Theory of Operation

The SaBLE-x Module is a radio module that implements a Bluetooth Low Energy (BLE) transceiver. A Texas Instruments CC2640 System-on-Chip (SoC) integrated circuit includes a 2.4 GHz BLE RF transceiver and ARM Cortex microcontroller. All of the radio functions use an on-module 24 MHz Crystal Oscillator as the station frequency reference. An on module 32 kHz crystal oscillator is used for low-power operation.

The data source/sink and command interface for the transceiver is via the integrated ARM Cortex microcontroller.

The transmitter is based on a direct PLL modulation for the FSK-based modulations (BLE 4.1 signalling. The receiver uses a near-zero IF architecture. Both the transmit and receive local oscillators are generated at two-times the carrier frequency and divided by two. A bandpass filter is included on the path between the CC2640 RF signal and the antenna terminal.

The radio transceiver power supplies are provided by internal voltage regulators.

2.4 GHz – 2.5 GHz FlexNotch 2 dBi Antenna w/U.FL Cable

ORDERING INFORMATION

Order Number	Description
001-0015	2.4 GHz FlexNotch Antenna w/U.FL cable

Table 1 Orderable Part Numbers

KEY FEATURES

- Can be installed on flat or curved surfaces.
- Simple custom options with trimming length.
- Quick and easy Installation
- Flexible, ultra-low profile
- RoHS Compliant
- Adhesive holds to surface during humidity exposure and hot/cold cycles

SPECIFICATIONS

Specification	Value
Typical Gain	+2 dBi
Efficiency	>-1.5 dB
Impedance	50 ohms
Type	Flexible Notch
Polarization	Linear
VSWR	< 2.5:1, 2400 - 2480 MHz
Frequency	2400 – 2480 MHz
Weight	0.85g
Size	32.0mm × 21.08mm
Antenna Color	Clear Yellow
Adhesive	3M 100MP
Operating Temp	-40°C to +85°C

Table 2 Specifications

PHYSICAL DIMENSIONS (MM)

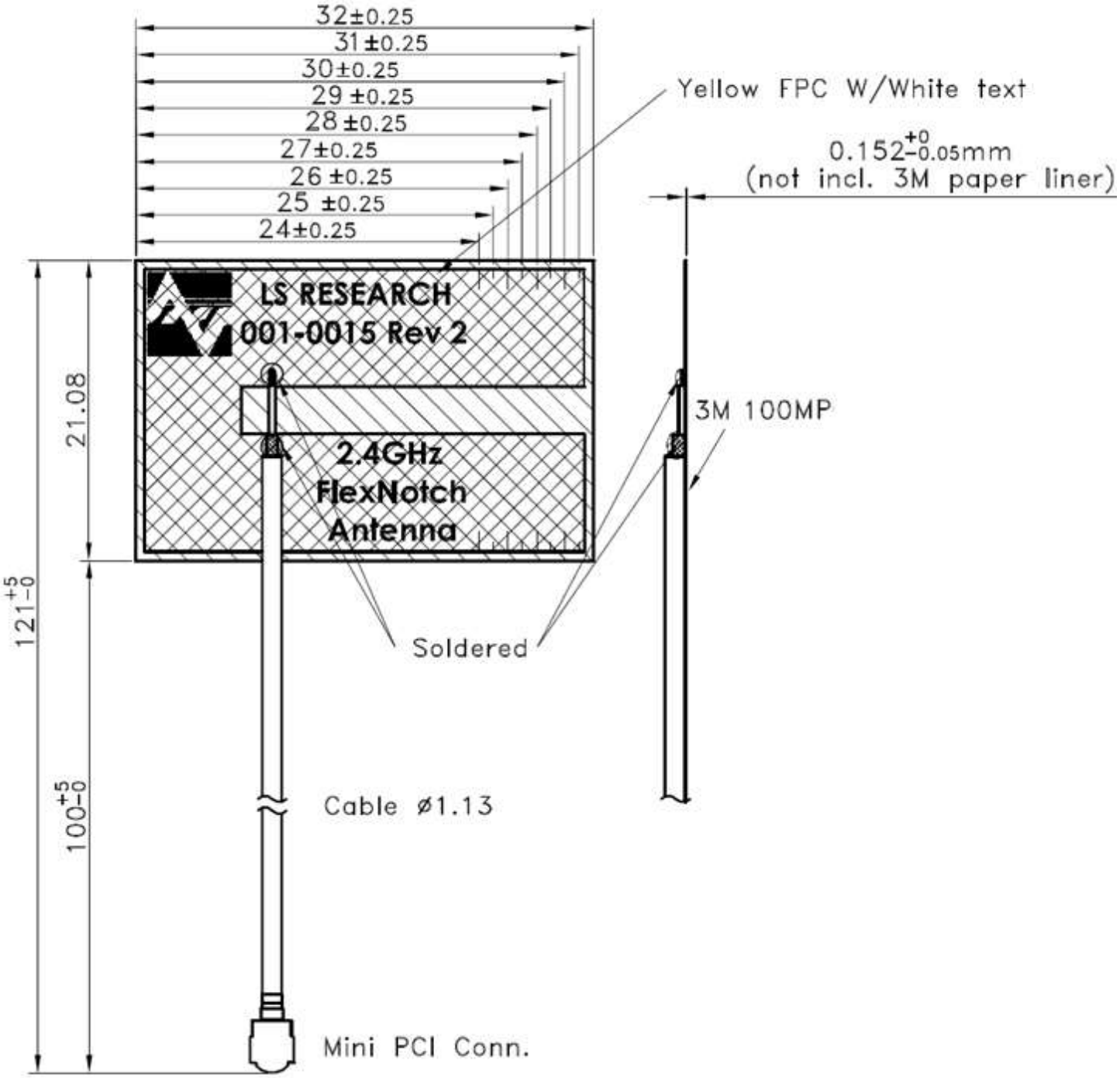


Figure 1 Physical Dimensions

TEST SETUP

Antenna measurements such as VSWR were measured with an Agilent E5071C Vector Network Analyzer. Radiation patterns were measured with an Agilent 5181A Signal Generator and Agilent E4445A Spectrum Analyzer in a 3 meter Anechoic Chamber.

Flat surface measurements were done with the antenna centered on a 1.5 mm thick plate of Polycarbonate.

FLAT SURFACE ANTENNA MEASUREMENTS

VSWR

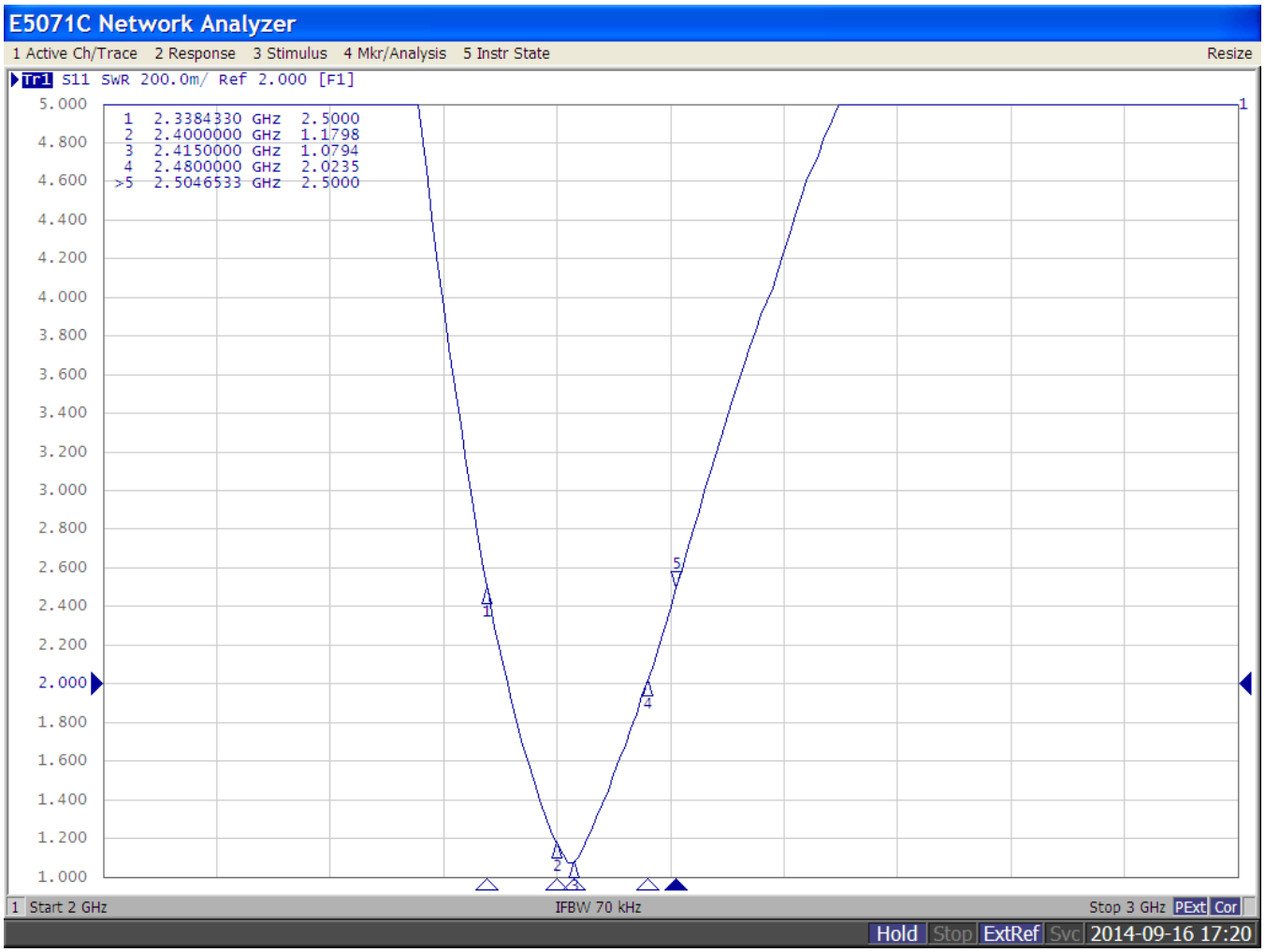


Figure 2 Antenna VSWR measured on a 1.5 mm thick plate of Polycarbonate

FLAT SURFACE ANTENNA RADIATION PERFORMANCE

FlexNotch centered on a 1.5 mm thick plate of Polycarbonate

Antenna Measurement Set-Up

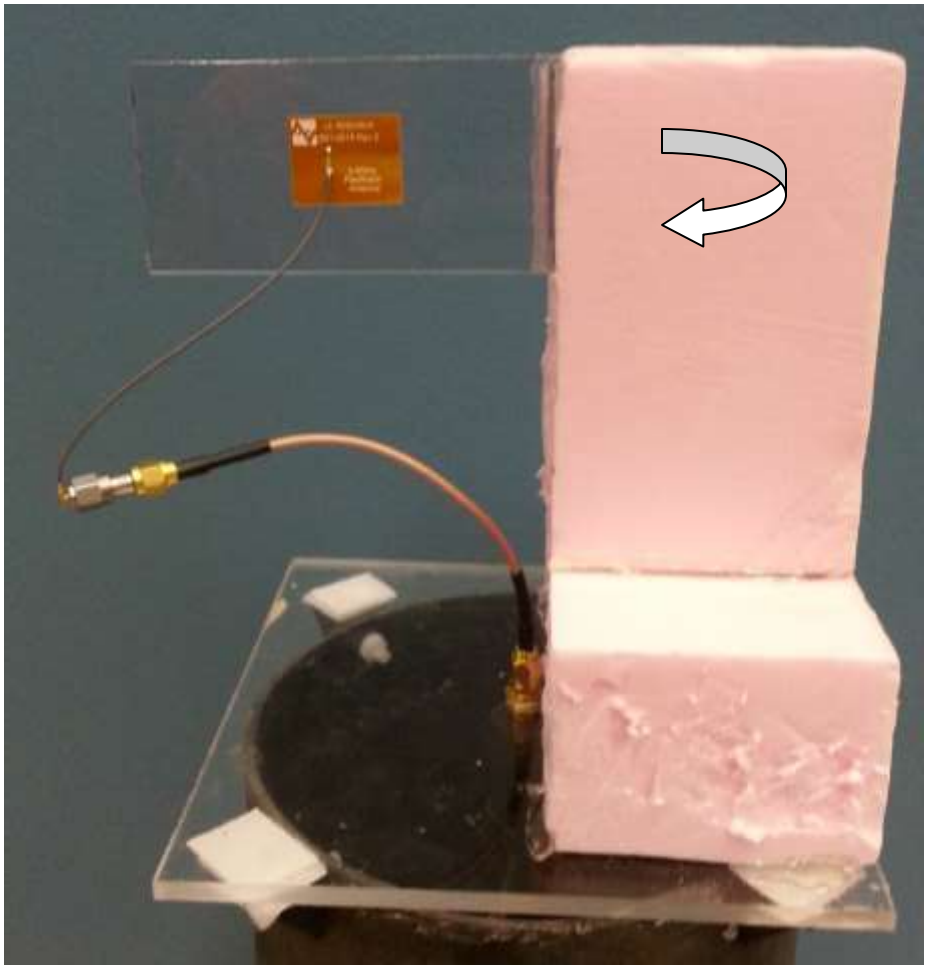


Figure 3 Horizontal Orientation Measurement

Horizontal Orientation at 2440 MHz:

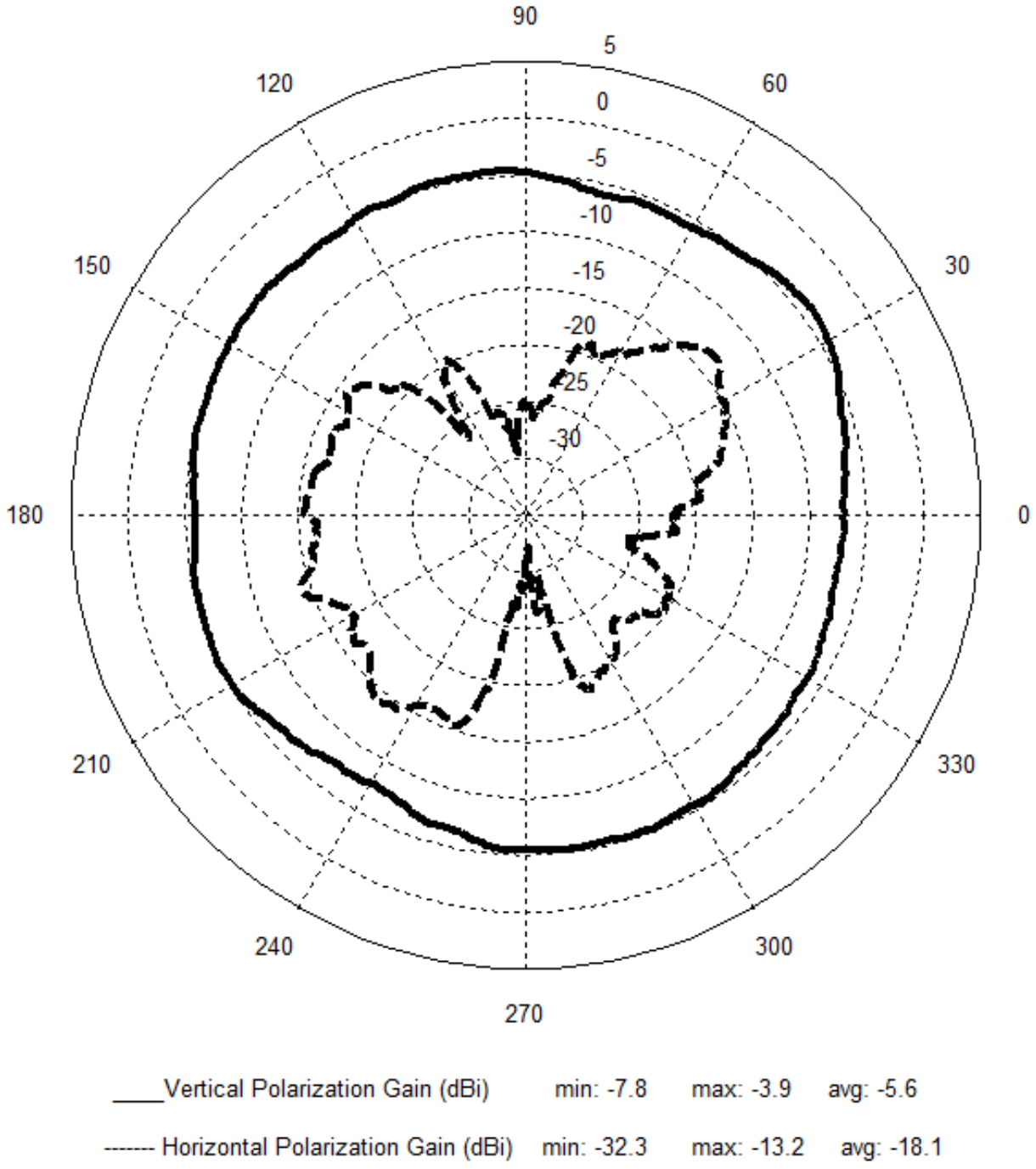


Figure 4 Horizontal Orientation Pattern

Antenna Measurement Set-Up

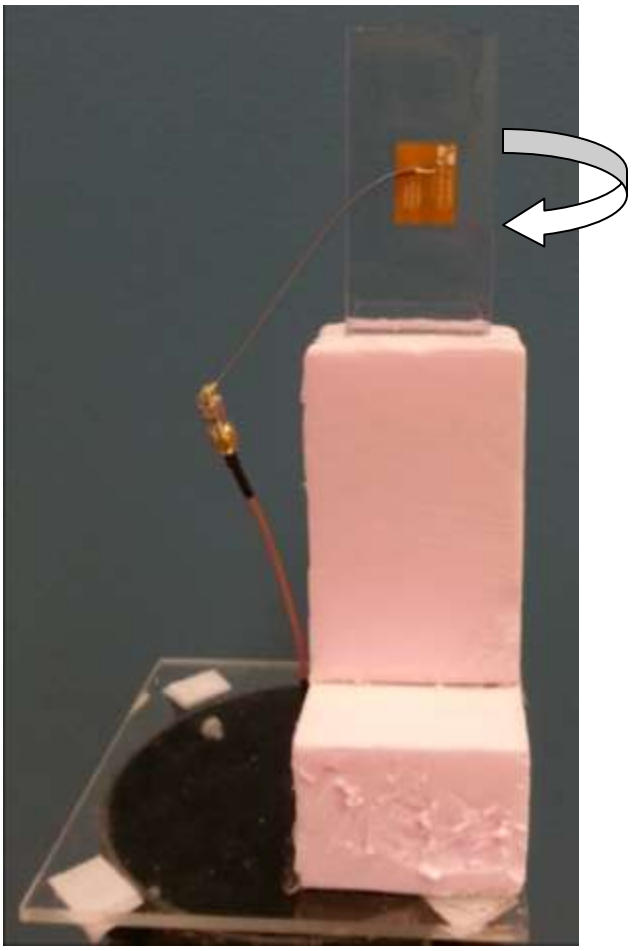


Figure 5 Vertical Orientation Measurement

Vertical Orientation at 2440 MHz:

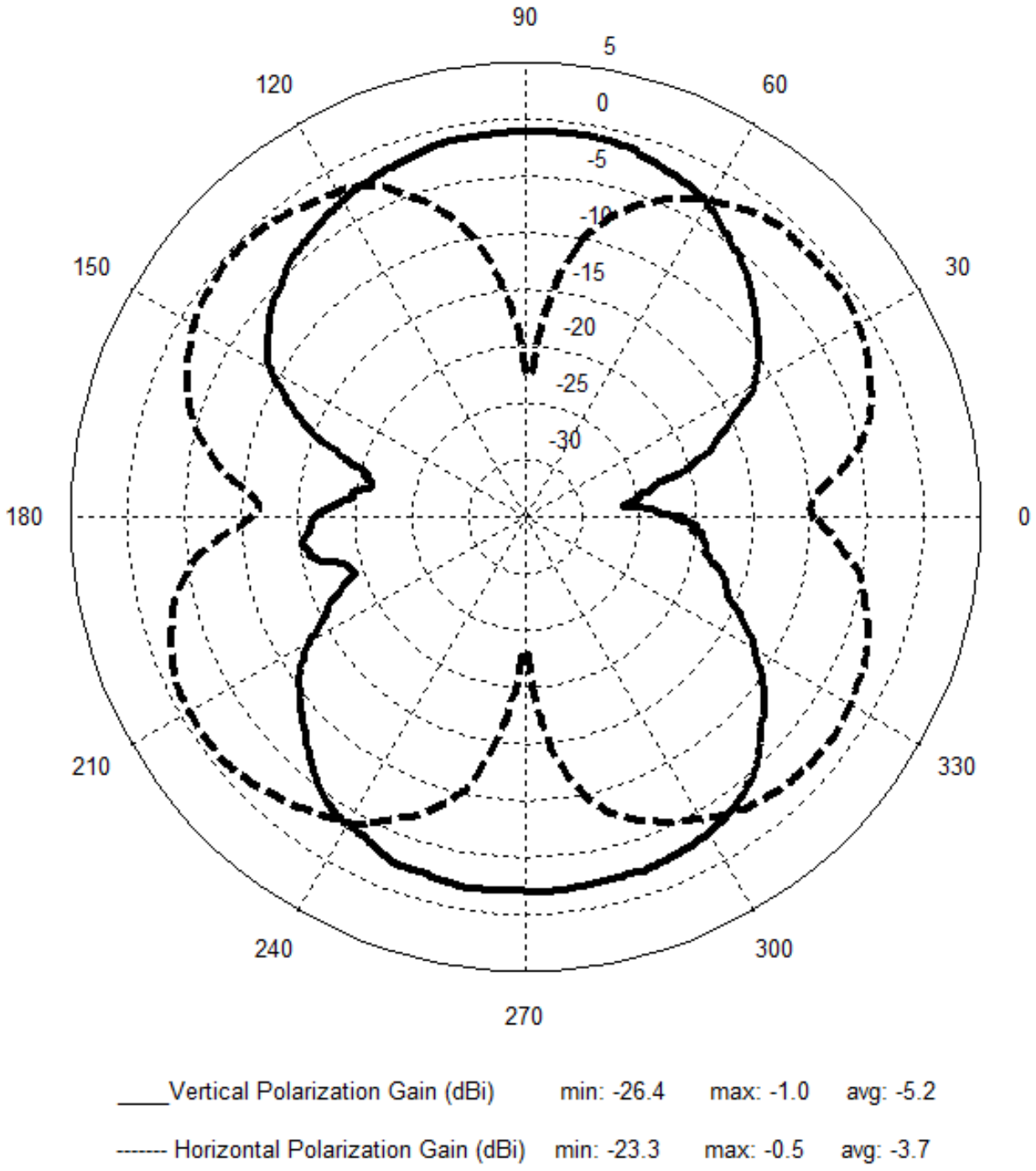


Figure 6 Vertical Orientation Pattern

Antenna Measurement Set-Up

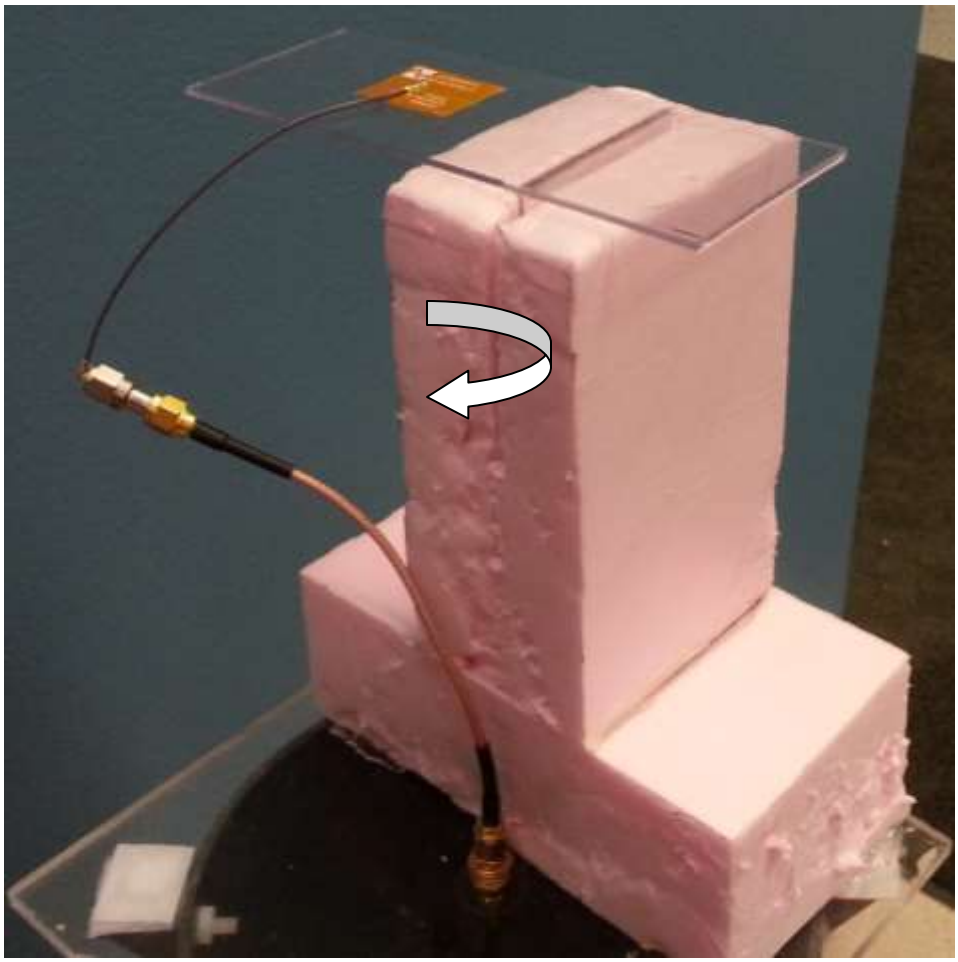


Figure 7 Flat Orientation Measurement

Flat Orientation at 2440 MHz:

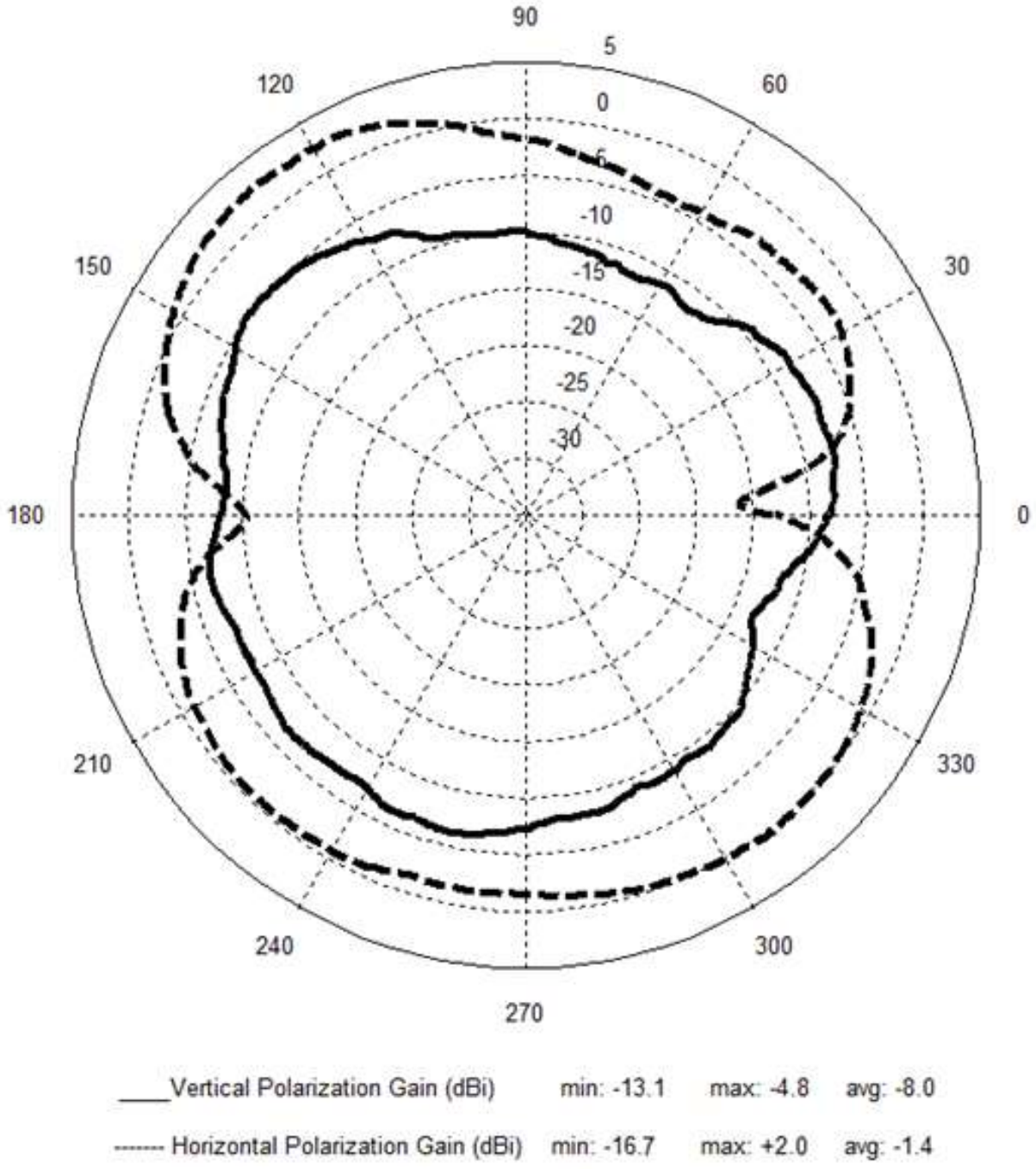


Figure 8 Flat Orientation Pattern

OPTIMAL INSTALLATION GUIDE

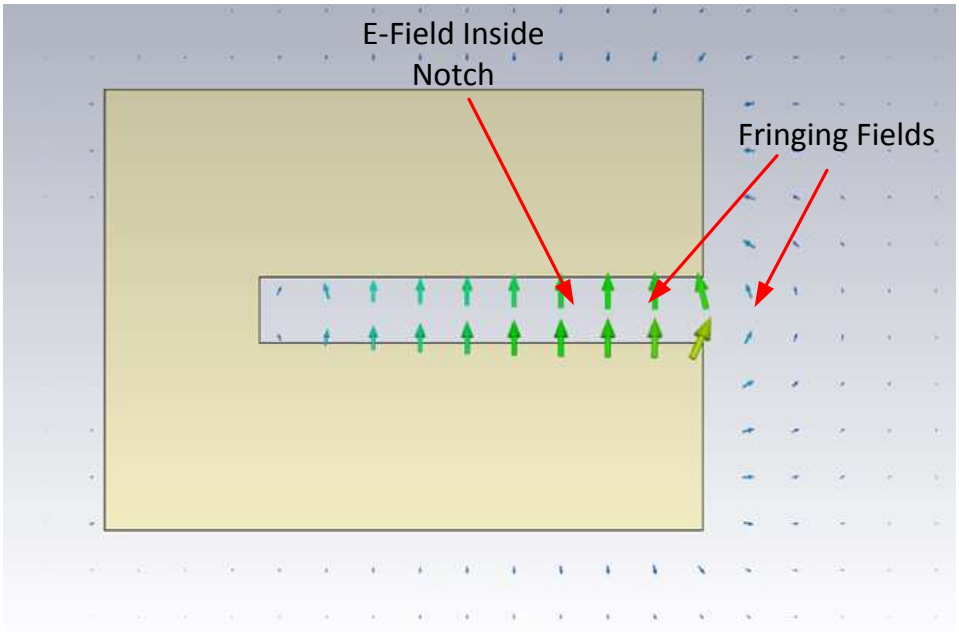


Figure 9 E-Field Radiation from FlexNotch, Taken from CST Simulation

The FlexNotch should be kept clear of any non-metal objects (such as plastics) on top of it by at least 5 mm (see Figure 10). Similarly, all four sides of the FlexNotch should be kept clear of any non-metal object by at least 1 mm (See Figure 11 and Figure 12). Mounting the FlexNotch in a situation that does not allow for these clearance recommendations may change the gain characteristics stated in the datasheet, which could impact overall range of the wireless system.

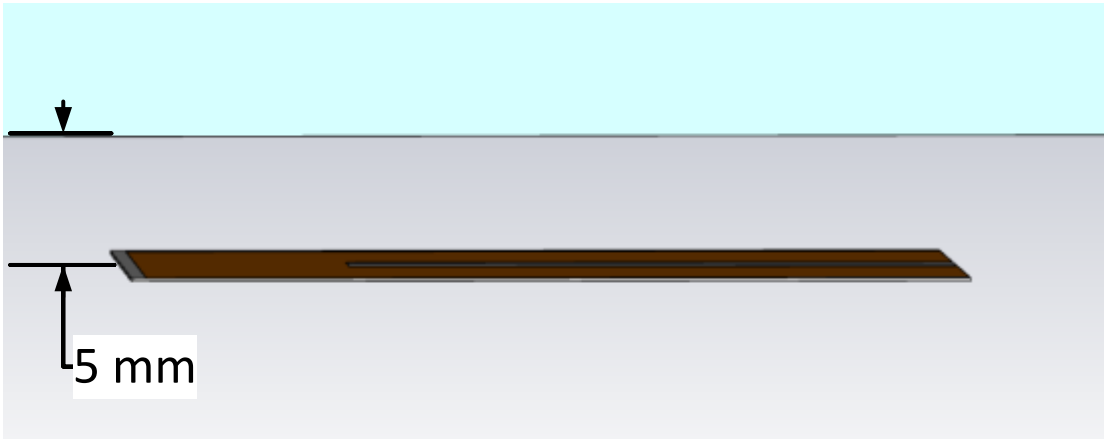
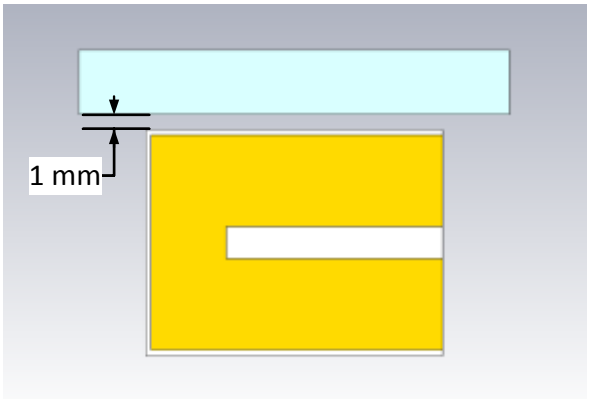
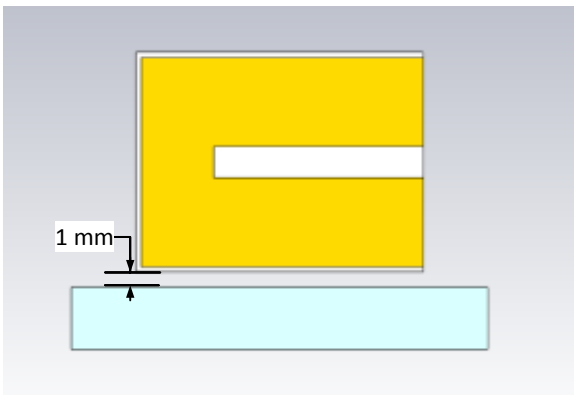


Figure 10 Above FlexNotch Clearance

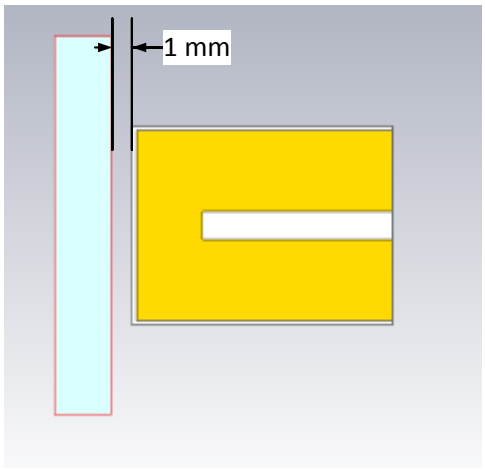


Top Clearance

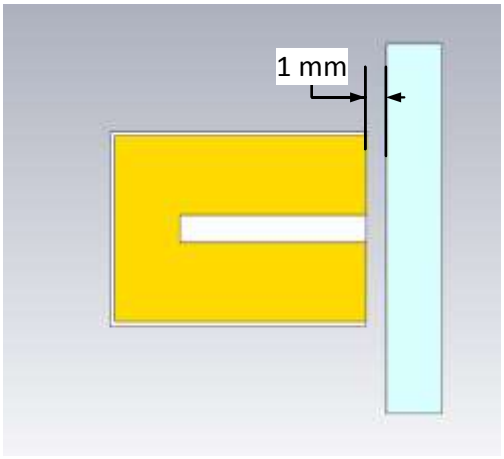


Bottom Clearance

Figure 11 Top and Bottom Clearance



Left 'Cold' Side Clearance

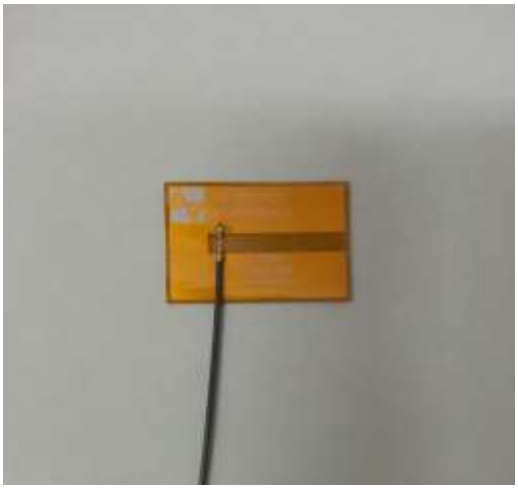


Open Side Clearance

Figure 12 Open Side Clearance

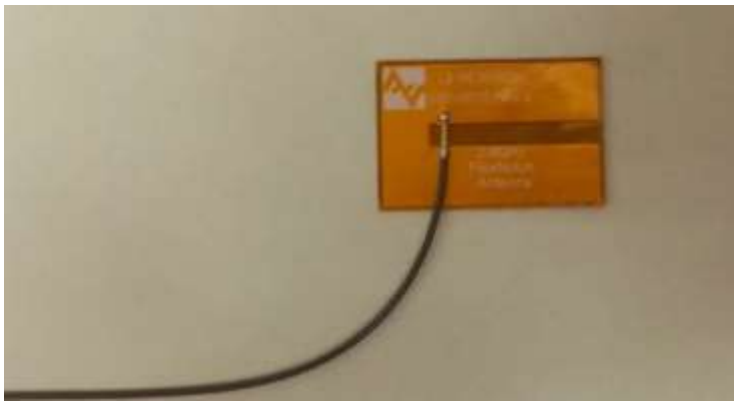
The ideal material for the FlexNotch to be mounted on is 1.5 mm thick polycarbonate; this will result in maximum performance. If the FlexNotch is mounted on a different material, the tuning will change. This can cause a decrease in performance. LSR can retune the FlexNotch for specific implementations and different materials on request.

The coaxial cable feeding the FlexNotch should be routed away from the antenna. Do not run the coaxial cable above the FlexNotch or near the open end of the notch. The cable should be routed perpendicular to the side of the FlexNotch (this is the way the cable comes assembled), around the cold side, or away from the ground wall. All three of these options are shown in Figure 13.



Perpendicular to the side

Around the ‘Cold’ Side



Away from the Notch wall

Figure 13 Recommended Cable Routing

As with any antenna, care should be taken not to place conductive materials or objects near the antenna. The radiated fields from the antenna will induce currents on the conductive surface; as a result those currents then produce their own radiation. These re-radiating fields from the metal will interfere with the fields radiating from the FlexNotch (this is true for any antenna). Other objects, such as an LCD display, placed in close proximity to the antenna may not affect its tuning but it can distort the radiation pattern. Materials that absorb electromagnetic fields should be kept away from the antenna to maximize performance. Common things to keep in mind when placing the antenna:

Wire Routing

Speakers – these generate magnetic fields

Metal Chassis and Frames

Battery Location

Proximity to Human Body

Display Screen – these will absorb radiation

Paint – do not use metallic coating or flakes

Flex Limits of the FlexNotch

One of the unique features of the FlexNotch is its ability to flex. However, due to the adhesive there are limits as to how much the antenna can be flexed and remain secured to the device. The FlexNotch should not be flexed in a convex position with a radius less than 16 mm. Going smaller than this may result in the antenna peeling off the surface over time. Should a tighter radius of curvature be required, it is recommended you contact LSR for assistance.

Figure 14 Convex Mounted

The FlexNotch should not be flexed in a concave position with a radius less than 16 mm. Similar to the restrictions on the convex position, potential exists for the adhesive to peel off over time if the FlexNotch is bent beyond a 16 mm radius. If a tighter radius of curvature is required, it is recommended you contact LSR for assistance. The FlexNotch is not designed to be twisted or crumpled. The adhesive back should lay flush with the surface it is mounted on.

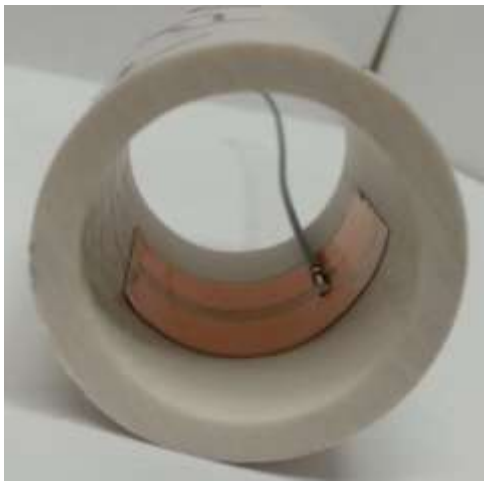


Figure 15 Concave Mounted

Mounting on Metal and Body Loaded Applications

The FlexNotch can tolerate being near conductive surfaces. A 1 mm clearance should be observed between the top, bottom, and cold sides of the FlexNotch from any metal (see Figure 11). Metal should be kept away from the open end of the FlexNotch by at least 10 mm. However, any metal in close proximity to the open end will disrupt the radiation pattern and could cause a decrease in antenna gain.

Keep any metal above the FlexNotch away by at least 10 mm; this will prevent the antenna from detuning. However this will still cause some distortion of the radiation pattern. **Do NOT mount the FlexNotch on a metal surface**.

These same guidelines also apply to body worn applications.

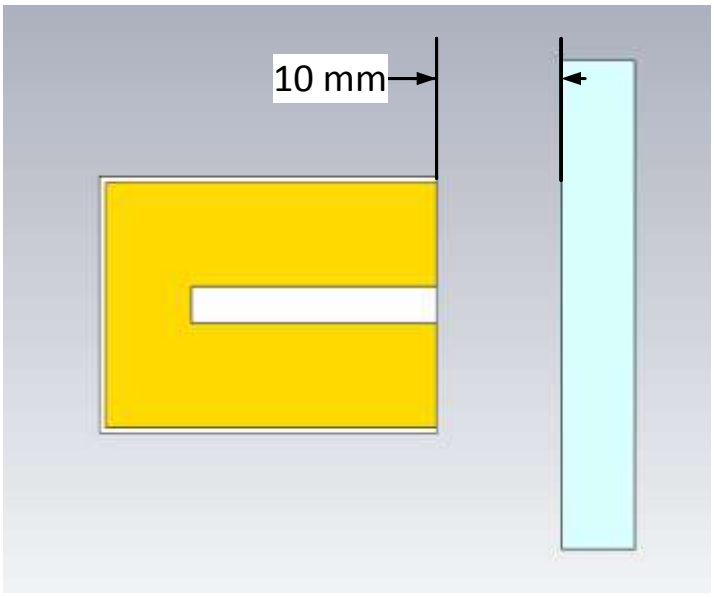


Figure 16 Open Side Metal Clearance

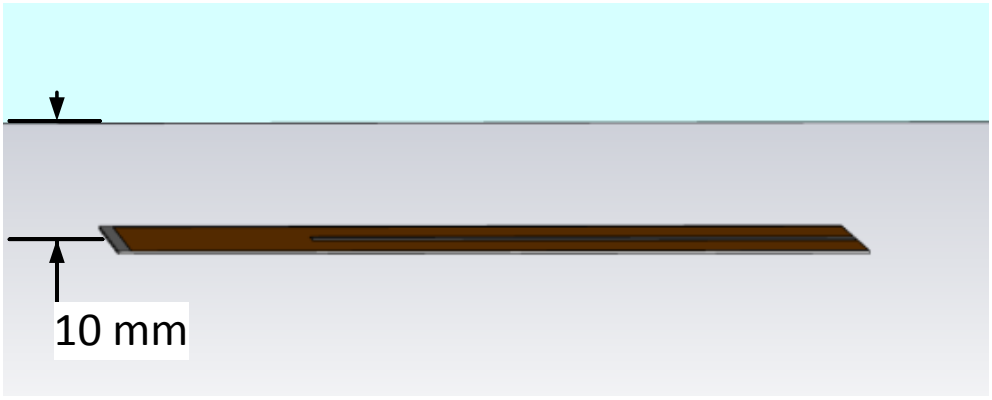


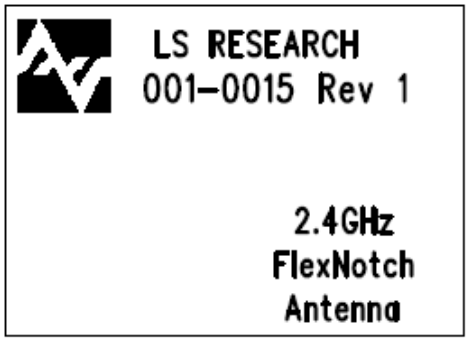
Figure 17 Above Notch Metal Clearance

CUSTOMER SPECIFIC TUNING

LSR will assist with custom tuning of the antenna for your specific end product. Simply send LSR a sample of your enclosure or platform, and LSR will tune an antenna for you. LSR will send the results back indicating which trim mark the antenna should be cut to, to optimize performance. You then trim the antennas at time of assembly to the indicated hash mark, and stick to your product.

PRODUCT REVISION HISTORY

Rev 1: Initial Production Release



Rev 2:

- Added Cut Hash Marks in intervals of 2 mm

CONTACTING LSR

Headquarters	LSR W66 N220 Commerce Court Cedarburg, WI 53012-2636 USA Tel: 1(262) 375-4400 Fax: 1(262) 375-4248
Website	www.lsr.com
Wiki	www.lsr.com/products-wiki
Technical Support	www.lsr.com/products-forum
Sales Contact	sales@lsr.com

Cable Assembly – U.FL to Reverse Polarity SMA Bulkhead Female

ORDERING INFORMATION

Order Number	Description
080-0001	Cable assembly: 105mm in length with reverse polarity SMA female bulkhead and U.FL connector using 1.13mm diameter cable.

SPECIFICATIONS

Specification	Value
Frequency Range	DC to 6GHz
Impedance	50 ohms
Temperature	-40° to +85° C
Rated Voltage	AC 60V
Contact Resistance	20m ohm max – signal and ground
Withstand Voltage	AC 200V
Insulation Resistance	500M ohm minimum/DC 100V
VSWR	< 1.2:1 @ 900MHz
	< 1.4:1 @ 2400MHz
	< 2.0:1 @ 4900MHz
	< 2.0:1 @ 5900MHz
IL	< 0.4dB @ 900MHz
	< 0.7dB @ 2400MHz
	< 1.5dB @ 4900MHz
	< 2.0dB @ 5900MHz
Bend Radius	6.8mm minimum

PHYSICAL DIMENSIONS (MM)

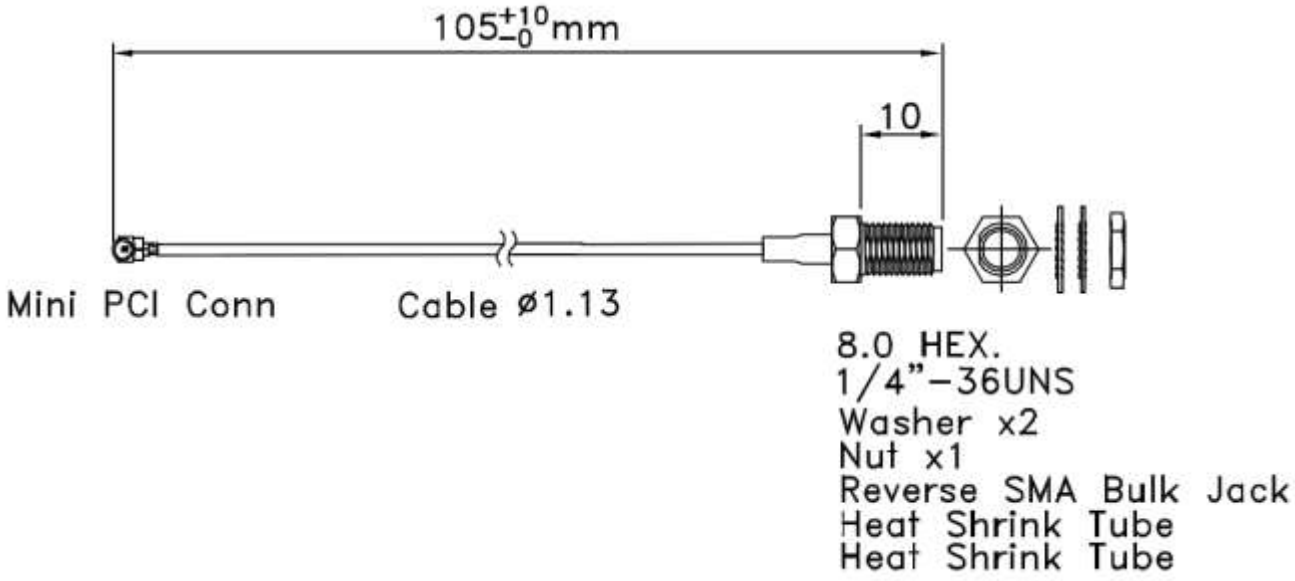


Figure 1

PANEL CUTOUT

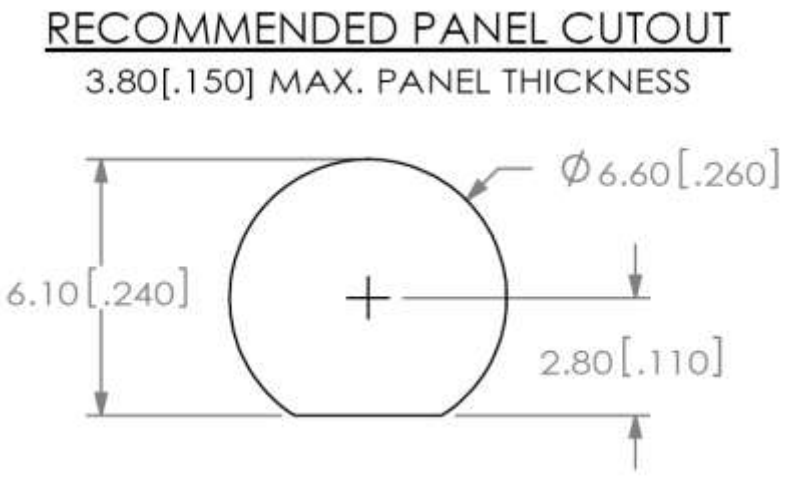


Figure 2

CONTACTING LS RESEARCH

Headquarters	LS Research, LLC W66 N220 Commerce Court Cedarburg, WI 53012-2636 USA Tel: (262) 375-4400 Fax: (262) 375-4248
Website	www.lsr.com
Wiki	wiki.lsr.com
Technical Support	forum.lsr.com
Sales Contact	sales@lsr.com

2.4 GHz – 2.5 GHz FlexPIFA 2 dBi Antenna w/U.FL Cable, 100mm

ORDERING INFORMATION

Order Number	Description
001-0014	2.4 GHz FlexPIFA Antenna w/U.FL cable, 100mm

Table 1 Orderable Part Numbers

KEY FEATURES

- Can be installed on different non-conductive surfaces and thicknesses.
- Can be installed near metals or the human body.
- Can be installed on flat or curved surfaces.
- Quick and easy Installation
- Adhesive holds to surface during humidity exposure and hot/cold cycles.
- RoHS Compliant

SPECIFICATIONS

Specification	Value
Typical Gain	+2 dBi
Typical Efficiency	>60%
Impedance	50 ohms
Type	Flexible Planar Inverted F Antenna (FlexPIFA)
Polarization	Linear
VSWR	< 2.5:1, 2400 - 2480 MHz
Frequency	2400 – 2480 MHz
Weight	1.13g
Size	40.1mm × 11mm × 2.5mm
Antenna Color	Clear Yellow
Adhesive	3M 100MP
Operating Temp	-40°C to +85°C

Table 2 Specifications

PHYSICAL DIMENSIONS (MM)

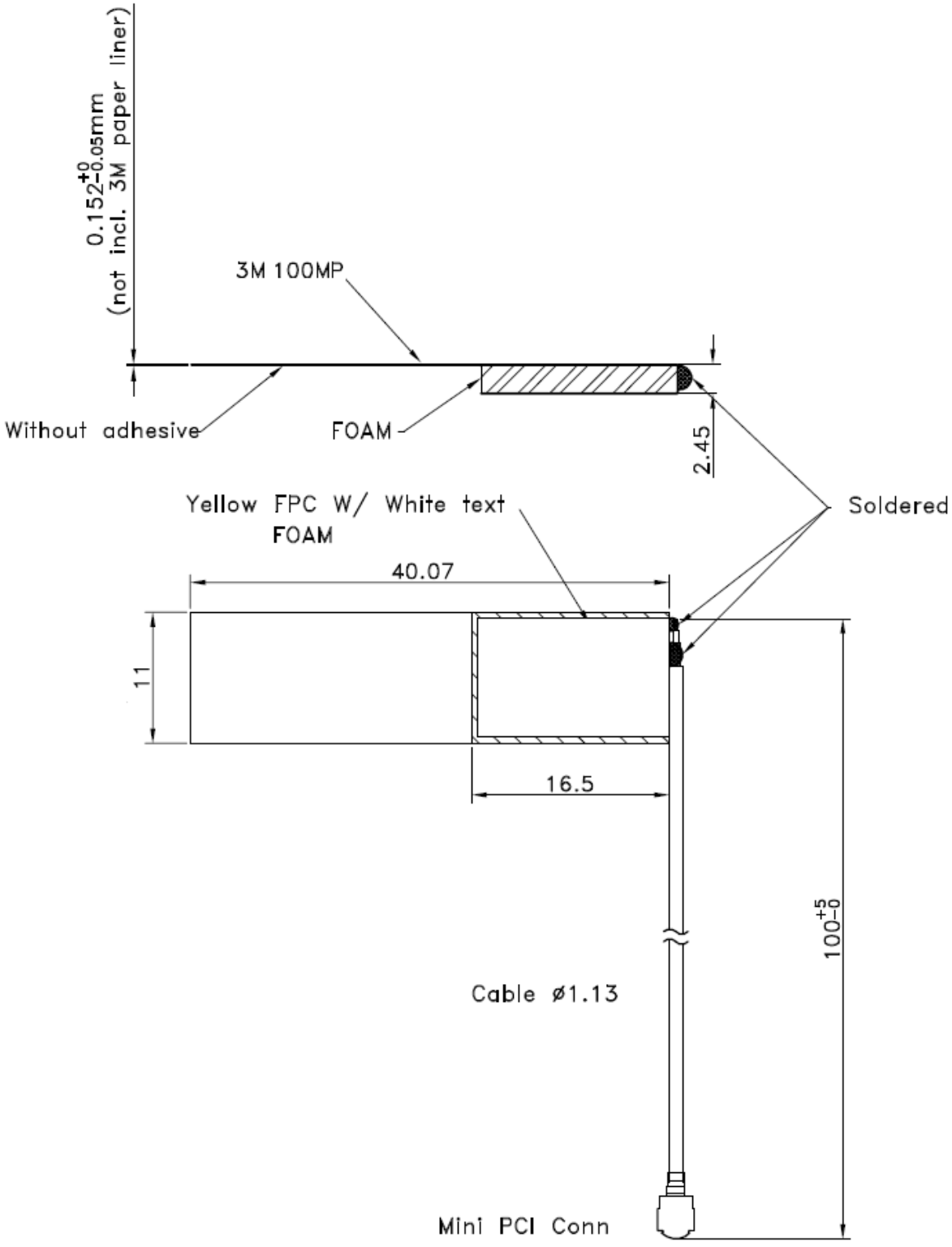


Figure 1 Physical Dimensions

TEST SETUP

Antenna measurements such as VSWR were measured with an Agilent E5071C Vector Network Analyzer. Radiation patterns were measured with an Agilent 5181A Signal Generator and Agilent E4445A Spectrum Analyzer in a 3 meter Anechoic Chamber.

Flat surface measurements were done with the antenna centered on a 1.5 mm thick plate of Polycarbonate. Curved surface measurements were taken by placing the antenna on the inside and outside of different diameter PVC tubing.

FLAT SURFACE ANTENNA MEASUREMENTS

VSWR

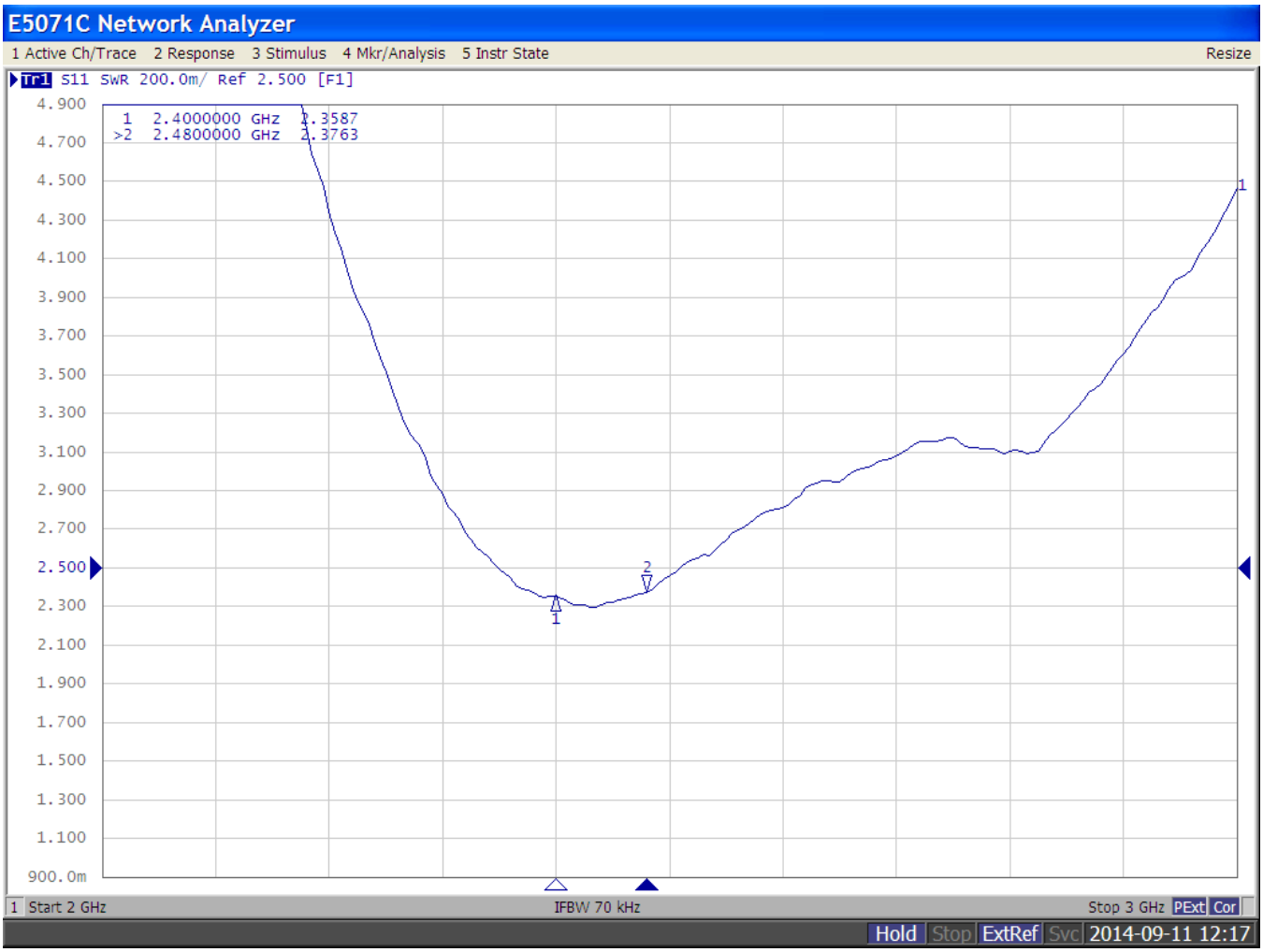


Figure 2 Antenna VSWR measured on a 1.5 mm thick plate of Polycarbonate

CURVED SURFACE ANTENNA RADIATION PERFORMANCE

Flex PIFA inside 51 mm Inner Diameter PVC tube.

Antenna Measurement Set-Up:

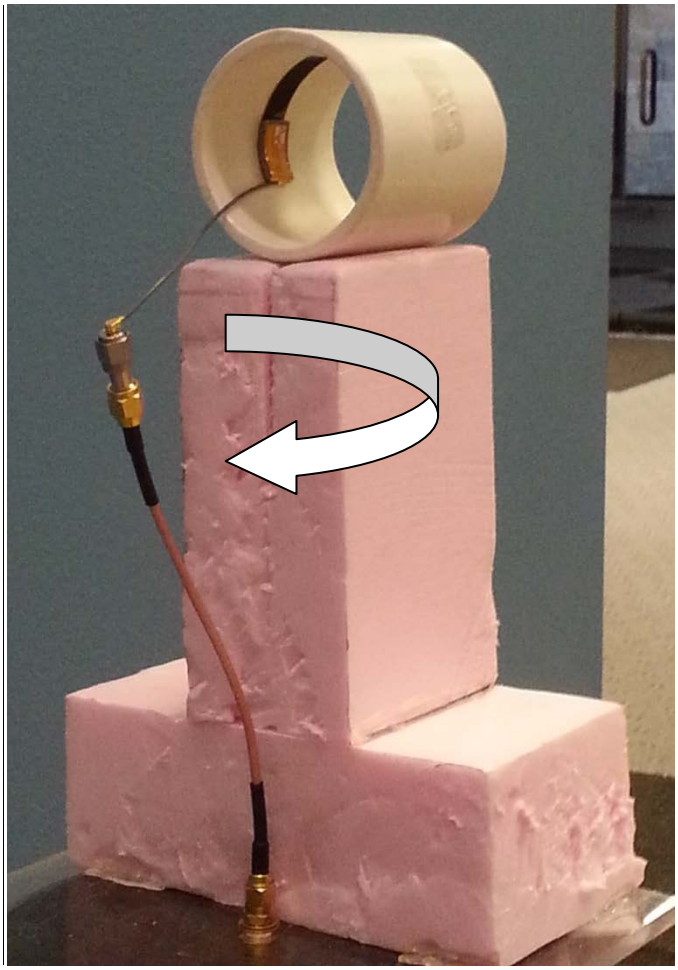


Figure 3 Vertical Orientation Set-Up

Vertical Orientation at 2440 MHz:

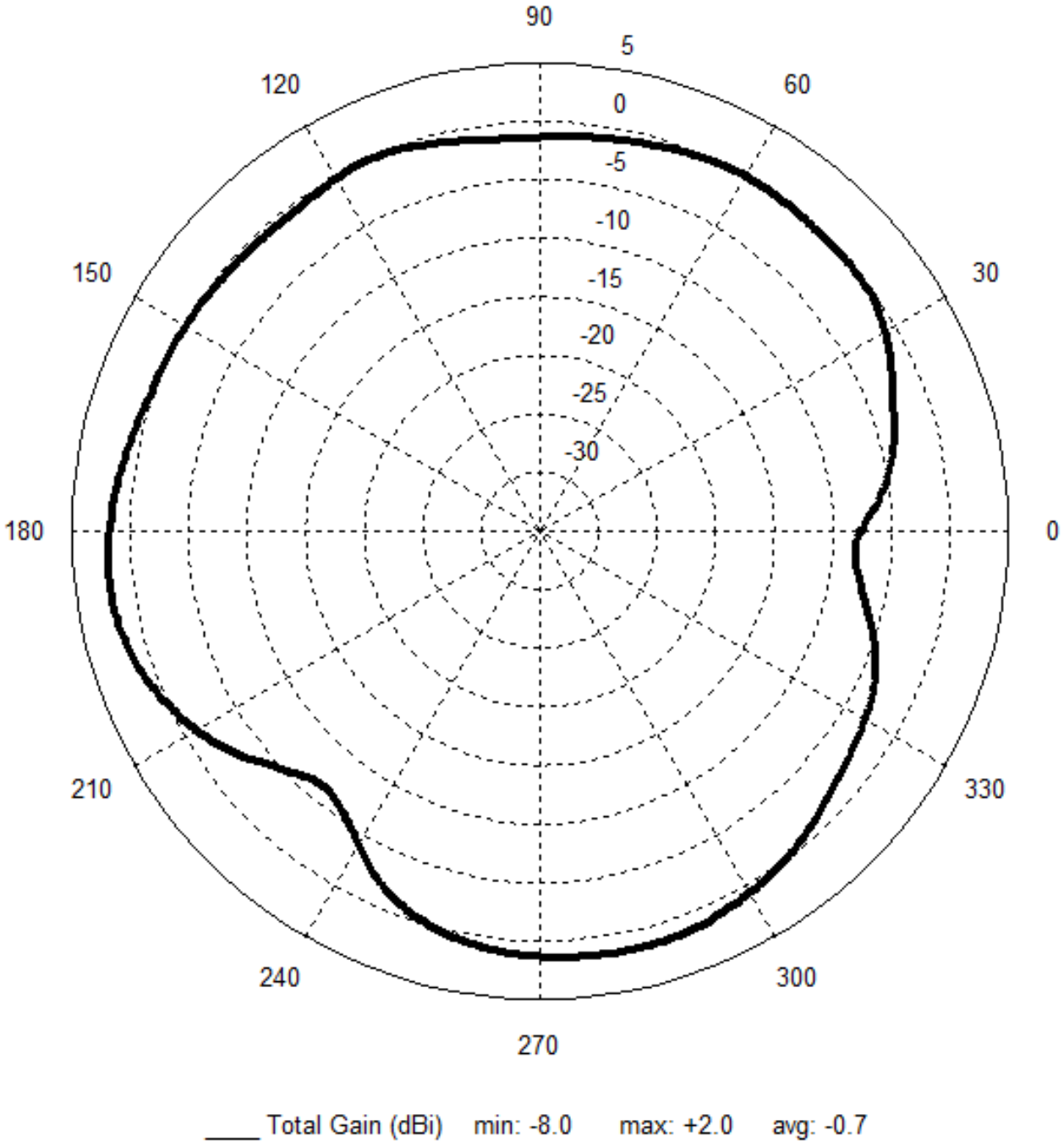


Figure 4 Vertical Orientation Pattern

Antenna Measurement Set-Up:

Figure 5 Horizontal Orientation Set-Up

Horizontal Orientation at 2440 MHz:

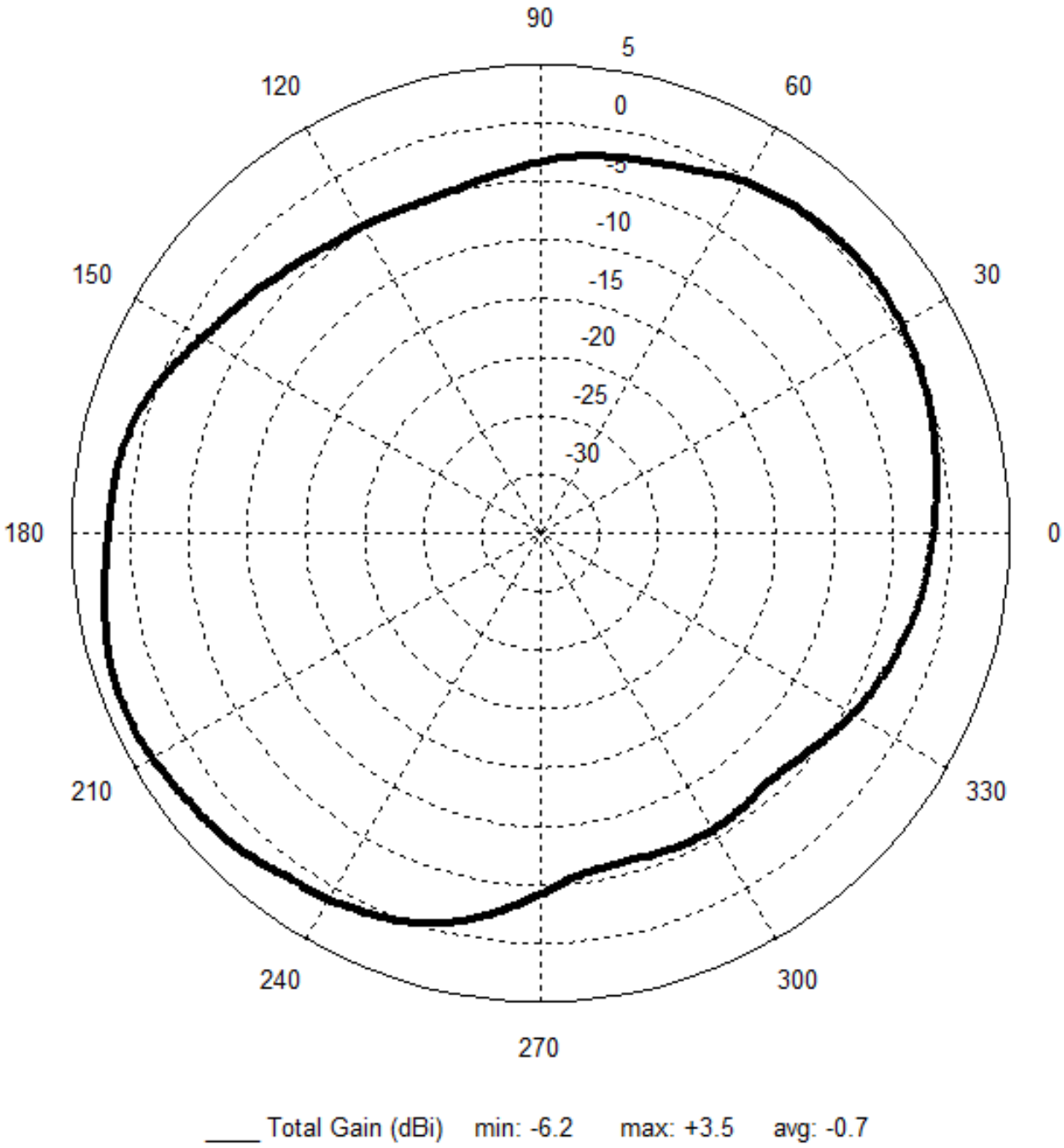


Figure 6 Horizontal Orientation Pattern

Antenna Measurement Set-Up:

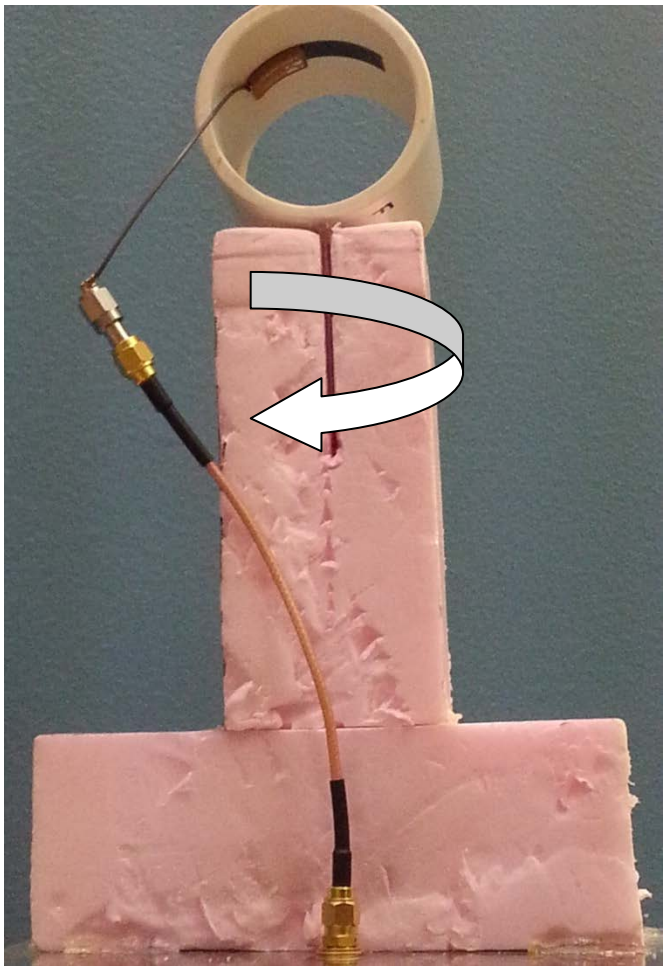


Figure 7 Flat Orientation Set-Up

Flat Orientation at 2440 MHz:

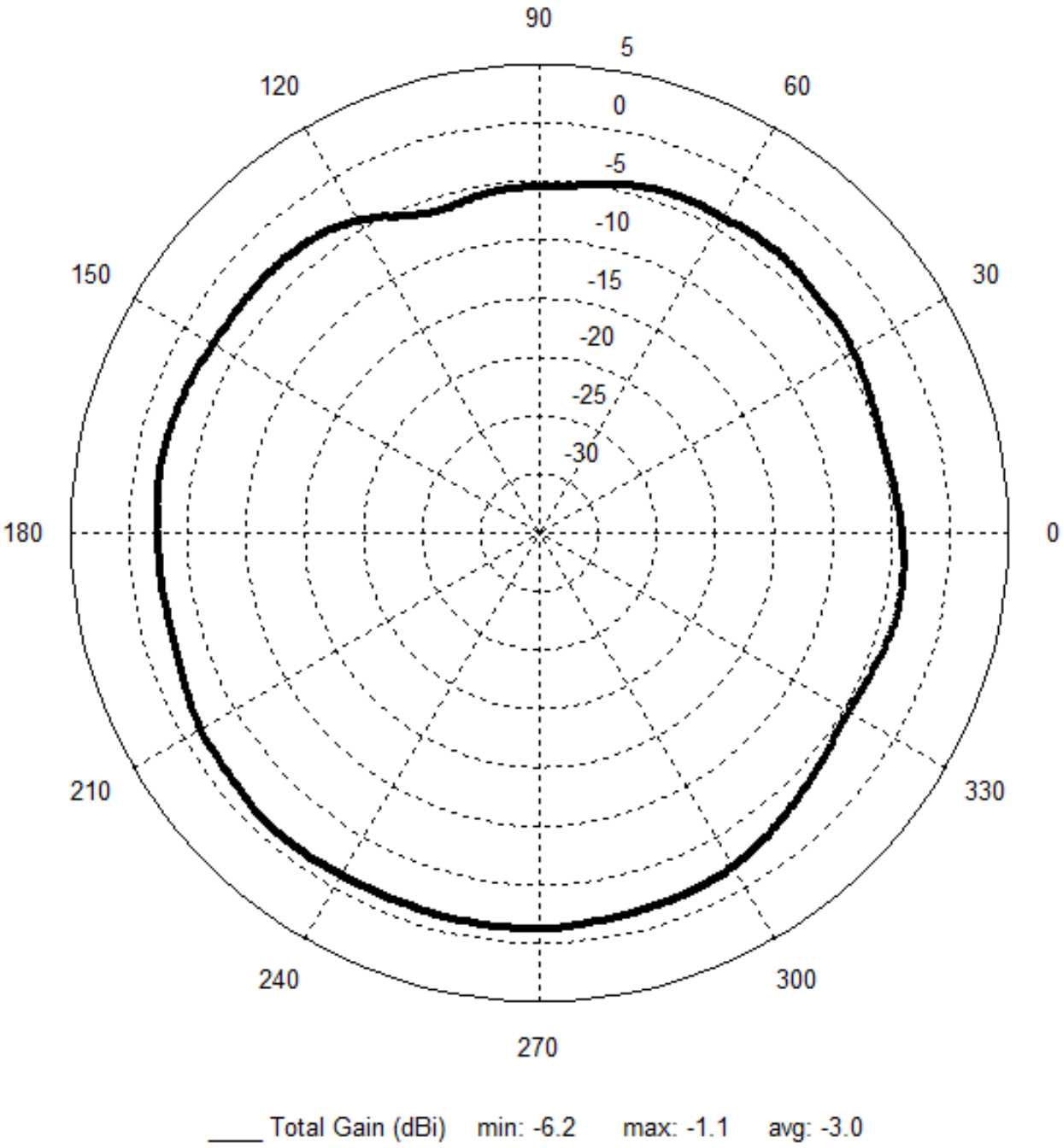


Figure 8 Flat Orientation Pattern

Flex PIFA outside 60 mm Outer Diameter PVC tube.

Antenna Measurement Set-Up:

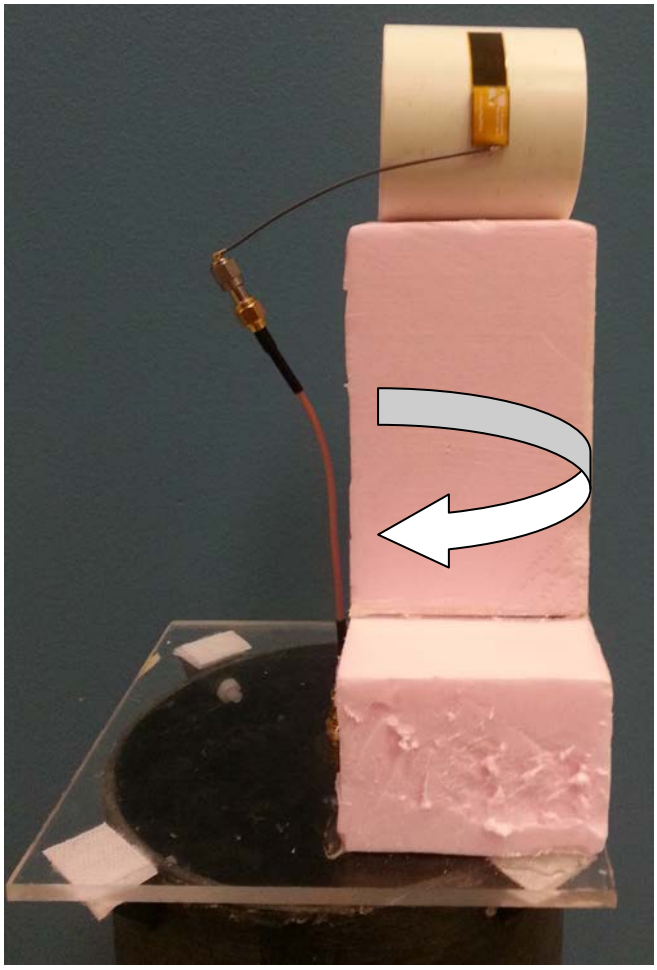


Figure 9 Vertical Orientation Set-Up

Vertical Orientation at 2440 MHz:

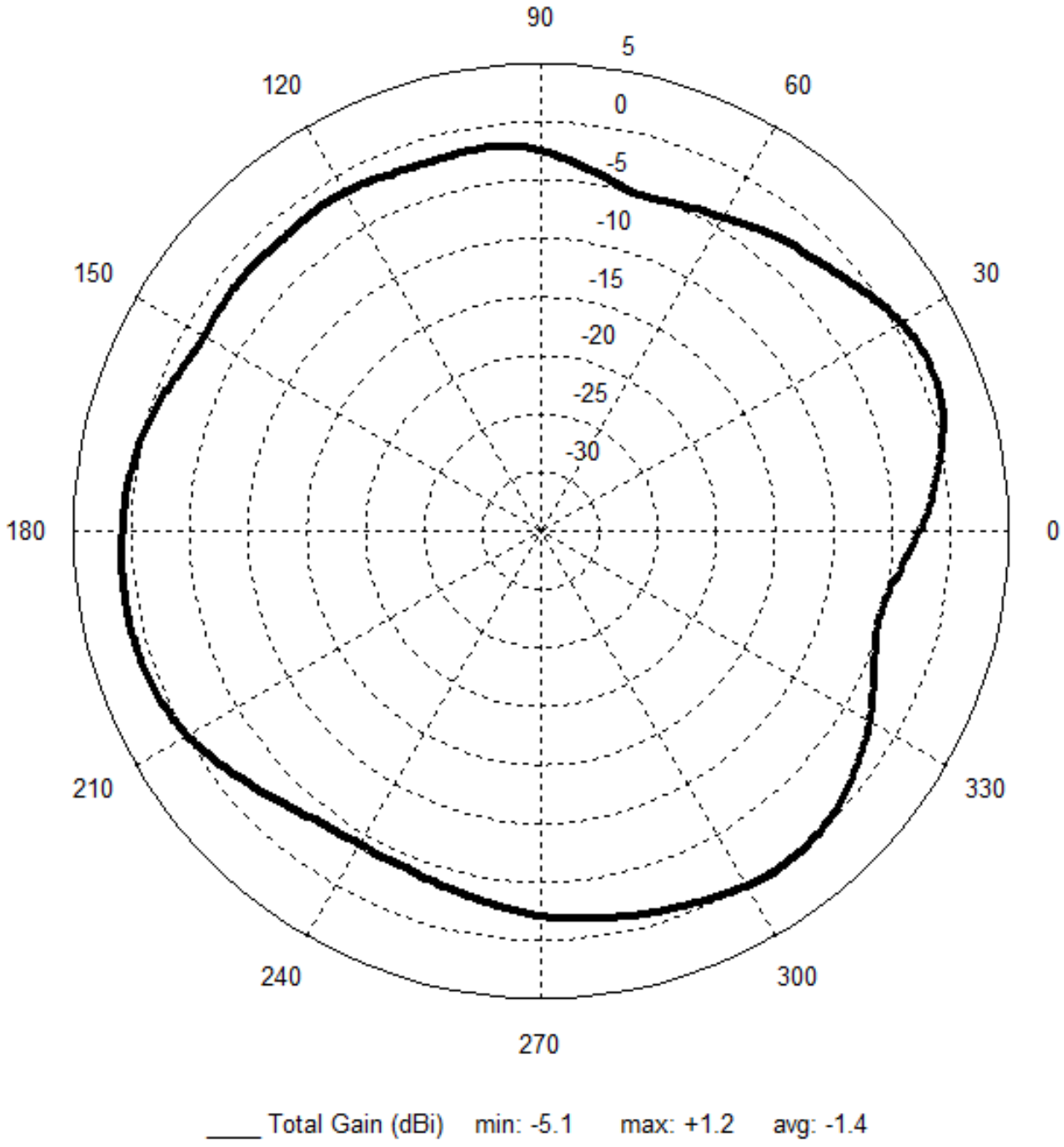


Figure 10 Vertical Orientation Pattern

Antenna Measurement Set-Up:

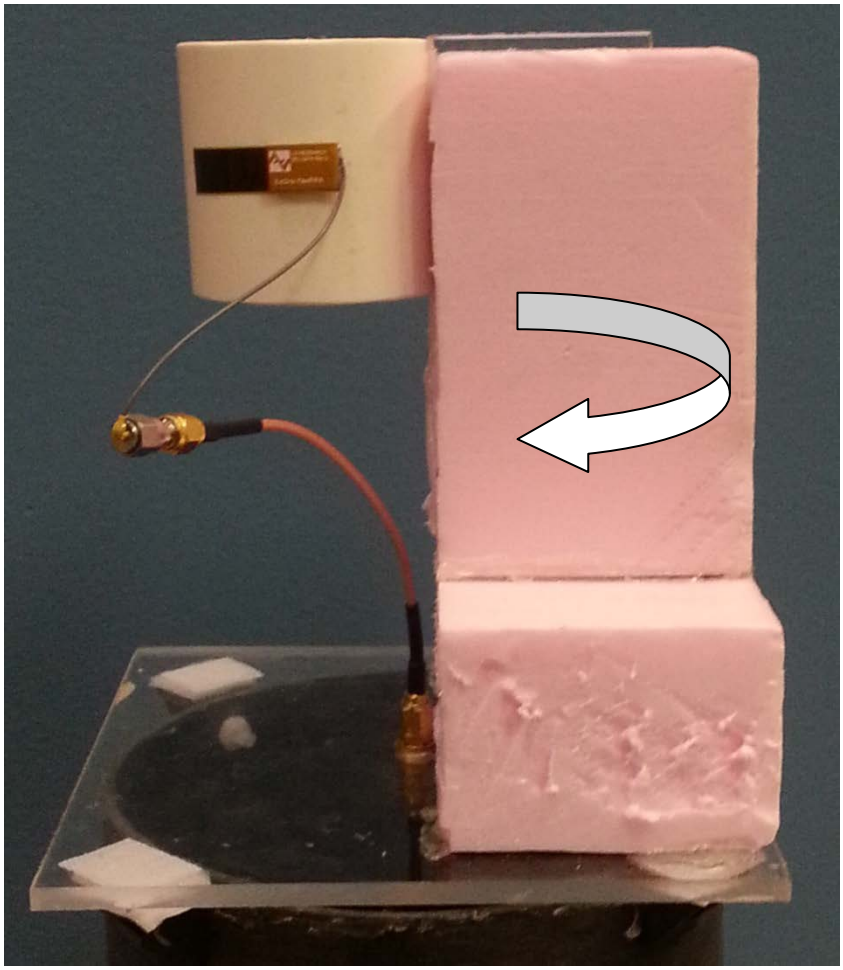


Figure 11 Horizontal Orientation Set-Up

Horizontal Orientation at 2440 MHz:

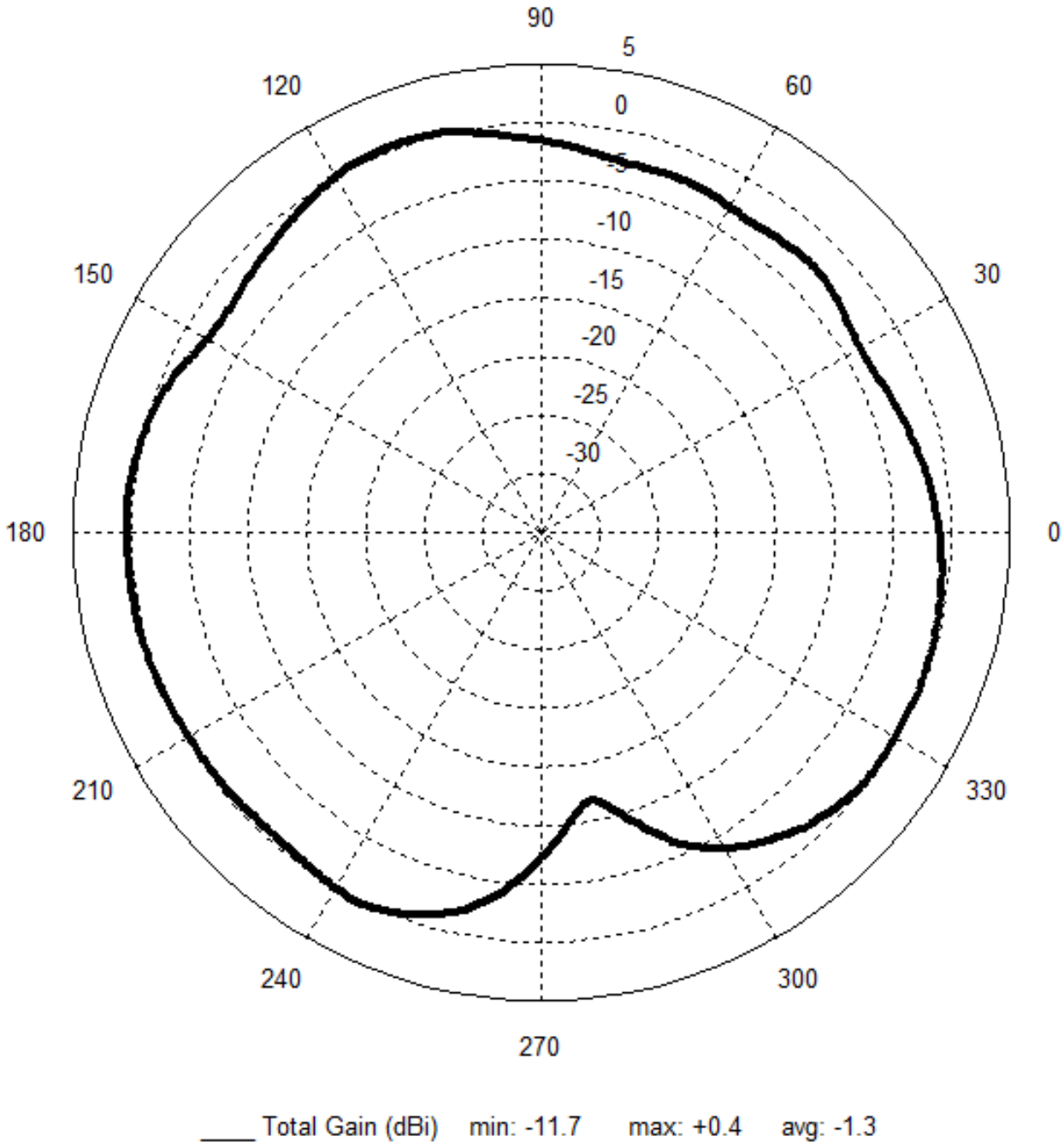


Figure 12 Horizontal Orientation Pattern

Antenna Measurement Set-Up:

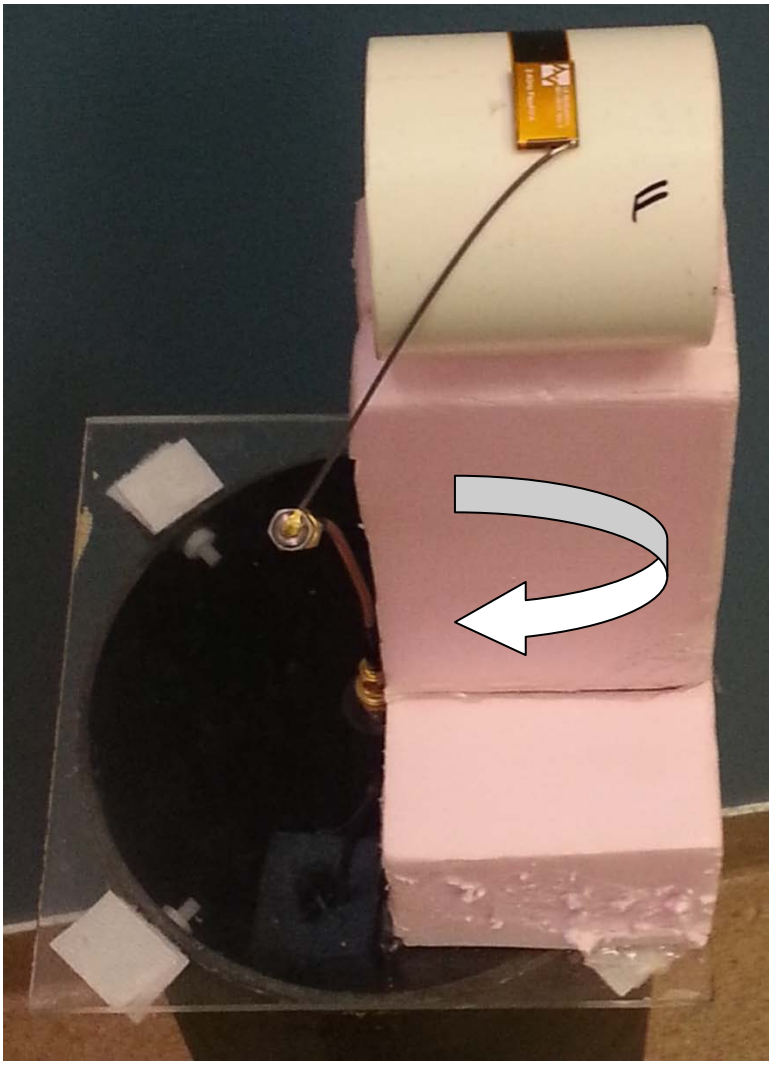


Figure 13 Flat Orientation Set-Up

Flat Orientation at 2440 MHz:

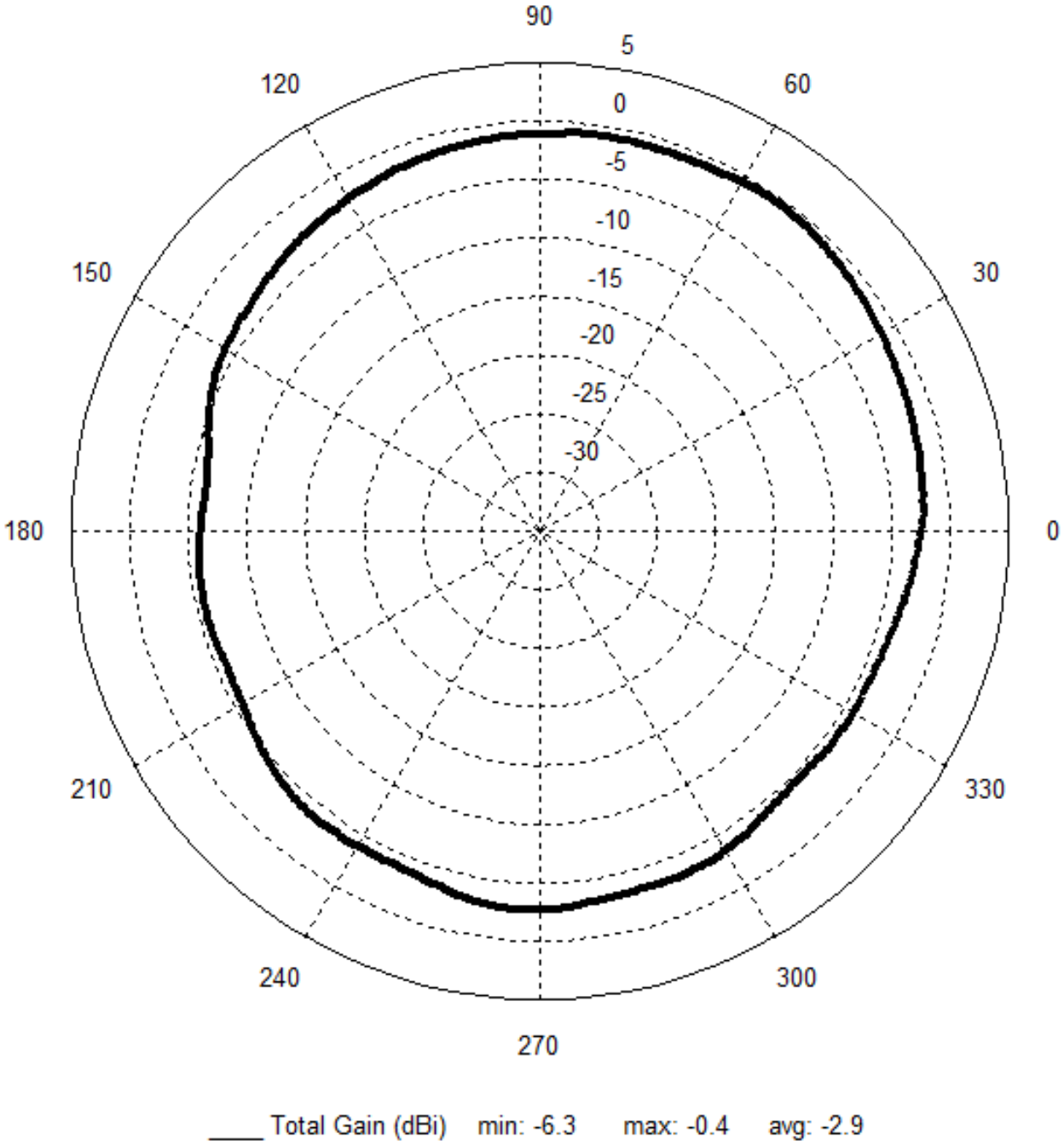


Figure 14 Flat Orientation Pattern

FLAT SURFACE ANTENNA RADIATION PERFORMANCE

FlexPIFA centered on a 1.5 mm thick plate of Polycarbonate

Antenna Measurement Set-Up:

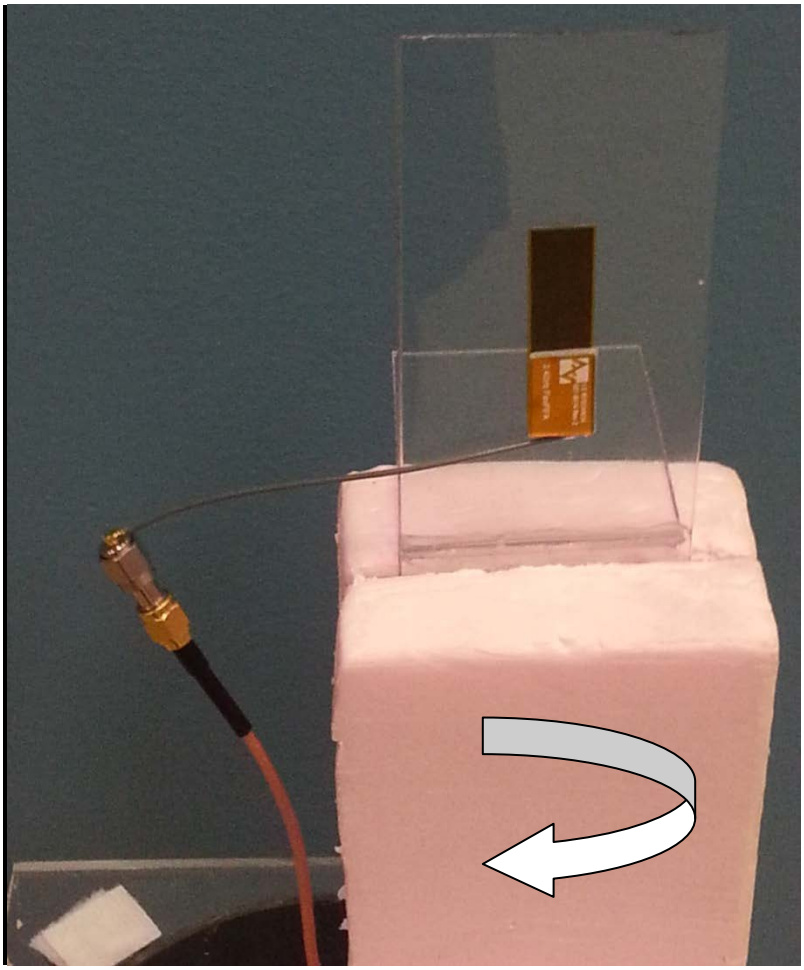


Figure 15 Vertical Orientation Set-Up

Vertical Orientation at 2440 MHz:

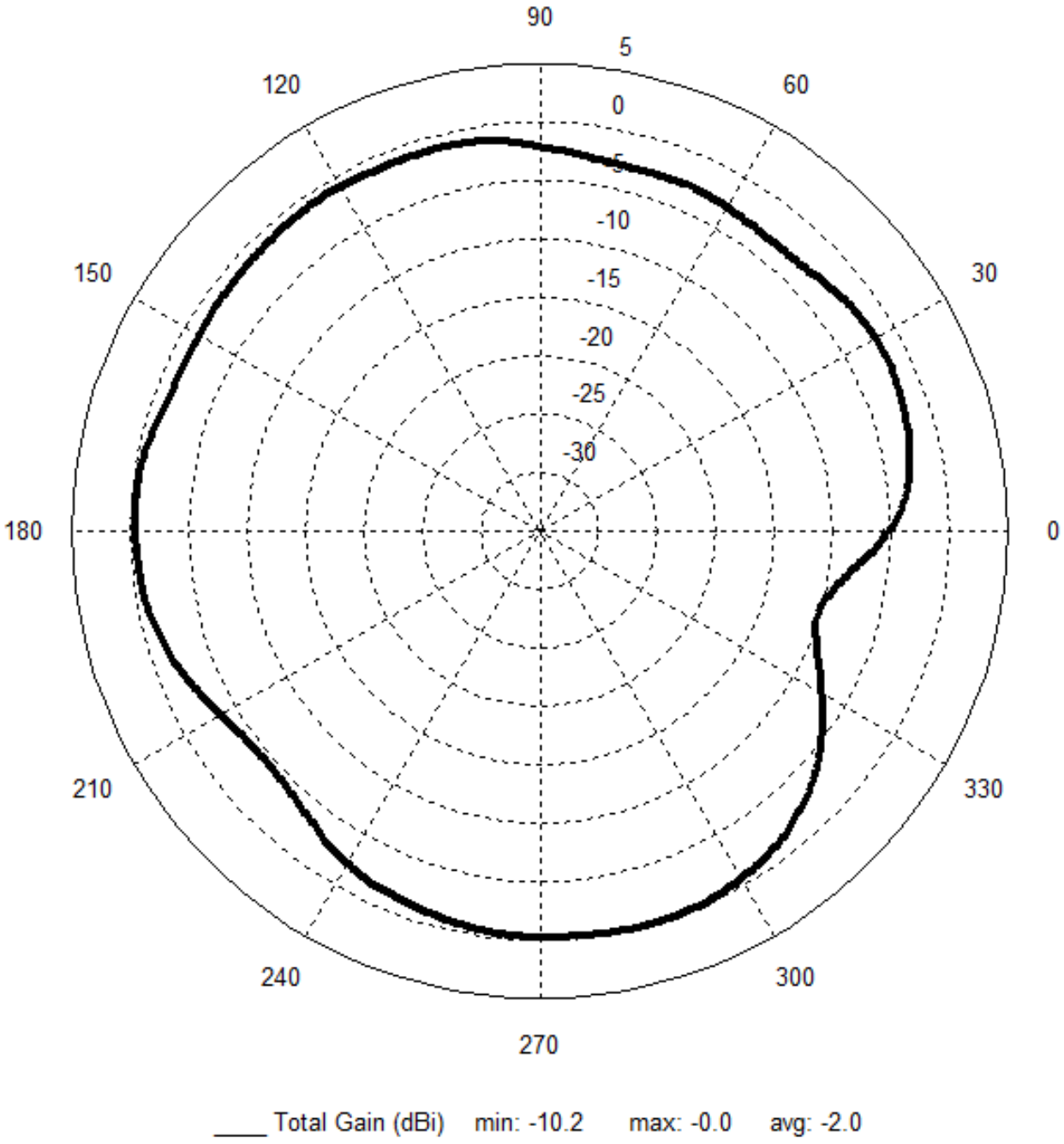


Figure 16 Vertical Orientation Pattern

Antenna Measurement Set-Up:

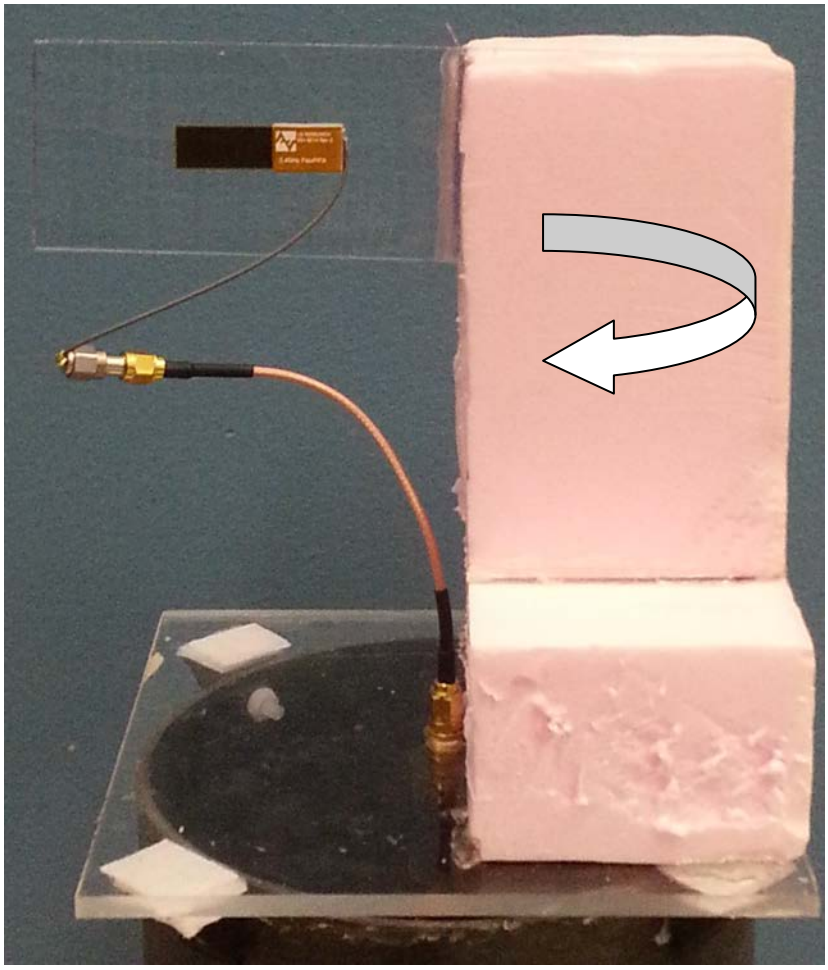


Figure 17 Horizontal Orientation Set-Up

Horizontal Orientation at 2440 MHz:

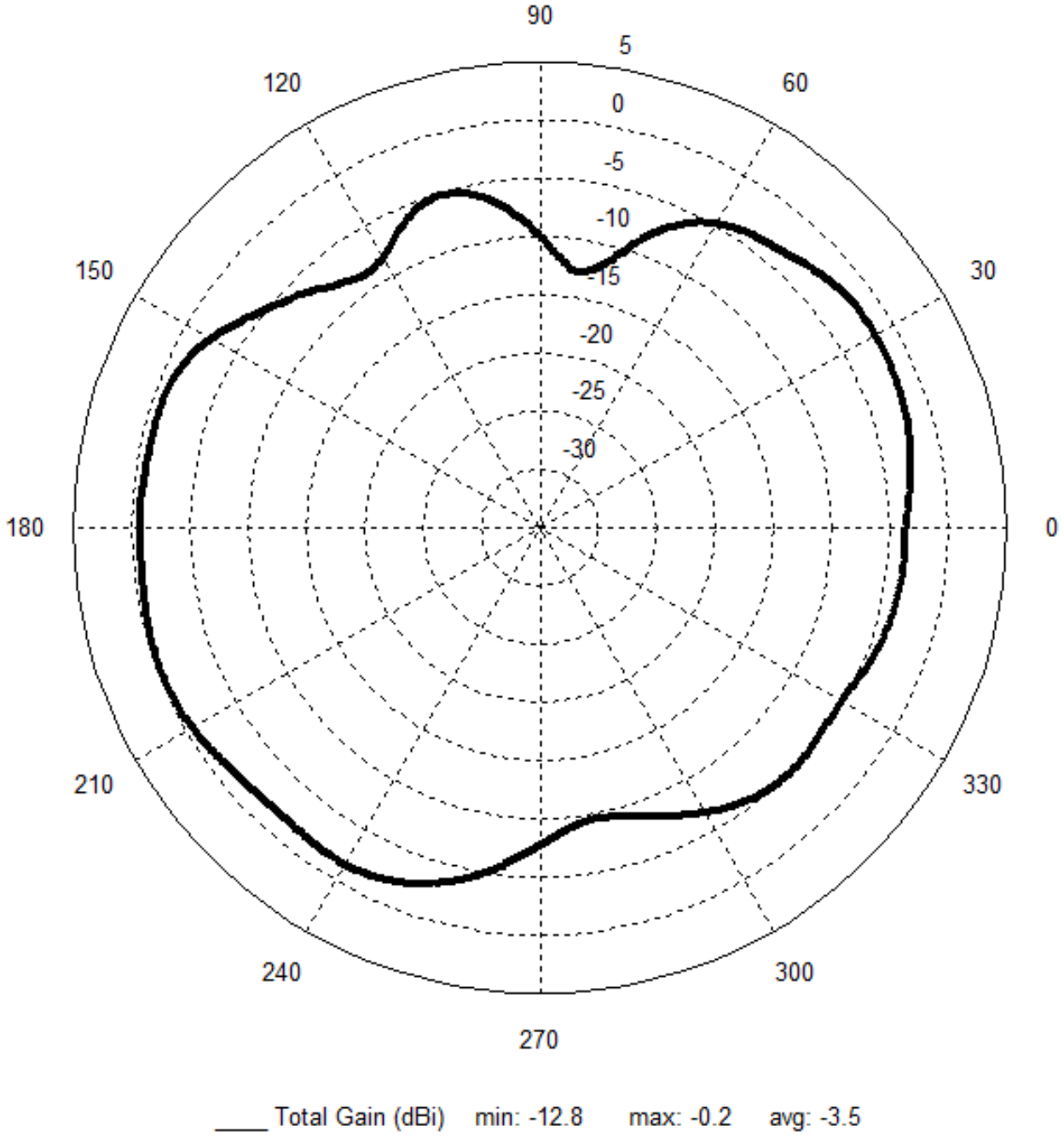


Figure 18 Horizontal Orientation Pattern

Antenna Measurement Set-Up:

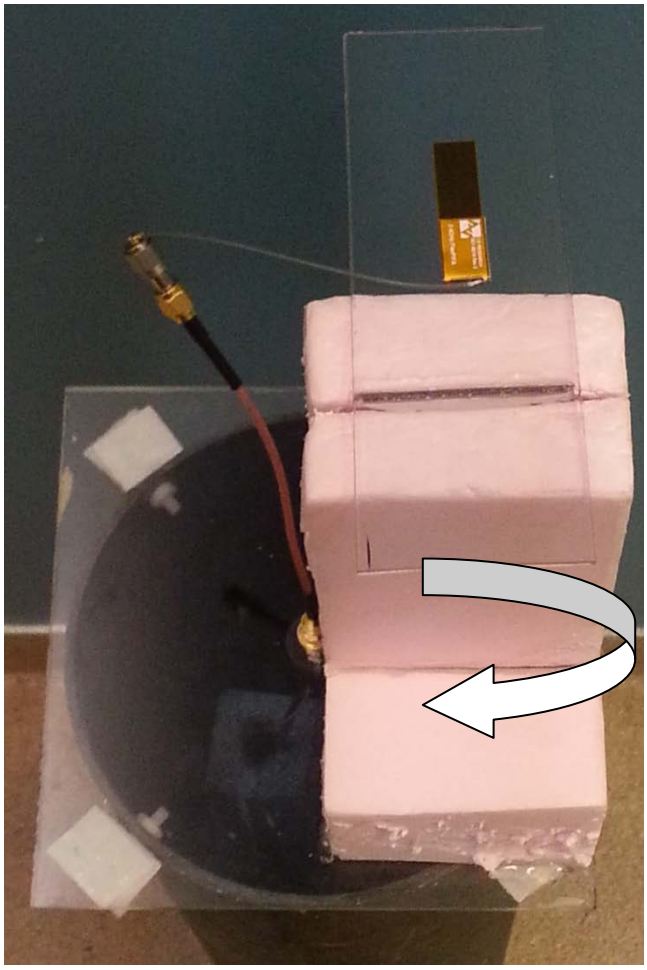


Figure 19 Flat Orientation Set-Up

Flat Orientation at 2440 MHz:

Figure 20 Flat Orientation Pattern

OPTIMAL INSTALLATION GUIDE

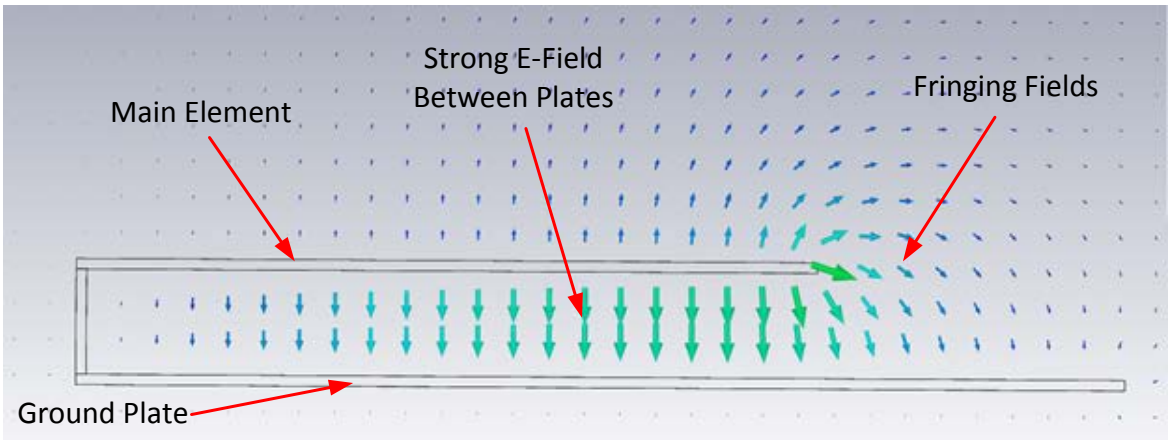


Figure 21 E-Field Radiation from FlexPIFA, Taken from CST Simulation

The main element should be kept clear of any non-metal objects (such as plastics) on top of it by at least 3 mm (see **Figure 22**). Similarly, the two long sides of the FlexPIFA should be kept clear of any non-metal object by at least 2 mm (See **Figure 23**). A 1 mm clearance should be observed from the ground wall to any non-metal object. Mounting the FlexPIFA in a situation that does not allow for these clearance recommendations may change the gain characteristics stated in the datasheet, which could impact overall range of the wireless system.

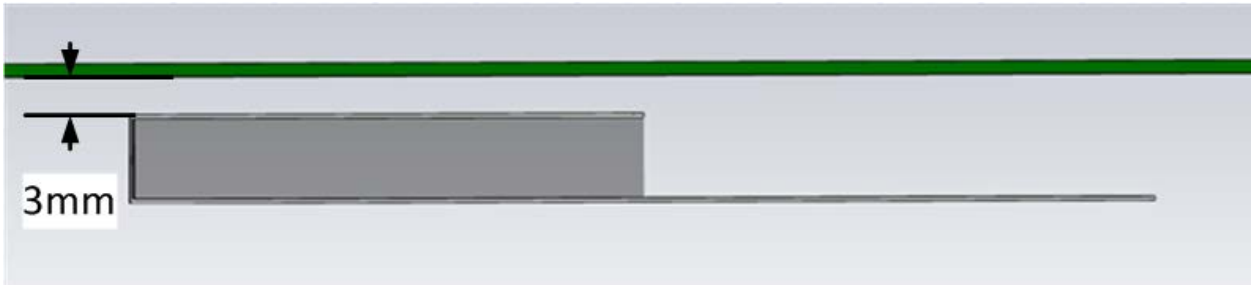


Figure 22 Top Clearance

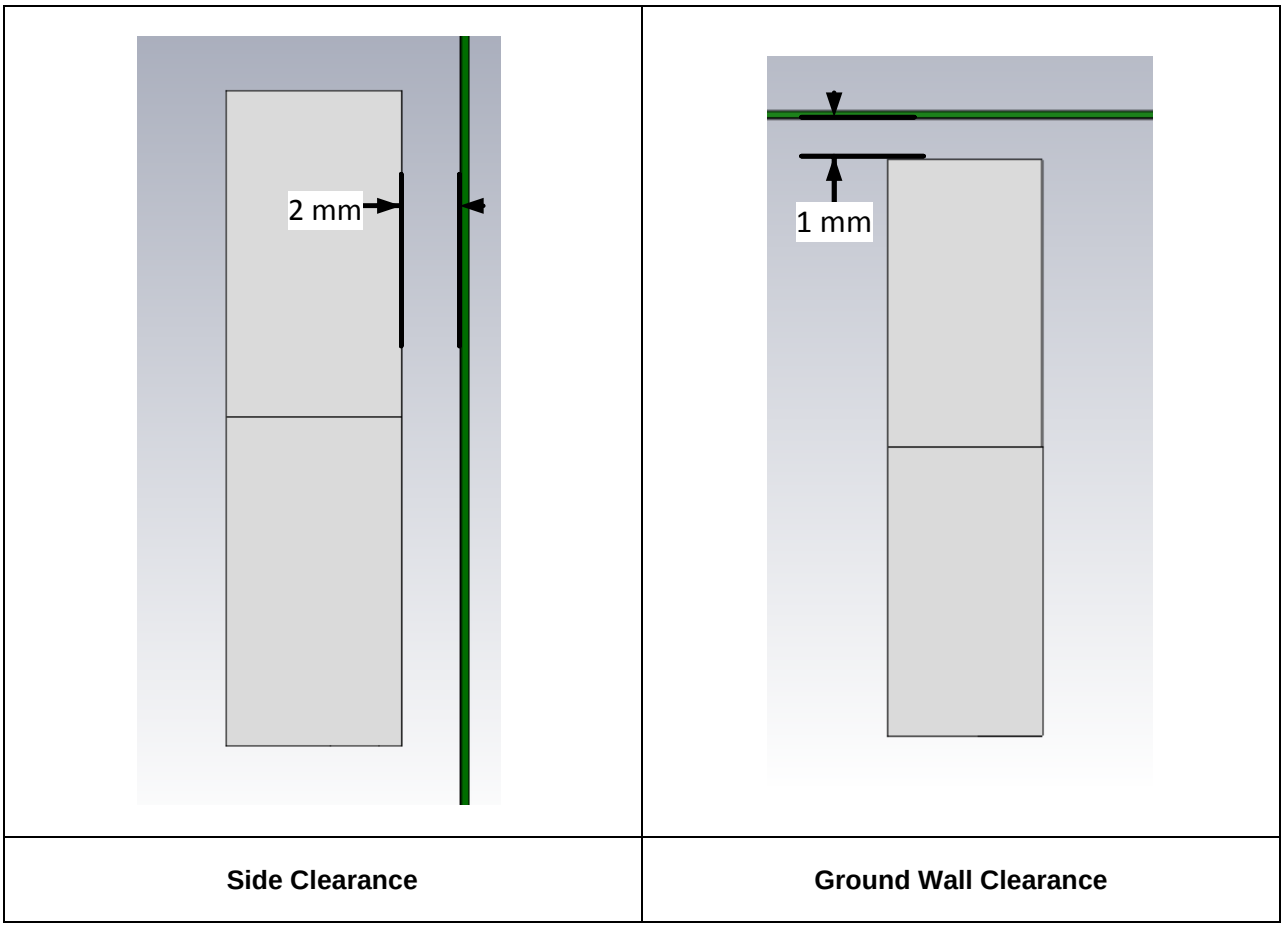
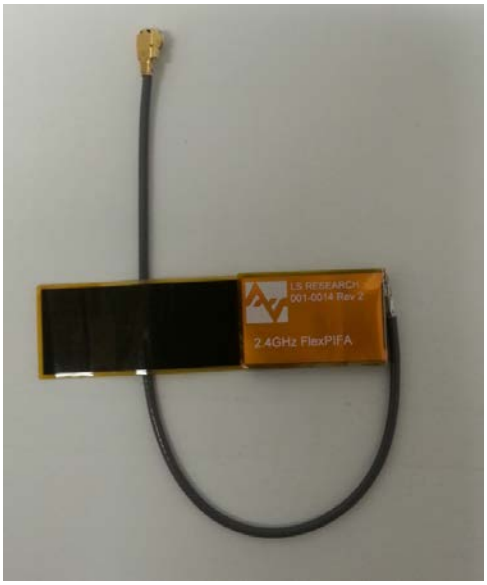


Figure 23 Side and Ground Wall Clearance

The ideal material for the FlexPIFA to be mounted on is 1.5 mm thick polycarbonate for maximum performance. However, as previously mentioned, the FlexPIFA can tolerate other non-metallic surfaces and thicknesses and still radiate effectively. Depending on the type of material, the FlexPIFA may be detuned.

The coaxial cable feeding the FlexPIFA should be routed away from the antenna. Do not run the coaxial cable over the top of the FlexPIFA or near the tip of the main element. The cable should be routed perpendicular to the side of the FlexPIFA (this is the way the cable comes assembled), underneath the ground plate, or away from the ground wall. All three of these options are shown in **Figure 24**.

Perpendicular to the side



Underneath the FlexPIFA

Away from the Ground wall

Figure 24 Recommended Cable Routing

As with any antenna, care should be taken not to place conductive materials or objects near the antenna (except as described in the next section). The radiated fields from the antenna will induce currents on the surface of the metal; as a result those currents then produce their own radiation. These re-radiating fields from the metal will interfere with the fields radiating from the FlexPIFA (this is true for any antenna). Other objects, such as an LCD display, placed in close proximity to the antenna may not affect its tuning but it can distort the radiation pattern. Materials that absorb electromagnetic fields should be kept away from the antenna to maximize performance. Common things to keep in mind when placing the antenna:

Wire Routing

Speakers – these generate magnetic fields

Metal Chassis and Frames

Battery Location

Proximity to Human Body

Display Screen – these will absorb radiation

Paint – do not use metallic coating or flakes

Flex Limits of the FlexPIFA

One of the unique features of the FlexPIFA is its ability to flex. However, due to the adhesive there are limits as to how much the antenna can be flexed and remain secured to the device. The FlexPIFA should not be flexed in a convex position with a radius less than 16mm. Going smaller than this may result in the antenna peeling off the surface over time. Should a tighter radius of curvature be required, it is recommended you contact LSR for assistance.

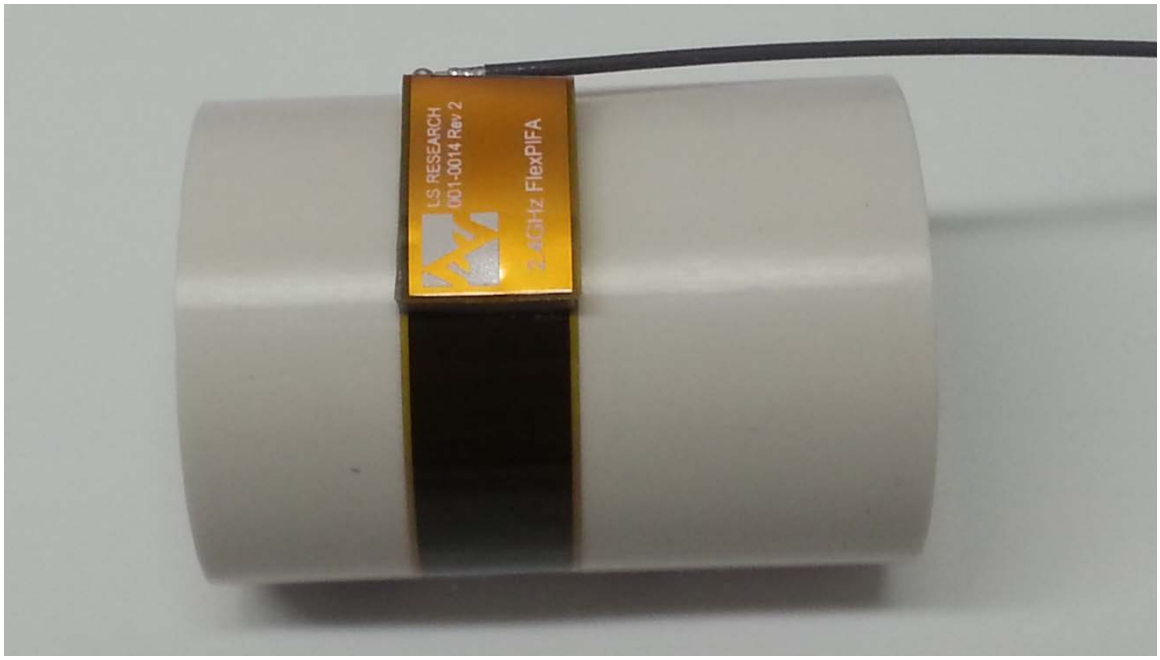


Figure 25 Convex Mounted

The FlexPIFA should not be flexed in a concave position with a radius less than 25mm. In this scenario, the limiting factor is performance. The ground plate of the antenna is pressed closer to the main element. As previously discussed in the introduction of this application note, the fringing fields developing off the end of the element are responsible for most of the radiation. In a concave position with a radius of curvature less than 25mm, the fringing fields are adversely affected and gain suffers. If a tighter radius of curvature is required, it is recommended you contact LSR for assistance.

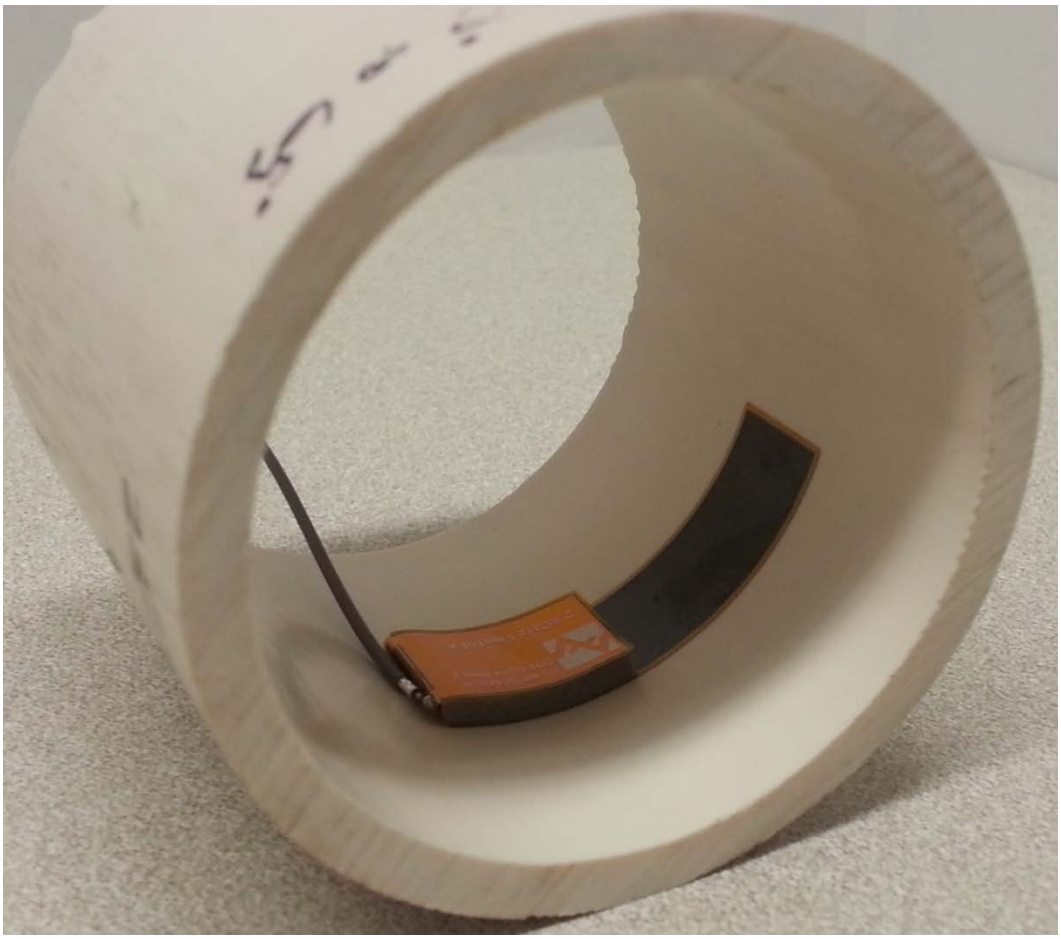


Figure 26 Concave Mounted

The FlexPIFA is not designed to be twisted or crumpled. The adhesive back should lay flush with the surface it is mounted on.

Mounting on Metal and Body Loaded Applications

The FlexPIFA can tolerate being mounted on conductive surfaces. There will be some detuning of the antenna, which translates into some gain reduction. Even though the FlexPIFA is optimized to work on non-metallic surfaces, it still radiates efficiently due to the fringing fields (Shown in **Figure 21**). The ground plate of the FlexPIFA carries the adhesive backing; placing the antenna onto a metal surface simply enlarges the size of the ground beneath the main element. Previously the fringing fields only interacted with the small ground of the FlexPIFA - however they are now interacting with the much larger ground. The fringing fields still develop and radiate, but the antenna will no longer tune as well to the 2.4 GHz frequency band. Consequently the VSWR increases and there is some loss in radiated power. If the FlexPIFA cannot meet your range requirements after being implemented on a metal surface, contact LSR for metal tuned samples.

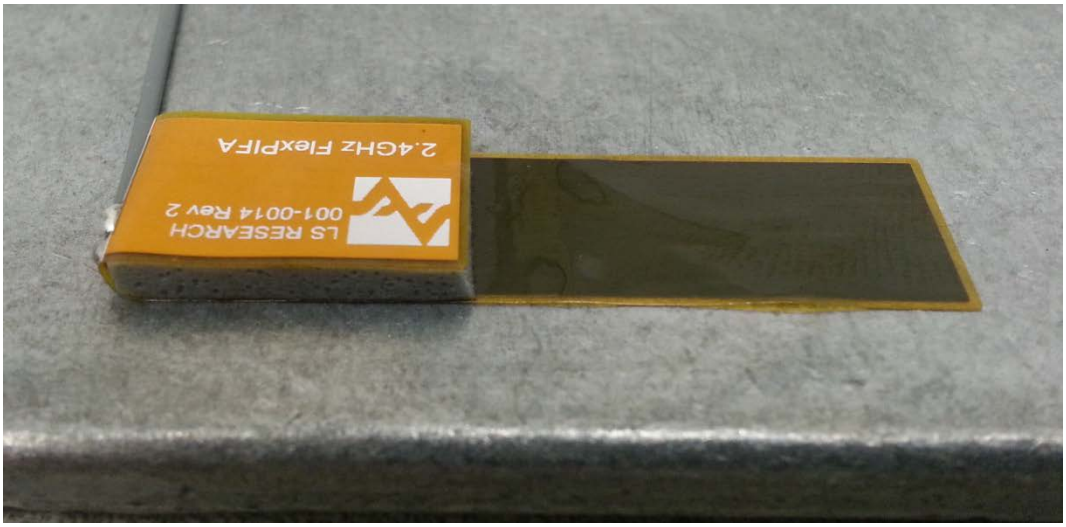


Figure 27 FlexPIFA Mounted on Metal

Do not mount the FlexPIFA where metal is within 10 mm above the main element (see **Figure 29**). Not only will this severely limit the radiation pattern (mainly due to the re-radiation problem previously described) it will detune the antenna inside of this range. Similarly, the two long sides of the FlexPIFA should be kept clear of any metal object by at least 5 mm. These keep out requirements pertain to **conductive** materials only, and are different from those listed in the previous sections which apply to **non-conductive** materials. In general, it is good practice to always keep metals as far away from the antenna as possible.

For the best performance, a spacer should be placed between the FlexPIFA and the conductive surface (see **Figure 28**). The spacer should be 1.5 mm thick polycarbonate. This will significantly improve performance and tuning of the FlexPIFA on a metal surface. Other non-conductive materials such as ABS plastic can be used; however polycarbonate will provide the best results.

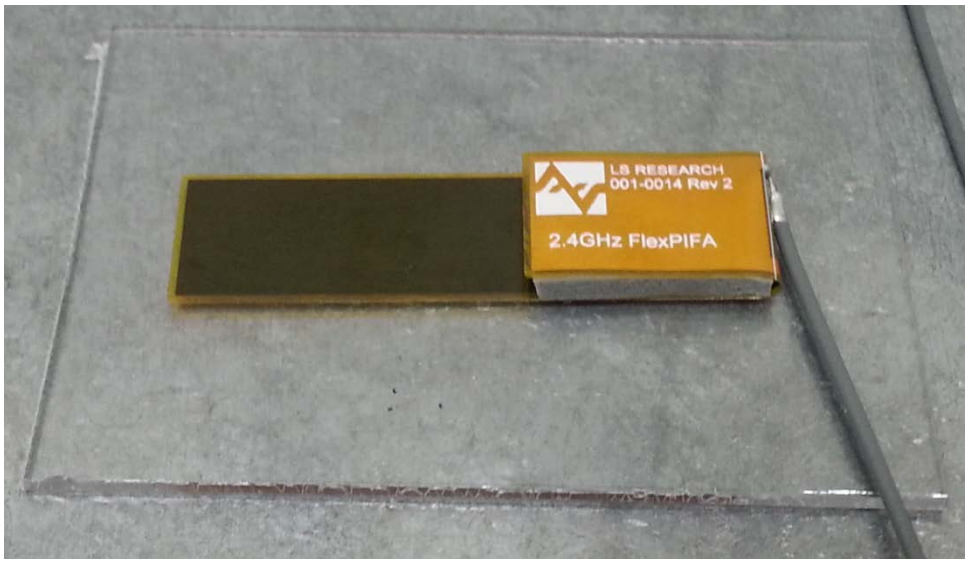


Figure 28 FlexPIFA Mounted on Metal Surface with 1.5mm Thick Polycarbonate Spacer

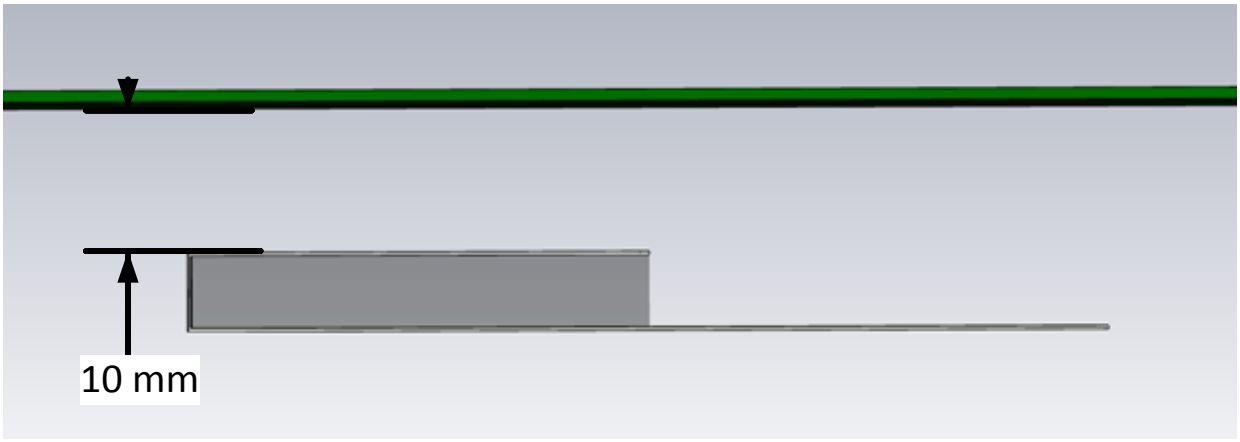


Figure 29 Metal near Main Element

For body worn applications, the FlexPIFA can tolerate the presence of the human body. It is not recommended that the antenna be mounted directly on body tissue, this will detune the FlexPIFA. Additionally the human body is an excellent absorber of 2.4GHz RF signals. As a result of this, expect a reduction in range due to the presence of a body. In a body worn application, the ground plate of the FlexPIFA should be closest to the body tissue. The main element should be pointed away from the body. Additionally, for handheld devices the FlexPIFA should be mounted in a location where it will not be covered by the hand. If the antenna is mounted in a location where the main element will be covered or near a human body, ensure that there is at least a 10mm separation distance between the main element and the body as shown in **Figure 29**. Additionally, when the FlexPIFA is mounted very close to body tissue, use a spacer to create separation distance between the body tissue and ground plate. This will ensure maximum performance and prevent the antenna from detuning. As previously mentioned, the ideal spacer material is 1.5 mm thick polycarbonate.

Quite often this separation distance between the body tissue and the FlexPIFA is already provided by the enclosure. **Figure 30** below is an example of a bracelet with the FlexPIFA integrated inside it. The enclosure provides enough spacing between the antenna and body tissue to prevent any major detuning. The enclosure is made of polycarbonate.

Figure 30 FlexPIFA Integrated into Bracelet

PRODUCT REVISION HISTORY

Rev 1: Initial Production Release

Rev 2:

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