR	Gain (dB)			Efficiency	
			Max	Typical	Range +/-	Avg	Range +/-
617	698	2.5	-0.2	0.9	0.7	33%	3%
698	802	1.9	1.1	-0.3	1.4	34%	6%
824	960	2.0	2.1	0.6	1.6	36%	4%
1710	2200	1.6	4.4	2.6	1.9	31%	3%
2300	2690	1.4	4.8	2.7	2.1	29%	2%
3400	3800	1.4	4.7	2.5	2.2	26%	1%
5150	5950	1.3	5.8	1.9	3.9	16%	3%

Table 4: LTE Secondary (Diversity) (2 and 4)

F1 (MHz)	F2 (MHz)	VSWR	Gain (dB)			Efficiency	
			Max	Typical	Range +/-	Avg	Range +/-
617	698	3.4	-1.4	-3.0	1.6	16%	8%
733	802	2.0	0.0	-1.0	0.9	31%	4%
824	960	2.7	0.0	-1.6	1.5	28%	8%
1805	2200	1.6	1.7	0.9	0.8	29%	4%
2300	2690	2.0	1.5	-0.5	2.0	20%	6%
3400	3800	1.9	2.2	0.4	1.8	20%	3%
5150	5950	1.4	2.6	1.3	1.4	16%	1%

Table 5: Wi-Fi

F1 (MHz)	F2 (MHz)	VSWR	Gain (dB)			Efficiency	
			Max	Typical	Range +/-	Avg	Range +/-
2400	2500	1.3	9.1	7.2	1.9	74%	74%
4900	5900	1.5	11.4	9.1	2.3	59%	14%

The following notes apply to the tables provided:

Note Gain and efficiency measured with no cable and no ground plane.

Note VSWR measured with 17-ft cables and no ground plane.

Note For all items listed in the above tables, the following applies:

- Polarization is Linear
- Nominal Impedance is 50 ohms
- Maximum Power is 25 watts

The following table provides GNSS Specifications:

Table 6: GNSS Specifications

Specification	Measurement
Frequency Band	1565-1608 MHz
Amplifier Gain	@ 3.0 VDC: 26 dB (typical)
Output VSWR	2.0:1 (maximum)
DC Current	25 mA (typical)
DC Voltage	2.8-6.0 V (operating) ≤ 12.0 V (survivability)
Noise Figure	< 2.0 dB (typical)
Out-of-Band Rejection	f0 = 1586 MHz f0 ± 50 MHz: ≥ 60 dBc f0 ± 60 MHz: ≥ 70 dBc
Nominal Gain	3 dBic @ 90° -2 dBic @ 20°
Polarization	Right hand circular
Nominal Impedance	50 ohms

Environmental and Operational Specifications

Table 7: Environmental and Operational Specifications for the Antenna

Specification	Description
Operating temperature range	-40°C to +85°C
Vibration, Shock, Thermal, Corrosion, Seismic	Outdoor IP67. Tested to a variety of appropriate industrial, vehicular, transportation, and mil-spec standards.

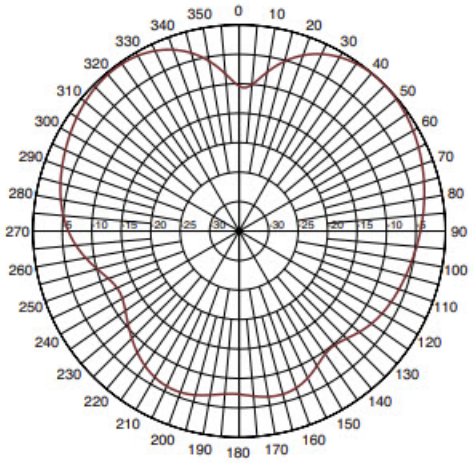
Antenna Radiation Patterns

The following sections illustrate the radiation patterns for the antenna.

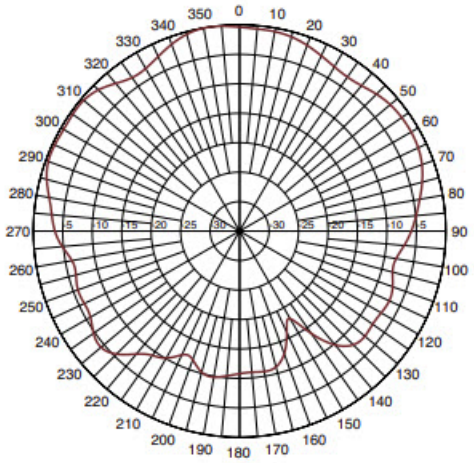
Primary LTE/5G Antenna Radiation Patterns (LTE1)

Refer to the following graphics.

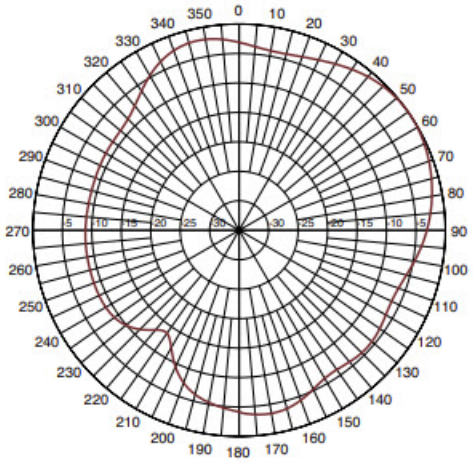
Elevation Pattern at 750 MHz



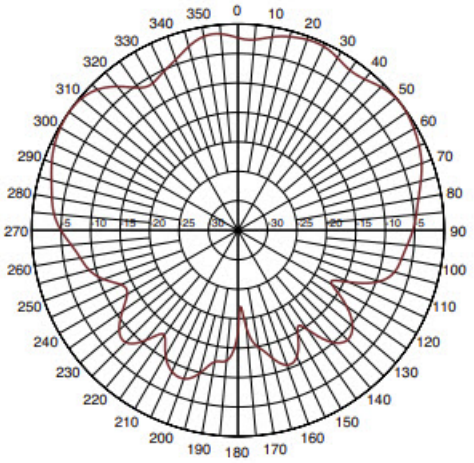
Elevation Pattern at 960 MHz



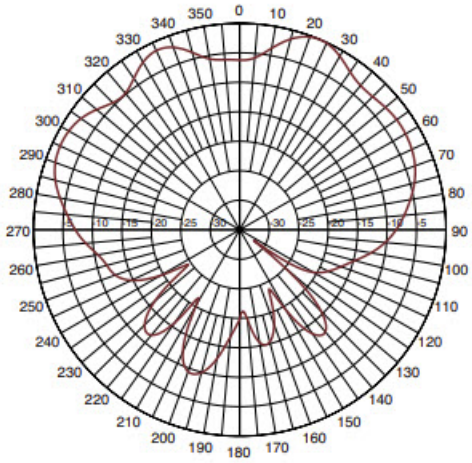
Elevation Pattern at 850 MHz



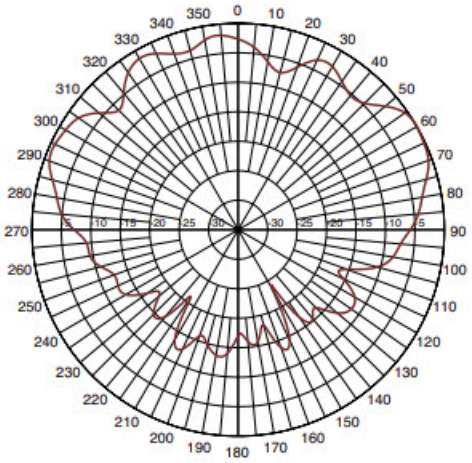
Elevation Pattern at 1.75 GHz



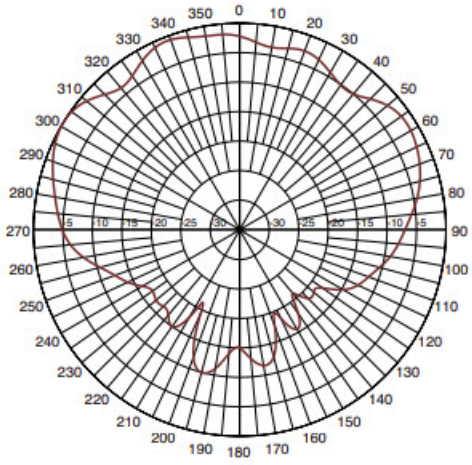
Elevation Pattern at 1.9 GHz



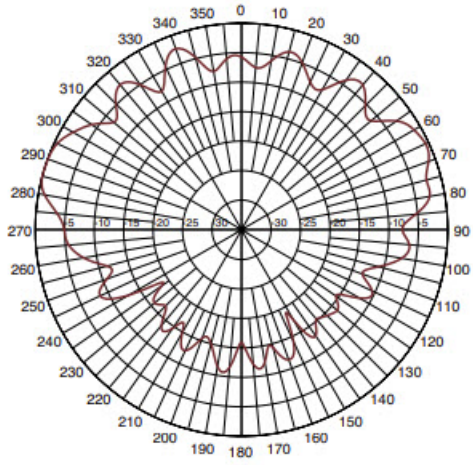
Elevation Pattern at 2.6 GHz



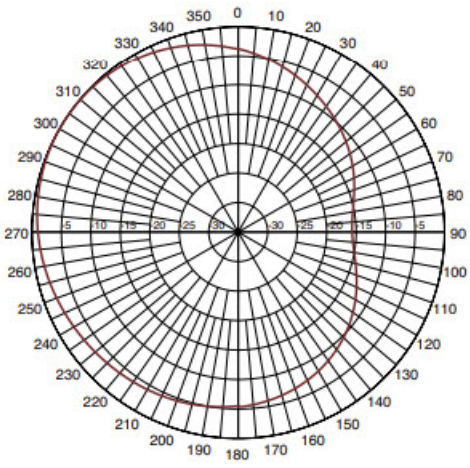
Elevation Pattern at 2.2 GHz



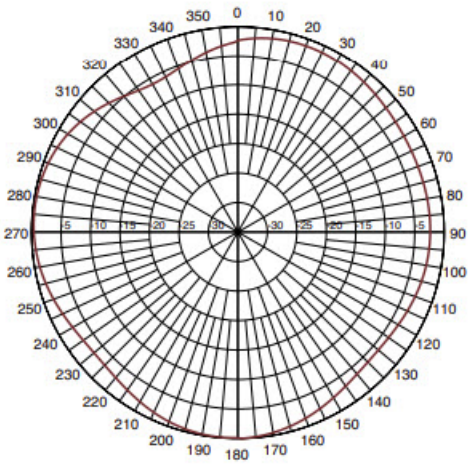
Elevation Pattern at 3.6 GHz



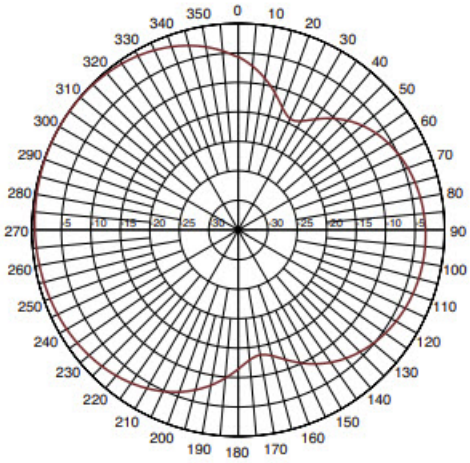
Azimuth Pattern at 750 MHz



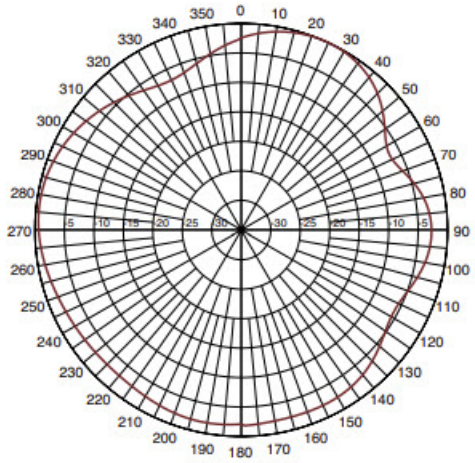
Azimuth Pattern at 960 MHz



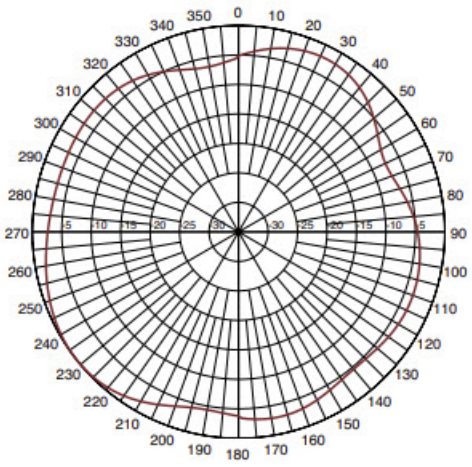
Azimuth Pattern at 850 MHz



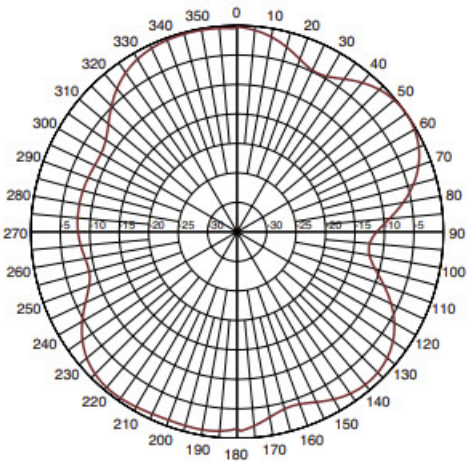
Azimuth Pattern at 1.75 GHz



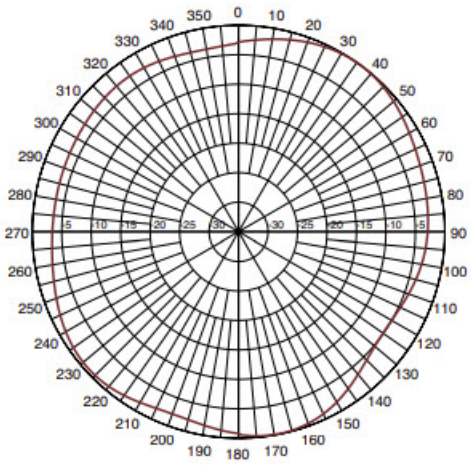
Azimuth Pattern at 1.9 GHz



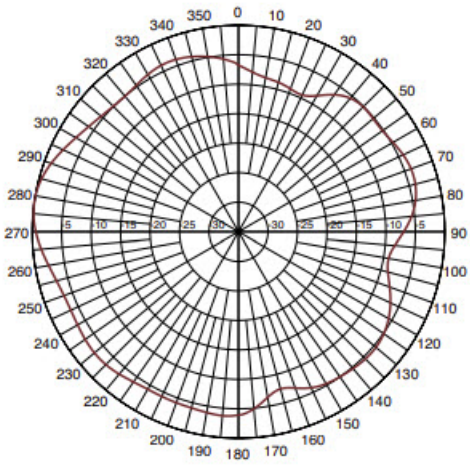
Azimuth Pattern at 2.6 GHz



Azimuth Pattern at 2.2 GHz



Azimuth Pattern at 3.6 GHz

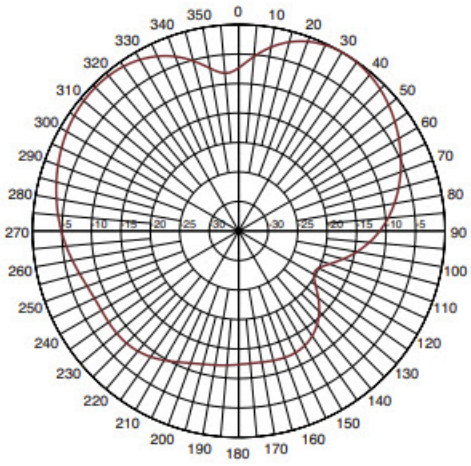


Secondary (Diversity) LTE/5G Antenna Radiation Patterns (LTE2)

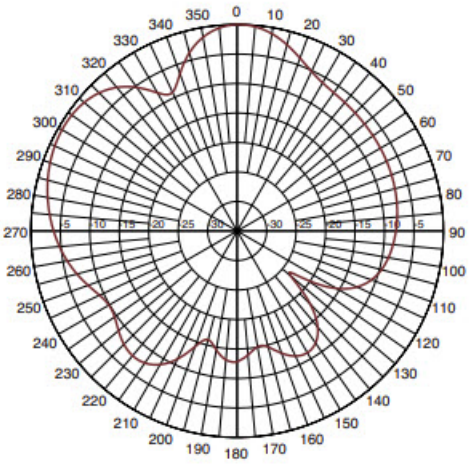
Note LTE2 is referred to as "Secondary" or Diversity". Both terms are correct.

Refer to the following graphics.

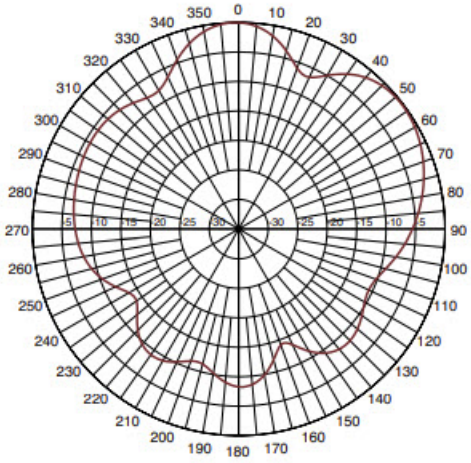
Elevation Pattern at 750 MHz



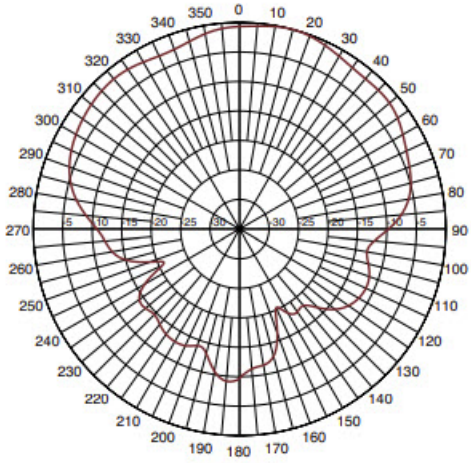
Elevation Pattern at 960 MHz



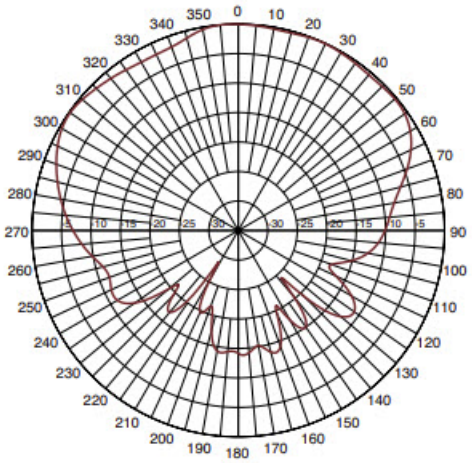
Elevation Pattern at 850 MHz



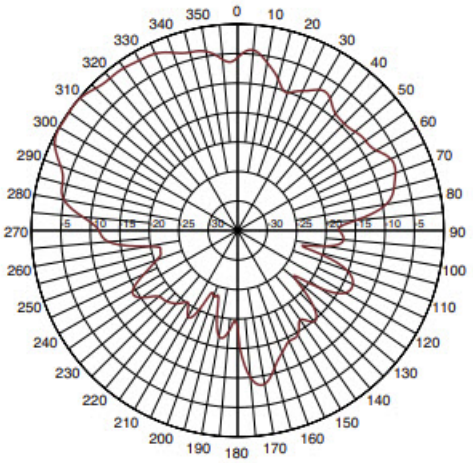
Elevation Pattern at 1.9 GHz



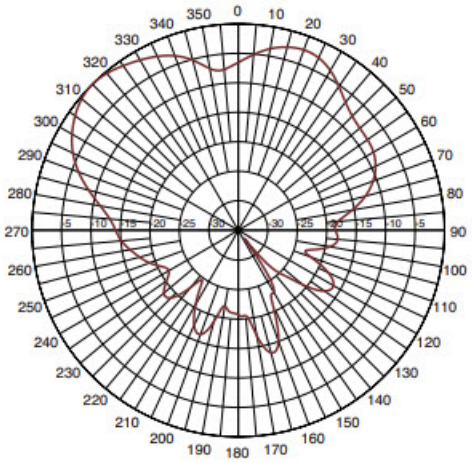
Elevation Pattern at 2.2 GHz



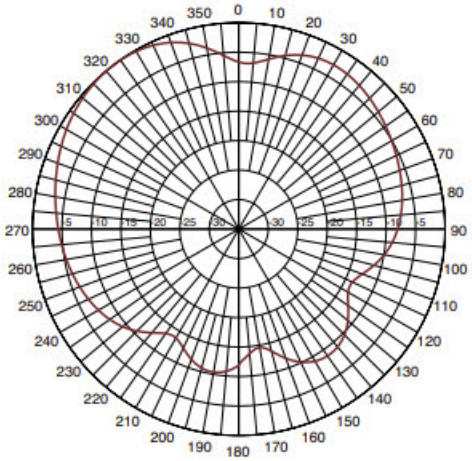
Elevation Pattern at 3.6 GHz



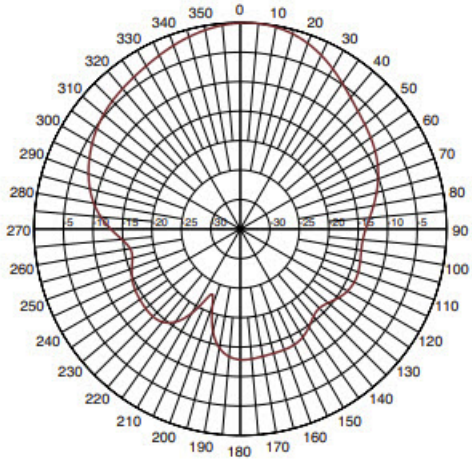
Elevation Pattern at 2.6 GHz



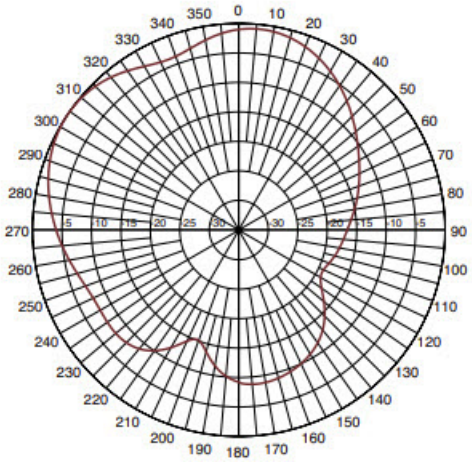
Phi-90 Azimuth Pattern at 750 MHz



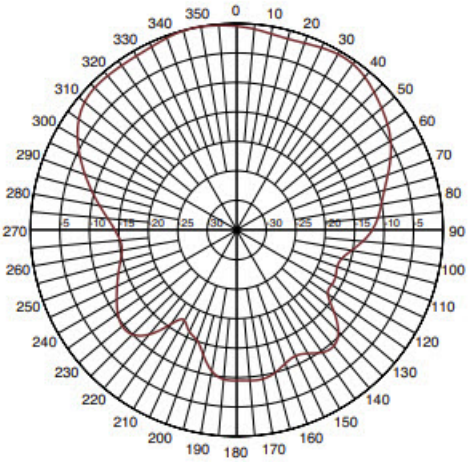
Phi-90 Azimuth Pattern at 960 MHz



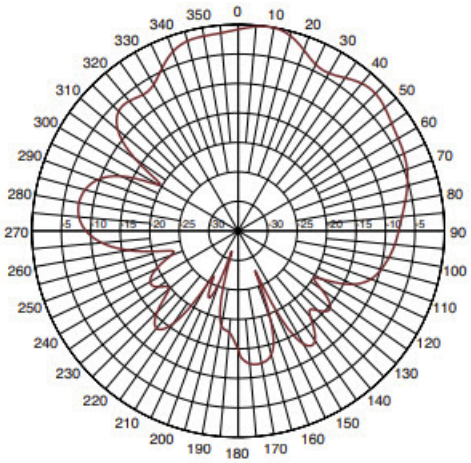
Phi-90 Azimuth Pattern at 850 MHz



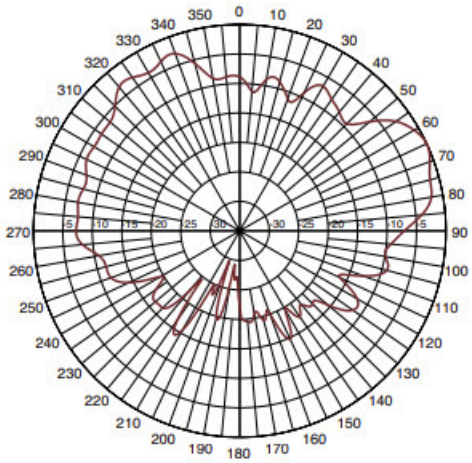
Phi-90 Azimuth Pattern at 1.9 GHz



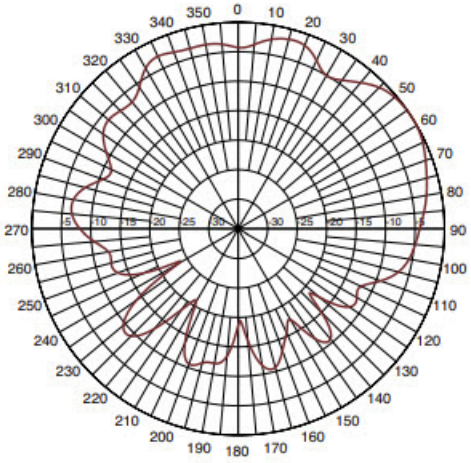
Phi-90 Azimuth Pattern at 2.2 GHz



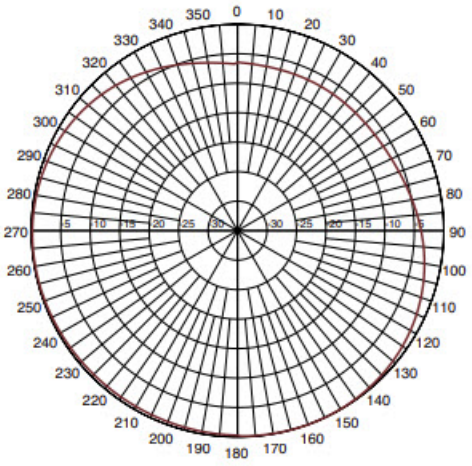
Phi-90 Azimuth Pattern at 3.6 GHz



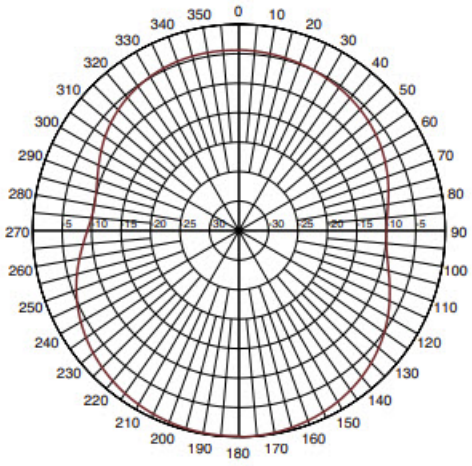
Phi-90 Azimuth Pattern at 2.6 GHz



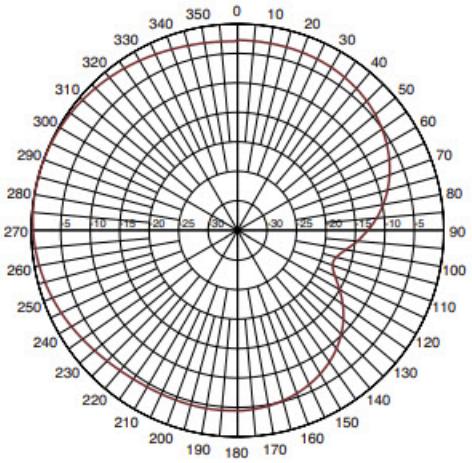
THETA-90 Azimuth Pattern at 750 MHz



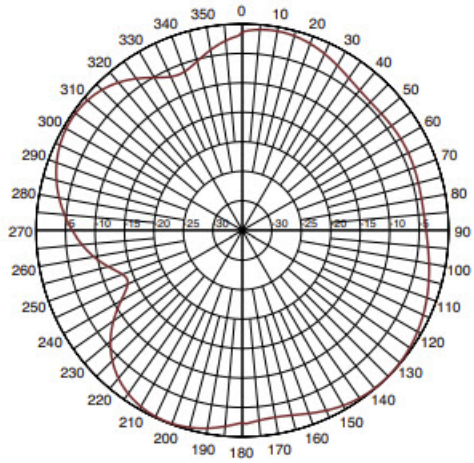
THETA-90 Azimuth Pattern at 960 MHz



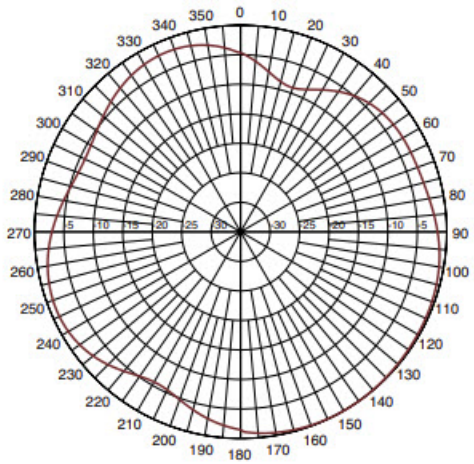
THETA-90 Azimuth Pattern at 850 MHz



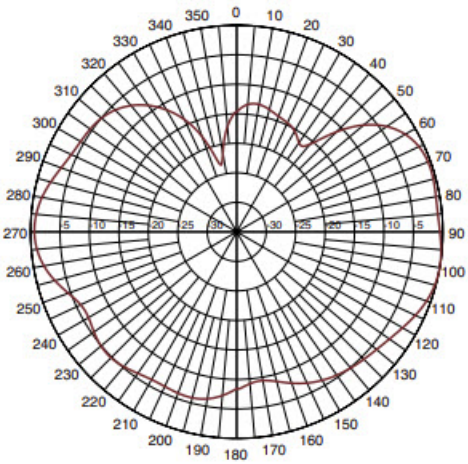
THETA-90 Azimuth Pattern at 1.9 GHz



THETA-90 Azimuth Pattern at 2.2 GHz



THETA-90 Azimuth Pattern at 3.6 GHz



General Safety Precautions

Warning This warning symbol means danger. You are in a situation that could cause bodily injury. Before you work on any equipment, be aware of the hazards involved with electrical circuitry and be familiar with standard practices for preventing accidents. Use the statement number provided at the end of each warning to locate its translation in the translated safety warnings that accompanied this device. **Statement 1071**

Warning Do not work on the system or connect or disconnect cables during periods of lightning activity. **Statement 1001**

Warning Do not locate the outdoor antenna near overhead power lines or other electric light or power circuits, or where it can come into contact with such circuits. When installing the antenna, take extreme care not to come into contact with such circuits, as they may cause serious injury or death. For proper installation and grounding of the antenna, please refer to national and local codes (for example, U.S.:NFPA 70, National Electrical Code, Article 810, Canada:Canadian Electrical Code, Section 54). **Statement 1052**

Warning In order to comply with FCC radio frequency (RF) exposure limits, antennas should be located at a minimum of 7.9 inches (20 cm) or more from the body of all persons. **Statement 332**

Each year hundreds of people are killed or injured when attempting to install an antenna. In many of these cases, the victim was aware of the danger of electrocution, but did not take adequate steps to avoid the hazard.

Warning For your safety, and to help you achieve a good installation, please read and follow these safety precautions. **They may save your life!**

For your safety, read and follow these safety precautions.

- If you are installing an antenna for the first time, for your own safety as well as others, seek professional assistance. Your Cisco sales representative can explain which mounting method to use for the size and type antenna you are about to install.
- Before you install an antenna, contact your Cisco account representative to explain which mounting method to use for the size and type of antenna that you are about to install.
- Find someone to help you—installing an antenna is often a two-person job.
- Select your installation site with safety, as well as performance, in mind. Remember that electric power lines and phone lines look alike. For your safety, assume that any overhead line can kill you.
- Contact your electric power company. Tell them your plans and ask them to come look at your proposed installation.
- Plan your installation carefully and completely before you begin. Each person involved in an installation should be assigned to a specific task, and should know what to do and when to do it. One person should be in charge of the operation to issue instructions and watch for signs of trouble.
- When installing your antenna, follow these guidelines:
  - Do not use a metal ladder.
  - Do not work on a wet or windy day.
  - Do dress properly—wear shoes with rubber soles and heels, rubber gloves, and a long-sleeved shirt or jacket.
- If the assembly starts to drop, move away from it and let it fall. Because the antenna, mast, cable, and metal guy wires are all excellent conductors of electrical current, even the slightest touch of any of these parts to a power line completes an electrical path through the antenna and the installer.
- If any part of the antenna system should come in contact with a power line, do not touch it or try to remove it yourself. Call your local power company to have it removed safely.
- If an accident should occur with the power lines, call for qualified emergency help immediately.

Installing the Antenna

The antenna can be installed in the following deployments:

Deployment Type	Description	Antenna Accessories Required
Transportation	The antenna is installed on a vehicle such as automobile, train, or other moving platform. The antenna is connected to a mobile router in the vehicle. **Note** This is the most common IoT installation scenario.	5G-ANTM-0-4-B antenna, accessories depend on the installation scenario.
Indoor ceiling mount	The antenna is installed on a grounded metal surface on a ceiling, and attached directly to a router.	5G-ANTM-GD
Indoor wall mount	The antenna is installed on a grounded metal bracket, on a drywall or wooden wall, and attached directly to a router.	5G-ANTM-BRACKET (mounting hardware included)
Outdoor wall mount	The antenna is installed outdoors on a metal bracket, on a brick or concrete wall, and attached directly to a router mounted indoors.	5G-ANTM-BRACKET (mounting hardware not included)

Contents of the Antenna Kit

The antenna kit contains:

- 1 x Cisco 5G-ANTM-0-4-B antenna
- SMA Plug (4x LTE/5G, GNSS)
- Reverse Polarity SMA Plug (4x Wifi)

Optional items that are not included, but may be needed for installation:

- Ground Disc (5G-ANTM-GD): Required for ceiling mount only
- L-shape mounting bracket and accessories (5G-ANTM-BRACKET): Required for indoor/outdoor wall-mount

Tools and Equipment Required

In addition to the parts included in the antenna kit described in the previous section, you must provide the following tool to install the antenna on the router:

- Open-ended wrench
- Electric drill

Note This list does not include the tools and equipment required to assemble and erect the tower, mast, or other structure you intend to mount your antenna on.

Mounting on a Ceiling

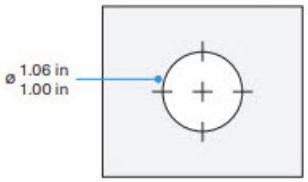
When choosing a location to mount the antenna, keep the following in mind:

- Attempt to center the antenna on a flat plane.
- Attempt to position the antenna so that it has 8 inches of flat plane in any given direction.
- Attempt to space at least 16 inches from an adjacent antenna or metallic structure and choose a location with gentle surface curves to ensure proper sealing.
- Ensure there is a space that is 2 inches deep and 2 inches in diameter below the mounting surface to allow sufficient clearance for the mounting stud, hardware, and cables.
- Ensure that the diameter of the hole is 1.00-1.06 inch.

Step 1 Select a mounting location with gentle surface curves to ensure a proper seal with 203.2 mm (8 inches) of ground plane in any given direction around the antenna. Position the antenna at least 406.4 mm (16 inches) from any adjacent antennas or metallic structures. Allow for 50.8 mm (2 inches) of clearance below the mounting surface for the mounting stud and cable routing. Ensure that there is 50.8 mm (2 inches) in diameter around the mounting hole for the mounting nut and tightening procedure.

Step 2 Drill a hole through the mounting surface where the center of the antenna is located, as shown in the following figure.

Figure 5: Mounting Hole Dimentions

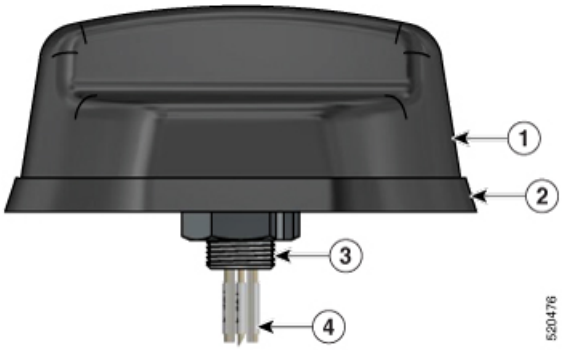


Step 3 Ensure that the hole is free of any burrs and sharp edges to prevent cable damage and VHB adhesive contamination during installation.

Step 4 Clean the mounting surface around the hole. The surface must be free of any debris that would otherwise prevent the inner VHB foam gasket from adhering, or the outer rubber gasket from forming a seal.

Step 5 Feed the cables and stud through the mounting surface hole and ground disc. Take care not to damage the jacket, and route them to the desired location. The following figure shows the cables and stud.

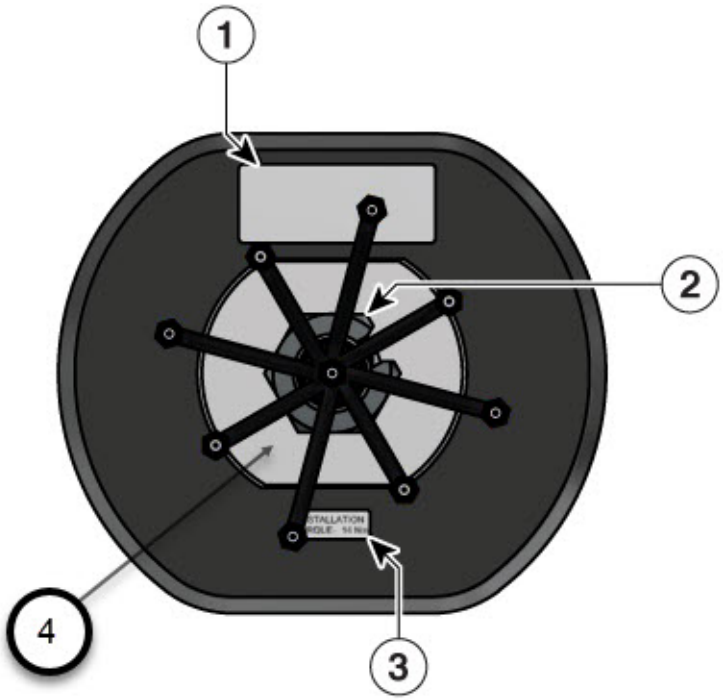
Figure 6: Side View



1	4 LTE/5G, 4 Wi-Fi, and GPS antennas inside black radome
2	VHB Compressed Foam Gasket
3	Mounting stud
4	Cables

Step 6 Remove the liner from the inner VHB foam gasket, insert the mounting stud through the hole, and position the antenna onto the mounting surface as shown in the following figure.

Figure 7: Bottom View

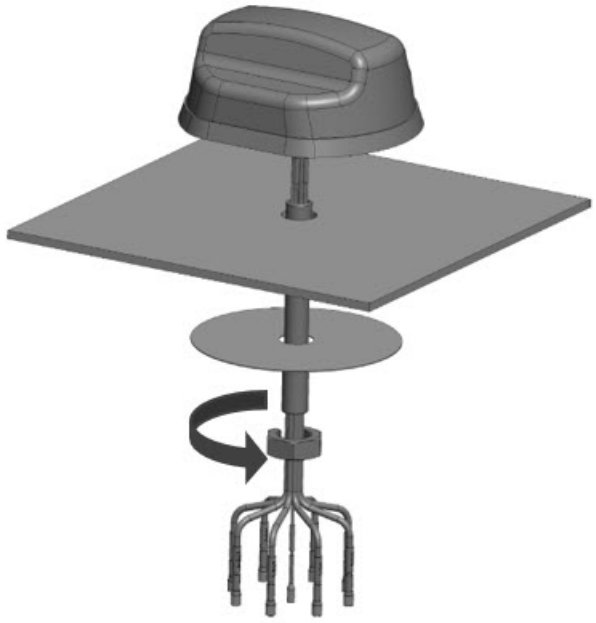


1	Product ID and Serialization Label

2	UNS Thread slotted lock-nut
3	Torque label
4	VHB Foam Gasket/Liner

Step 7 Beneath the mounting surface and ground disc, install the slotted lock nut onto the mounting stud. Hand tighten as shown in the following figure. Then tighten with a wrench until the antenna is fully seated, or with a torque wrench, tighten the nut to 14Nm (10.5 lbf*ft) minimum.

Figure 8: Hand Tighten



Step 8 Visually inspect the outer rubber gasket to ensure it has made a proper seal against the mounting surface and radome. If the locking nut includes a set screw locking feature, torque down the locking nut as directed above, then torque the set screw to 3.5 Nm (2.2 lbft).

Step 9 The completed antenna installation is shown in the following figure.

Figure 9: Completed Installation

What to do next

Connect the antenna to the device according to specific installation instructions for each product.

Mounting on an Indoor Wall

When choosing a location to mount the antenna, keep the following in mind:

- Attempt to center the antenna on a flat plane.
- Attempt to position the antenna so that it has 8 inches of flat plane in any given direction.
- Attempt to space at least 16 inches from an adjacent antenna or metallic structure and choose a location with gentle surface curves to ensure proper sealing.

Step 1 Drill holes and secure L-shape mounting bracket appropriate for your mounting surface and environment.

For indoor drywall mounting, the following items are required:

- Plastic wall plugs (4x)
- 30mm long pan-head ST3.5 screws (4x)
- 12mm OD/1mm thick washers (4x)

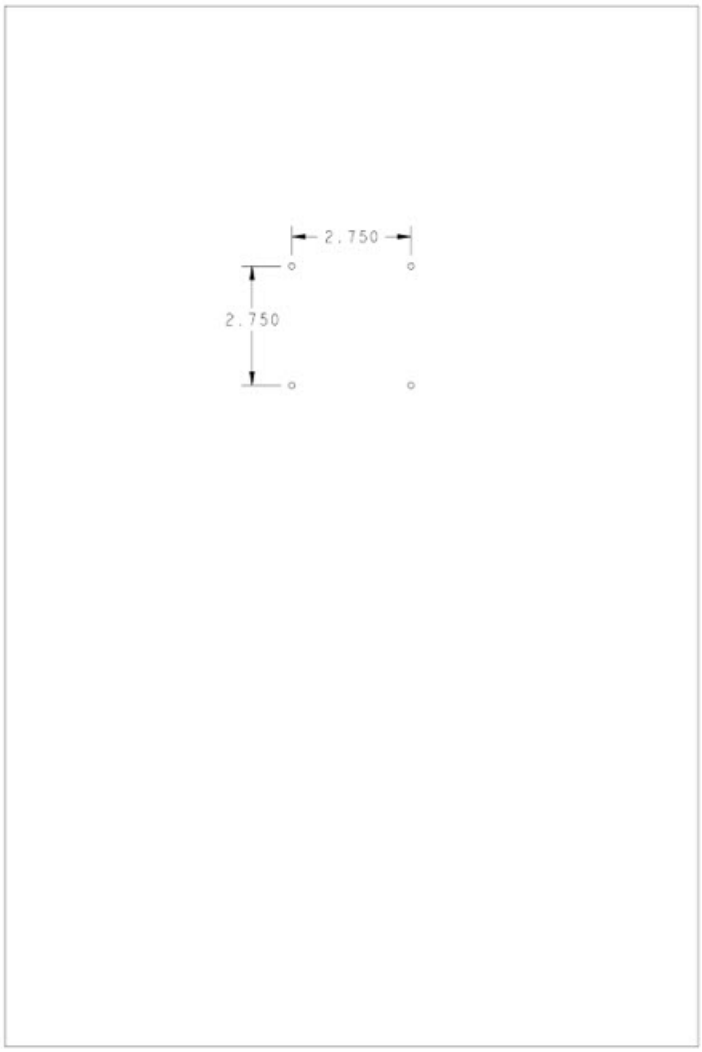
For indoor wood surface or stud mounting, the following items are required:

- 30mm long pan-head ST3.5 screws (4x)

- 12mm OD/1mm thick washers (4x)

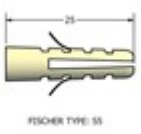
Step 2 Drill the four 5mm diameter holes at 2.75in spacing, at a minimum depth of 35mm.

Figure 10: Mounting Hole Template



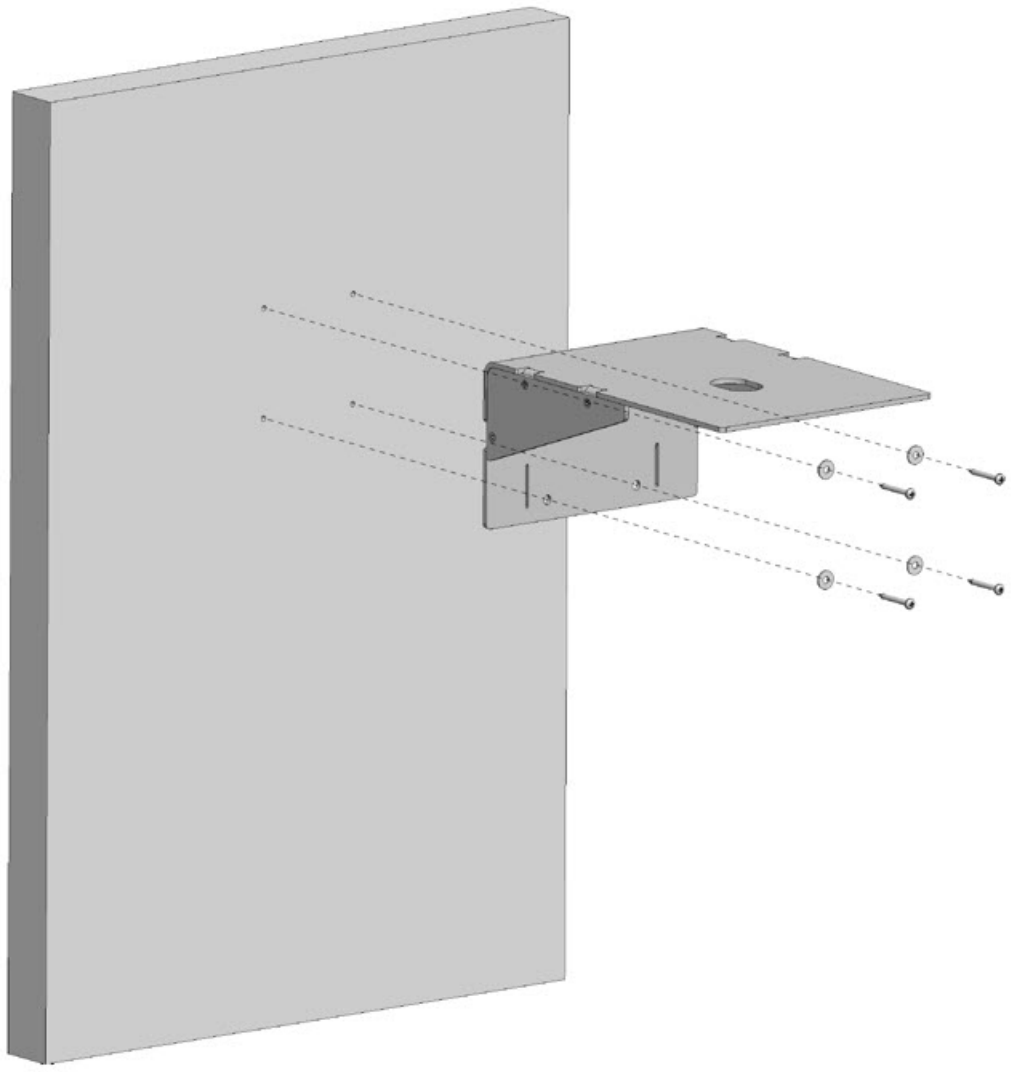
Step 3 Insert the plastic wall plugs into the holes until flushed with wall surface. The following figure shows an example of a plastic wall plug.

Figure 11: Plastic Wall Plug



Step 4 Align the four holes on the L-shape mounting bracket with the four holes on the wall.

Figure 12: Attach Brackets



Step 5 Secure and tighten with provided screws and washers.

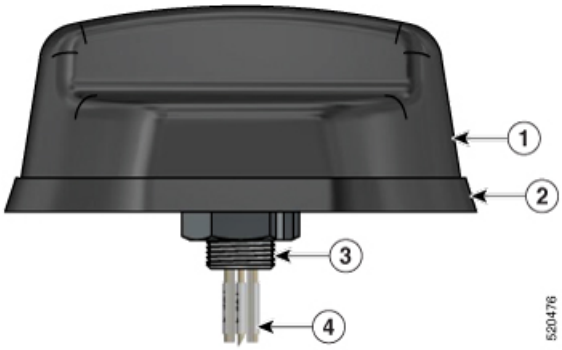
Step 6 For indoor wood surface or stud mounting, use steps 2, 4, and 5.

Step 7 Ensure that the hole is free of any burrs and sharp edges to prevent cable damage and VHB adhesive contamination during installation.

Step 8 Clean the mounting surface around the hole. The surface must be free of any debris that would otherwise prevent the inner VHB foam gasket from adhering, or the outer rubber gasket from forming a seal.

Step 9 Feed the cables and stud through the mounting surface hole and ground disc taking care not to damage the jacket, and route them to desired location as shown in the following figure.

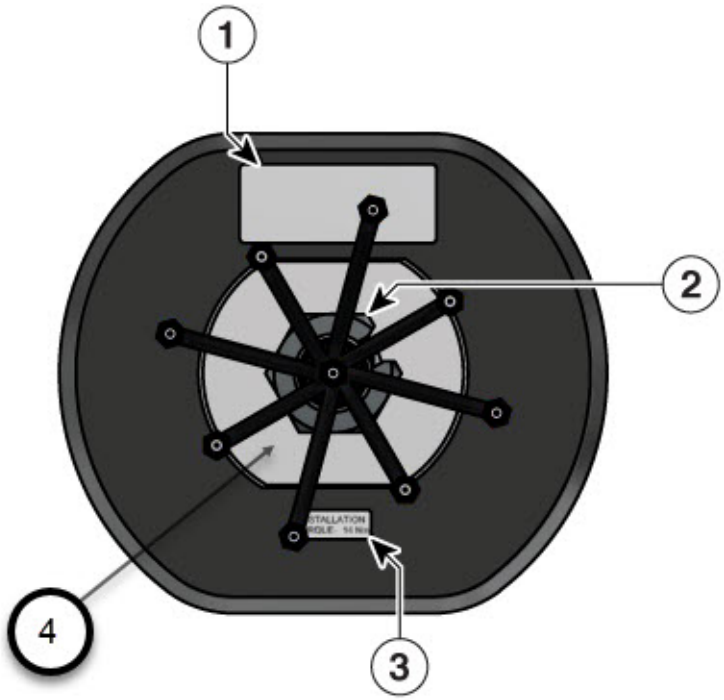
Figure 13: Side View



1	4 LTE/5G, 4 Wi-Fi, and GPS antennas inside black radome
2	VHB Compressed Foam Gasket
3	Mounting stud
4	Cables

Step 10 Remove the liner from the inner VHB foam gasket, insert the mounting stud through the hole, and position the antenna onto the mounting surface as shown in the following figure.

Figure 14: Bottom View

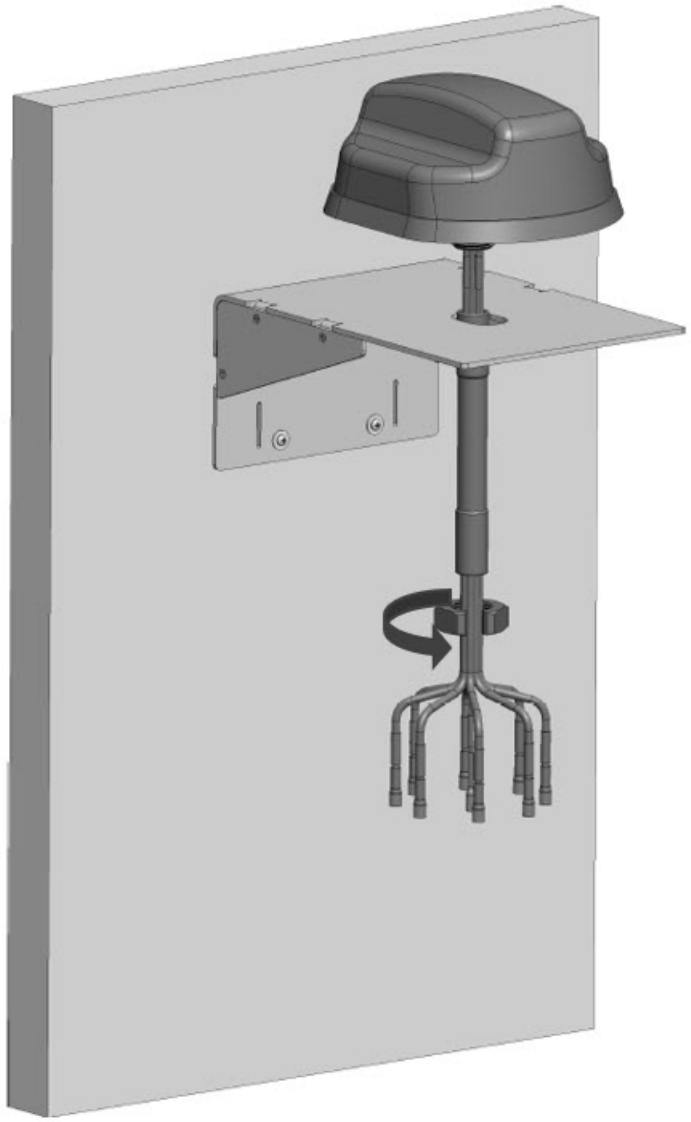


1	Product ID and Serialization Label

2	UNS Thread slotted lock-nut
3	Torque label
4	VHB Foam Gasket/Liner

Step 11 Beneath the mounting surface and ground disc, install the slotted lock nut onto the mounting stud and hand tighten as shown in the following figure. Then wrench tighten until antenna is fully seated, or with a torque wrench, tighten the nut to 14Nm (10.5 lbf*ft) minimum.

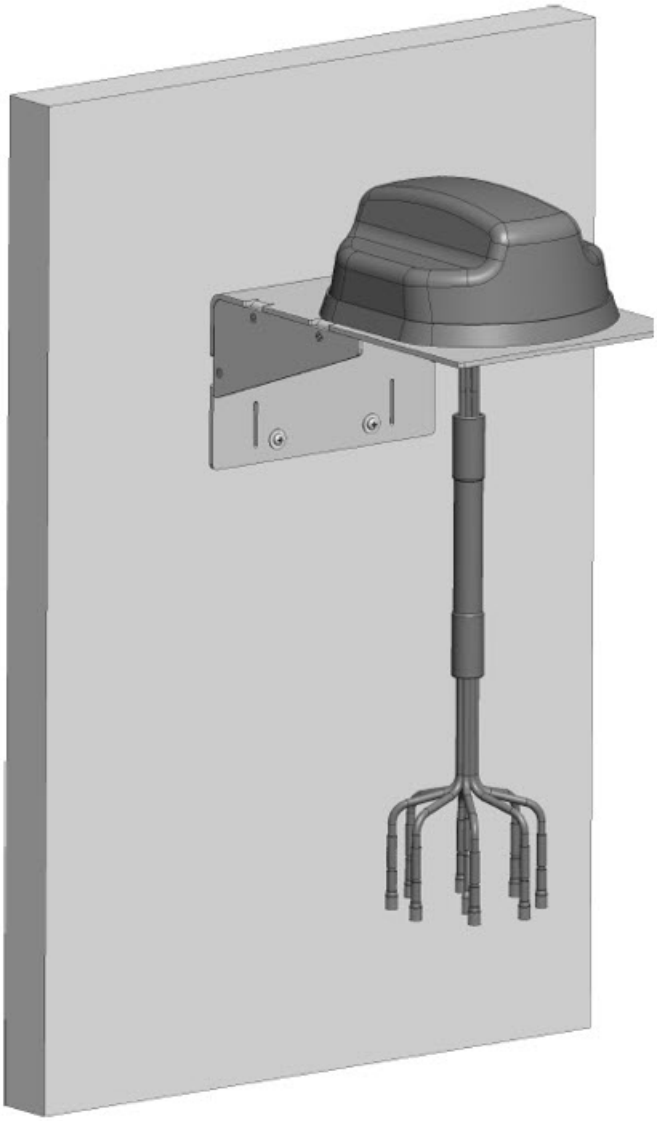
Figure 15: Hand Tighten



Step 12 Visually inspect the outer rubber gasket. Ensure it has made a proper seal against the mounting surface and radome. If the locking nut includes a set screw locking feature, torque down the locking nut as directed above, then torque the set screw to 3.5 Nm (2.2 lbft).

Step 13 The completed antenna installation is shown in the following figure.

Figure 16: Completed Installation



Mounting on an Outdoor Wall

When choosing a location to mount the antenna, keep the following in mind:

- Attempt to center the antenna on a flat plane.

- Attempt to position the antenna so that it has 8 inches of flat plane in any given direction.
- Attempt to space at least 16 inches from an adjacent antenna or metallic structure and choose a location with gentle surface curves to ensure proper sealing.

Step 1 Drill holes and secure L-shape mounting bracket appropriate for your mounting surface and environment.

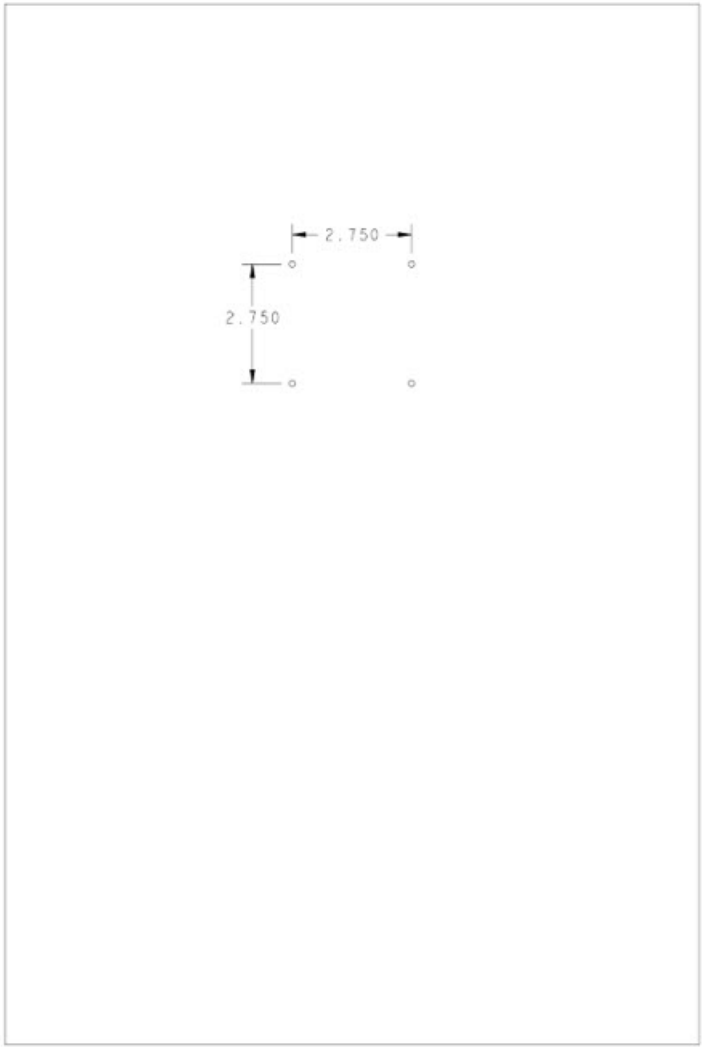
For outdoor brick or cement mounting, the following items are required:

- 3/16in hex washer head concrete screws, 1 1/4in in length or longer. (not provided)

One example of the concrete screws can be found here.

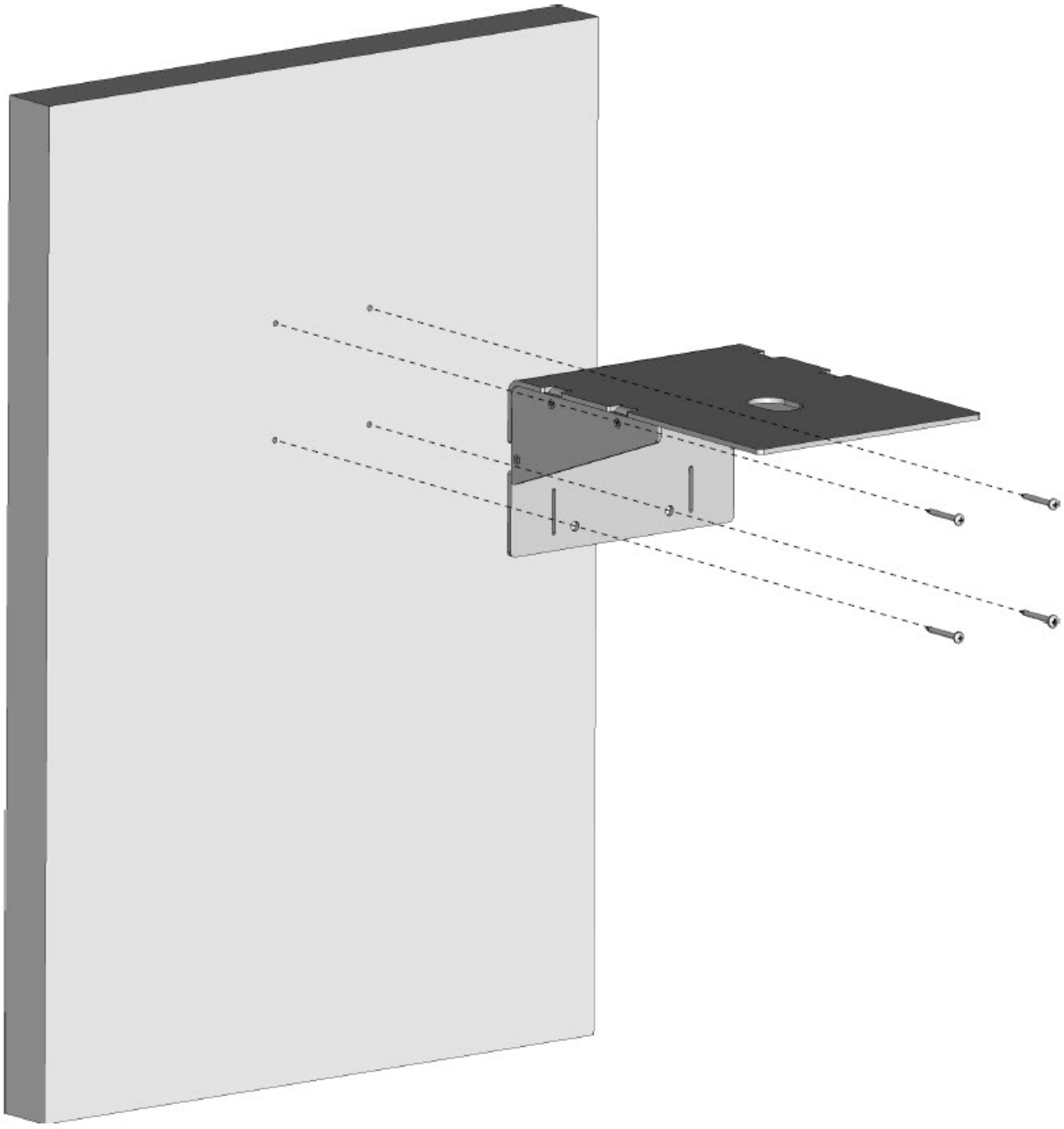
Step 2 Drill the four 5mm diameter holes at 2.75in spacing on the mounting surface according to manufacturer's specification.

Figure 17: Mounting Hole Template



Step 3 Align the four holes on the L-shape mounting bracket with the four holes on the wall.

Figure 18: Attach Brackets



Step 4 Using the four concrete screws, secure and tighten with a 3/16in hex head driver.

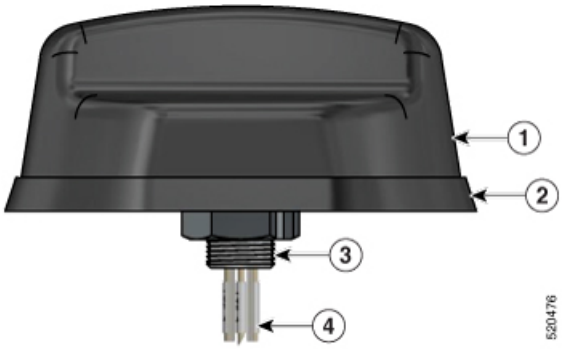
Note An access hole through the wall must be created to connect the outdoor antenna to an indoor router

Step 5 Ensure that the hole is free of any burrs and sharp edges to prevent cable damage and VHB adhesive contamination during installation.

Step 6 Clean the mounting surface around the hole. The surface must be free of any debris that would otherwise prevent the inner VHB foam gasket from adhering, or the outer rubber gasket from forming a seal.

Step 7 Feed the cables and stud through the mounting surface hole and ground disc taking care not to damage the jacket, and route them to desired location as shown in the following figure.

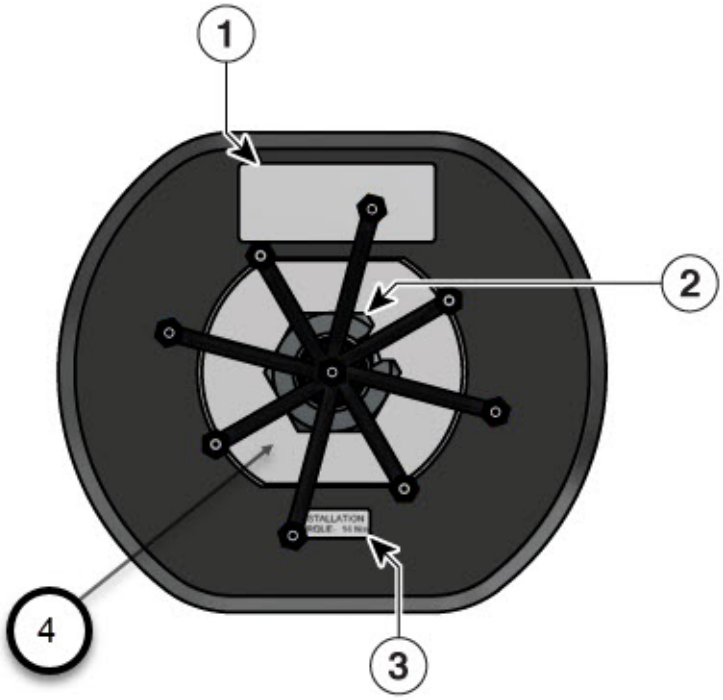
Figure 19: Side View



1	4 LTE/5G, 4 Wi-Fi, and GPS antennas inside black radome
2	VHB Compressed Foam Gasket
3	Mounting stud
4	Cables

Step 8 Remove the liner from the inner VHB foam gasket, insert the mounting stud through the hole, and position the antenna onto the mounting surface as shown in the following figure.

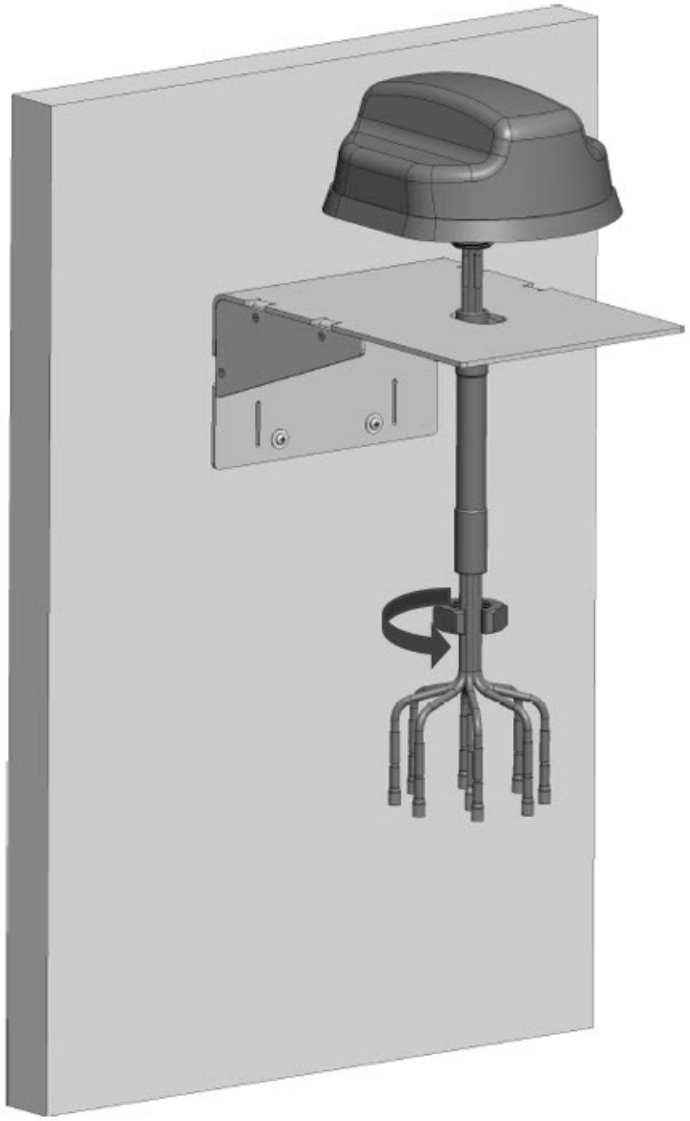
Figure 20: Bottom View



1	Product ID and Serialization Label
2	UNS Thread slotted lock-nut
3	Torque label
4	VHB Foam Gasket/Liner

Step 9 Beneath the mounting surface and ground disc, install the slotted lock nut onto the mounting stud and hand tighten as shown in the following figure. Then wrench tighten until antenna is fully seated, or with a torque wrench, tighten the nut to 14Nm (10.5 lbf*ft) minimum.

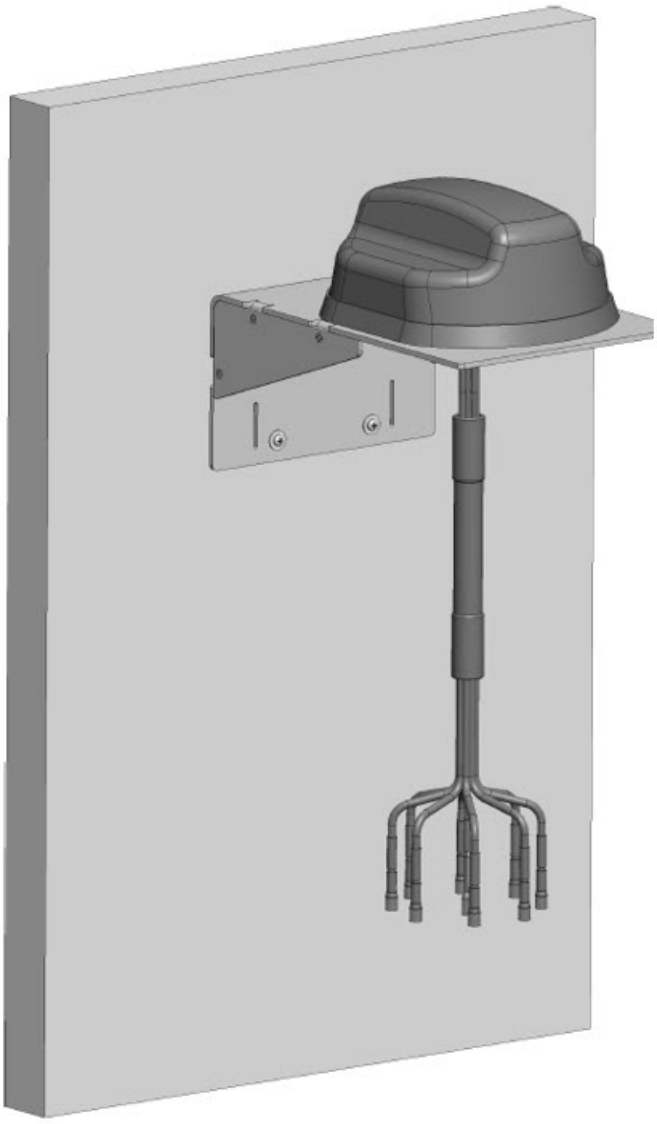
Figure 21: Hand Tighten



Step 10 Visually inspect the outer rubber gasket. Ensure it has made a proper seal against the mounting surface and radome. If the locking nut includes a set screw locking feature, torque down the locking nut as directed above, then torque the set screw to 3.5 Nm (2.2 lbft).

Step 11 The completed antenna installation is shown in the following figure.

Figure 22: Completed Installation



Connecting the Antenna to the Router

To attach the router-end of the cable to your router, please see your platforms Hardware Installation Guide.

Note Coaxial cable loses efficiency as the frequency increases, resulting in signal loss. The cable should be kept as short as possible because cable length also determines the amount of signal loss—the longer the cable length or run, the greater the loss).

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