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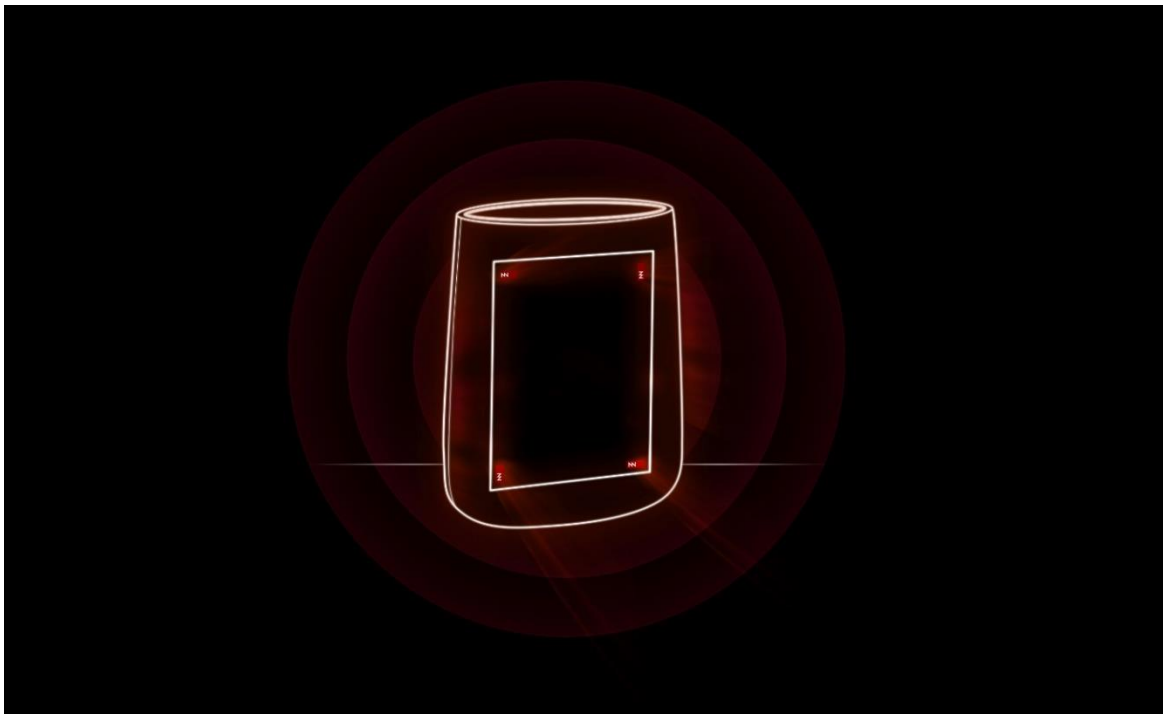
Miniature antenna for Wi-Fi 6E in a MIMO 4x4 configuration

APPLICATION NOTE
ONE mXTEND™ (NN02-201)

Miniature antenna for Wi-Fi 6E in a MIMO 4x4 configuration

- **Antenna Component:** ONE mXTEND™ NN02-201
- **Dimensions :** 7.0 mm x 3.0 mm x 1.0 mm
- **Frequency regions:** 2.400-2.483 GHz, 5.170-5.835 GHz, and 5.925-7.125 GHz



Ready for 4x4 MIMO

The Wi-Fi 6E extends support for Multiple-Input, Multiple-Output (MIMO) 4x4 antenna configurations. The need to accommodate multiple antennas in tight spaces, to boost Wi-Fi capacity, plays well with Ignion's tiny Virtual Antenna® chip technology.

When you have antennas too close together, it can result in sub-optimal coupling, with our innovative solution you can place our chip antennas on or around the PCB frame, in the access point or device, knowing that the antennas occupy the minimum space while delivering high multiband performance.

Discover within this Application Note how the Virtual Antenna® component ONE mXTEND™, thanks to its miniature size, only 7.0 x 3.0 x 1.0 mm, fits in just about any platform.

The Virtual Antenna™ system provides peace of mind for makers of Wi-Fi-enabled devices, makes their lives much easier, and allows them to make the most of a booming market.

*Please note that the ONE mXTEND™ is a versatile antenna solution that can cover other frequency ranges besides those covered in this document. If your device is to operate in any other band, please contact to support@ignion.io for assistance. We are here to help.

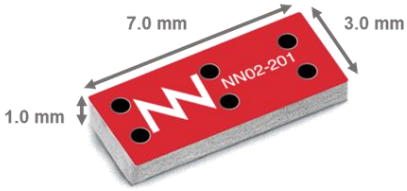
TABLE OF CONTENTS

1. PRODUCT DESCRIPTION NN02-201

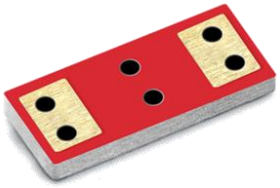
The Wi-Fi market expects small, sleek, sexy devices, whether you are consumer or enterprise, and you want to get those out to market fast. That means reducing design cycles and reducing risk, which is all possible with our unique Virtual Antenna® boosters. The 6 GHz frequency band has been added to the already unlicensed spectrum in the 2.4 GHz and 5 GHz frequency ranges. This additional frequency band offers more bandwidth with more available channels to improve data speed rates, while preserving coverage and minimizing spectrum congestion in high density environments.

The ONE mXTEND™, a multi-band miniature antenna booster, is capable of easy adaption to just about any kind of device. Featuring an extremely small package that requires only a nominal space, the ONE mXTEND™ is a versatile product capable of operating all the Wi-Fi 6E frequency bands through the same single antenna package. This application note gathers the performance of the ONE mXTEND™ in a 4x4 MIMO system in an access point size Evaluation Board (200 mm x 200 mm).

TOP



BOTTOM



Material: The ONE mXTEND™ antenna booster is built on glass epoxy substrate.

APPLICATIONS

- Routers and Gateways
- Modules
- IoT Sensors
- Handsets and smartphones
- Tablets and PCs
- Digital cameras

BENEFITS

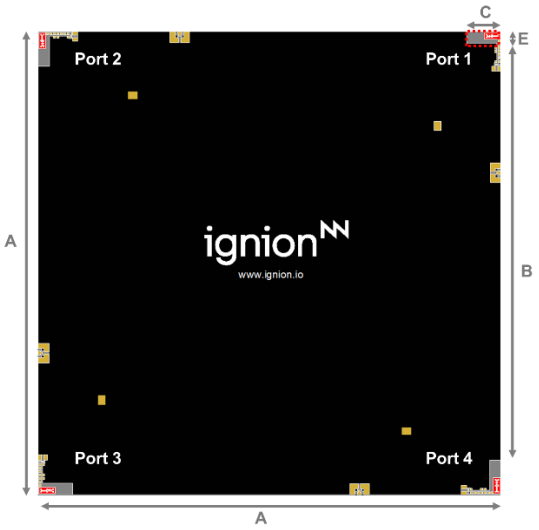
- Multiband
- High efficiency
- Small size
- Cost-effective
- Easy-to-use (pick and place)
- Off-the-Shelf standard product (no customization is required)

The ONE mXTEND™ antenna booster belongs to a new generation of antenna solutions based upon the Virtual Antenna® technology owned by Ignion. This technology replaces conventional and custom antenna solutions with a new class of antenna boosters, delivered in the form of a new range of miniature and off-the-shelf chip antenna components. These new chip antennas are multiband and multipurpose. They fit in a variety of wireless platforms to provide a wireless link at many different communication services. By using a Virtual Antenna® component the design becomes more predictable compared to a custom solution, making the whole process ***faster, cost effective and simple.***

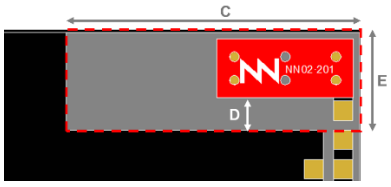
2.1 CONFIGURATION 1: ANTENNAS ON THE CORNERS

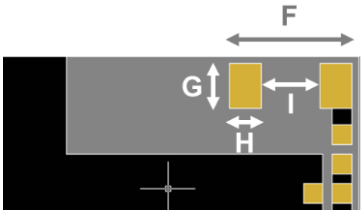
2.1.1 EVALUATION BOARD

The performance of the ONE mXTEND™ antenna boosters in MIMO 4x4 configuration operating in the Wi-Fi 6E frequency bands is simulated in an access point size Evaluation Board (200 mm x 200 mm). This application note is intended to illustrate on one hand, how the ONE mXTEND™ works in a MIMO 4x4 configuration, and on the other hand, how our ONE mXTEND™ antenna booster can be easily adapted to the different scenarios by simply adjusting the matching network design. The antenna part remains the same and the operating frequencies can be easily tuned by properly adjusting the matching network.



200mm x 200mm (AxA)





Measure	mm	Measure	mm
A	200	**F**	6.3
B	180	**G**	2.3
C	15	**H**	1.65
D	2.0	**I**	3.0
E	5.0		

Tolerance: ±0.2 mm

D: Distance between the ONE mXTEND™ antenna booster and the ground plane.

Material: The evaluation board is built on FR4 substrate. Thickness is 1 mm.

Clearance Area: 15 mm x 5.0 mm (CxE) (indicated in dashed red line)

Figure 1 – Evaluation board used for MIMO 4x4 with the ONE mXTEND™ antenna boosters placed in each of the corners of the PCB.

2.1.2 VSWR AND EFFICIENCY

This section explains antenna performance in terms of VSWR (Voltage Standing Wave Ratio) and Total Efficiency results versus frequency (GHz) for each of the antenna boosters for the Wi-Fi 6E frequency bands.

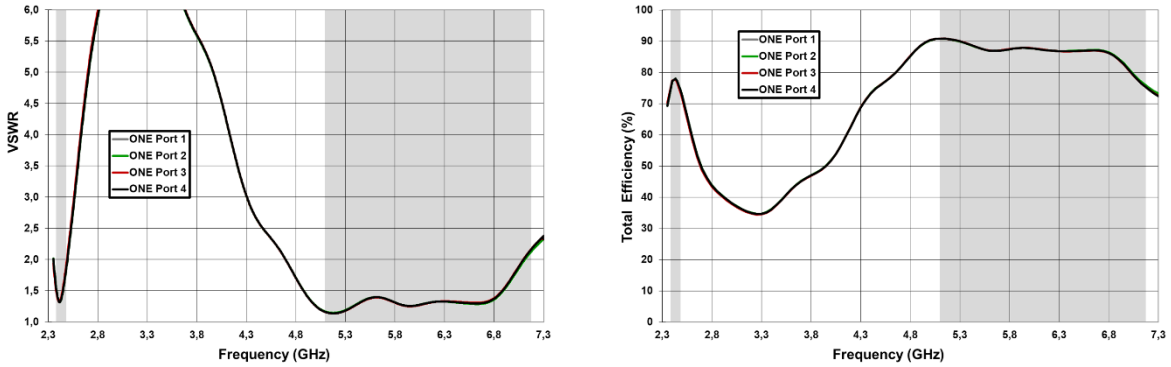


Figure 2 – VSWR and Total Efficiency for the 2.400 – 2.483 GHz frequency range and for the 5.170 – 7.125 GHz frequency range considering all the ONE mXTEND™ implemented (Figure 1).

	2.400 – 2.483GHz				
200mm x 200mm	**$\eta_{a\ 2400MHz}$**	**$\eta_{a\ 2483MHz}$**	**Min**	**Max**	**Av. η_a**
ONE Port 1	77.2	74.4	74.4	78.1	76.8
ONE Port 2	77.2	74.4	74.4	78.0	76.7
ONE Port 3	77.4	73.6	73.6	77.7	76.4
ONE Port 4	77.2	74.4	74.4	78.0	76.7

Table 1 – Antenna efficiency for 2.400 – 2.483 GHz frequency range (Figure 1).

	5.170 – 5.835GHz					5.925 – 7.125GHz				
200mm x 200mm	**$\eta_{a\ 5170MHz}$**	**$\eta_{a\ 5835MHz}$**	**Min**	**Max**	**Av. η_a**	**$\eta_{a\ 5925MHz}$**	**$\eta_{a\ 7125MHz}$**	**Min**	**Max**	**Av. η_a**
ONE Port 1	90.3	87.6	86.9	90.7	88.4	87.8	77.0	77.0	87.8	85.6
ONE Port 2	90.7	87.6	86.9	90.7	88.4	87.9	77.0	77.0	87.9	85.6
ONE Port 3	90.8	87.6	86.9	90.8	88.5	87.9	76.4	76.4	87.9	85.4
ONE Port 4	90.7	87.6	86.9	90.7	88.4	87.8	76.5	76.5	87.8	85.4

Table 2 - Antenna efficiency for 5.170 - 5.835 GHz and 5.925 – 7.125 GHz frequency ranges (Figure 1).

ONE mXTEND™ operates the required Wi-Fi 6E frequency spectrum with high efficiency values.

2.1.3 TRANSMISSION COEFFICIENTS

This section explains transmission coefficient results versus frequency (GHz) for each of the antenna boosters for the Wi-Fi 6E frequency bands.

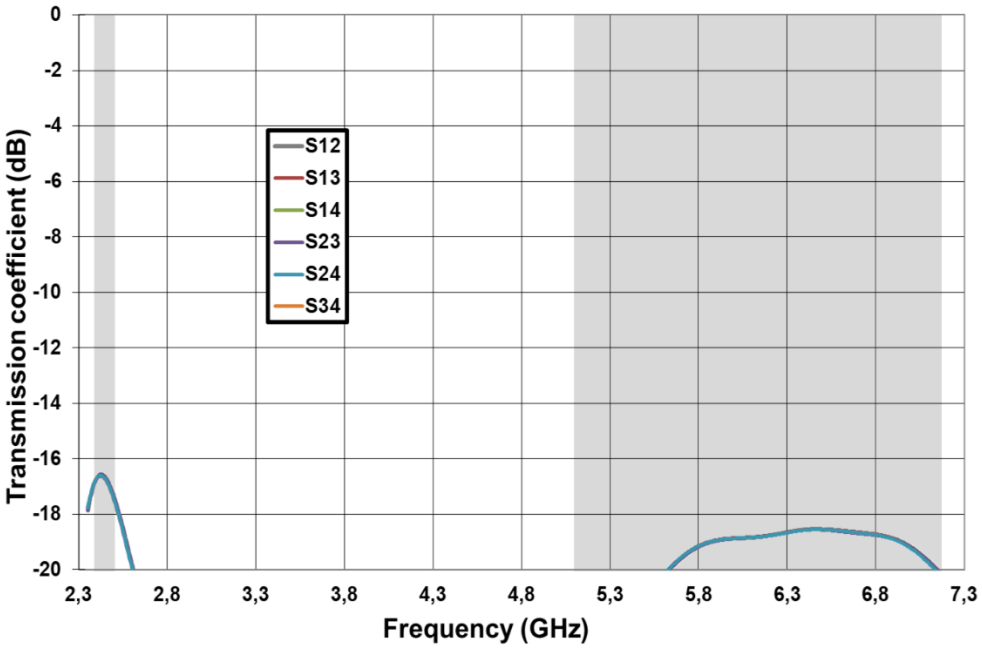


Figure 3 –Transmission coefficients for the 2.400 – 2.483 GHz frequency range and for the 5.170 – 7.125 GHz frequency range considering all the ONE mXTEND™ implemented (**Error! Reference source not found.**).

2.1.4 ENVELOPE CORRELATION COEFFICIENT (ECC) AND MULTIPLEXING EFFICIENCY

Envelope Correlation Coefficient (ECC) tells us how independent two antennas radiation patterns are. In MIMO systems, the ECC should be as low as possible, since this implies that the signals from both antennas are independent and, therefore, it is possible to increase the data transmission capacity. Multiplexing efficiency is a figure of merit that considers both correlation effects and those associated with the antenna efficiencies of each of the antennas that make up the MIMO system. This section explains ECC and Multiplexing Efficiency results versus frequency (GHz) for each of the antenna boosters for the Wi-Fi 6E frequency bands.

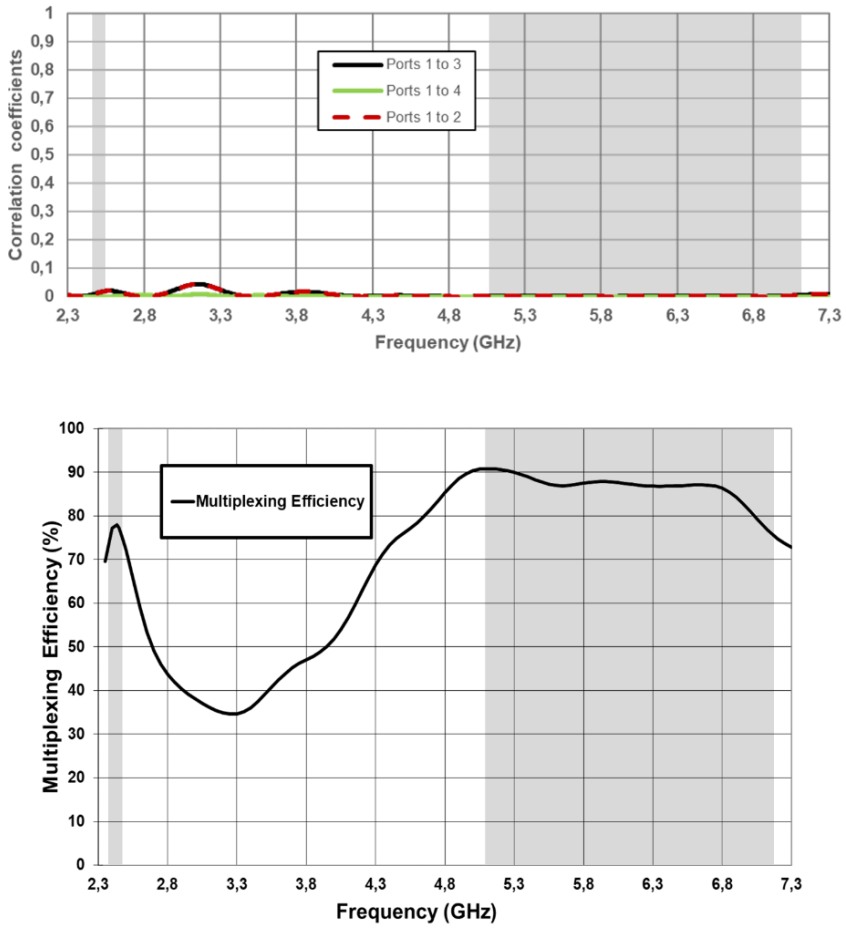


Figure 4 – Envelope Correlation Coefficient and Multiplexing efficiency for the 2.400 – 2.483 GHz frequency range and for the 5.170 – 7.125 GHz frequency range considering all the ONE mXTEND™ implemented (Figure 1).

2.1.5 MATCHING NETWORK

The ONE mXTEND™ antenna booster needs a matching network to connect to your Wi-Fi 6E transceiver. This section describes the recommended matching network topologies and values (Figure 5, Table 3 and Table 4) for each of the ONE mXTEND™ implemented (Figure 1).

Thanks to its versatility the ONE mXTEND™ antenna booster can be easily tuned to cover Wi-Fi 6E spectrum through just the proper adjustment of the matching network. The excellent tuning capabilities of the ONE mXTEND™ makes it ideal to avoid unnecessary product redesigns each time your product specifications and operating frequencies vary. It allows you to easily adapt your design to different applications, market segments, and devices through just the proper design of the matching network whilst maintaining the same antenna part.

Recommended Matching Network Topology for EB 200 mm x 200 mm

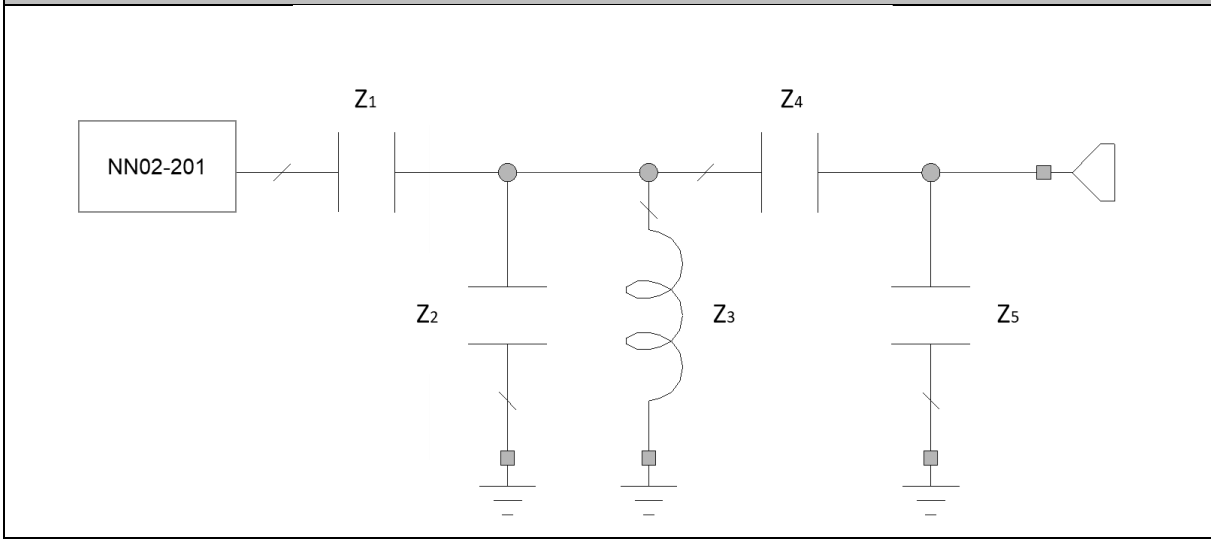


Figure 5 – Topology of the matching networks for each of the implemented antennas (Figure 1).

The matching network topology and values (Figure 5 and Table 4) remains equal for each of the implemented ONE mXTEND™. The recommended matching network component values for operating Wi-Fi 6E standards ranging from 2.400 – 2.483 GHz and 5.170 – 7.125 GHz are shown in Table 3 and Table 4.

A x A (mm)	Z_1	Z_2	Z_3	Z_4	Z_5
ONE Port 1	4.0pF	0.3pF	2.4nH	0.4pF	0.3pF
ONE Port 2	4.0pF	0.3pF	2.4nH	0.4pF	0.3pF
ONE Port 3	4.0pF	0.3pF	2.4nH	0.4pF	0.3pF
ONE Port 4	4.0pF	0.3pF	2.4nH	0.4pF	0.3pF

Table 3 - Values of the matching network components for the different antennas (Figure 1).

Value		Part Number
Z1	4.0pF	GJM1555C1H4R0WB01
Z2	0.3pF	GJM1555C1HR30WB01
Z3	2.4nH	LQW15AN2N4B80
Z4	0.4pF	GJM1555C1HR40WB01
Z5	0.3pF	GJM1555C1HR30WB01

Table 4 - Values and part numbers of the components used for the matching networks

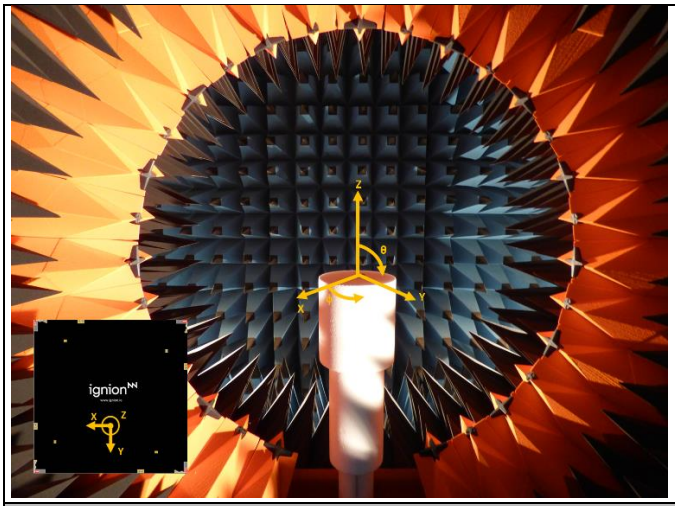
The antenna performance is always conditioned by its operating environment. Different devices with different printed circuit board sizes, components nearby the antenna, LCD's, batteries, covers, connectors, etc. may need a different matching network. Accordingly, it is highly recommended to place pads compatible with 0402 and 0603 SMD components for a matching network as close as possible to the feeding point of the antenna element in the ground plane area, not in the clearance area. This provides a degree of freedom to tune the ONE mXTEND™ antenna booster once the design is finished and takes into account all elements of the system (batteries, displays, covers, etc.). To ensure optimal results, the use of high-quality factor (Q) and tight tolerance components is highly recommended (e.g. Murata components (Table 3 and Table 4)).

If you need assistance to design your matching network beyond this application note, please contact to support@ignion.io, or if you are designing a **different device size** or a **different frequency band**, **we can assist you** in less than 24 hours. Please, try our free-of-charge[1] https://ignion.io/antenna-intelligence design service, which will get you a complete antenna design report including a custom matching network for your device in 24h[1]. Additional information related to Ignion's range of R&D services is available at: https://ignion.io/rdservices/

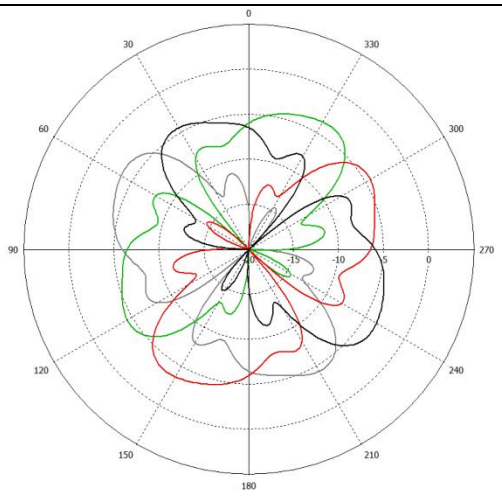
[1] See terms and conditions for a free Antenna Intelligence Cloud service in 24h at: https://www.ignion.io/antenna-intelligence/

2.1.6 RADIATION PATTERNS (2.400 - 2.483 GHz), GAIN, AND EFFICIENCY

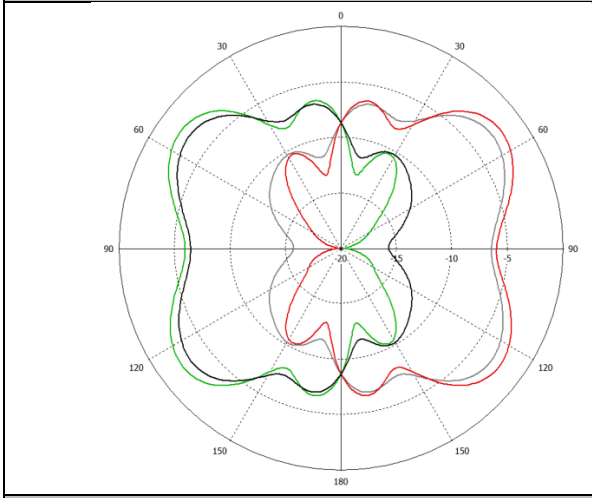
This section describes the different radiation patterns, gain and efficiency for each of the ONE mXTEND™ antenna booster implemented in the MIMO 4x4 system.



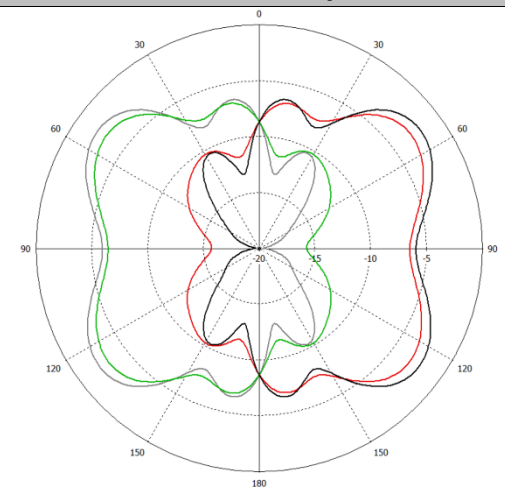
Measurement System Set-Up Evaluation Board in Plane XY



θ = 90º Plane XY at 2.450 GHz (ONE Port 1, ONE Port 2, ONE Port 3, ONE Port 4)



ϕ = 0º Plane XZ at 2.450 GHz (ONE Port 1, ONE Port 2, ONE Port 3, ONE Port 4)



ϕ = 90º Plane YZ at 2.450 GHz (ONE Port 1, ONE Port 2, ONE Port 3, ONE Port 4)

LFR Wi-Fi 6E 2.400-2.483 GHz	**Gain**	**Peak Gain**	4.8 dBi
		Average Gain across the band	4.9 dBi
		Gain Range across the band (min, max)	4.7 **<–>** 4.9 dBi
	Efficiency	**Peak Efficiency**	78.1 %
		Average Efficiency across the band	76.8 %
		Efficiency Range across the band (min, max)	74.4 – 78.1 %

Table 5 - Antenna gain and total efficiency from the Evaluation Board of ONE mXTEND™ port 1 (Figure 1) for 2.400 GHz – 2.483 GHz with the matching network of Figure 5. Simulated results obtained with CST.

LFR WiFi 6E 2.400-2.483 GHz	**Gain**	**Peak Gain**	4.9 dBi
		Average Gain across the band	4.8 dBi
		Gain Range across the band (min, max)	4.7 **<–>** 4.9 dBi
	Efficiency	**Peak Efficiency**	78.0 %
		Average Efficiency across the band	76.7 %
		Efficiency Range across the band (min, max)	74.4 – 78.0 %

Table 6 - Antenna gain and total efficiency from the Evaluation Board of ONE mXTEND™ port 2 (Figure 1) for 2.400 GHz – 2.483 GHz with the matching network of Figure 5. Simulated results obtained with CST.

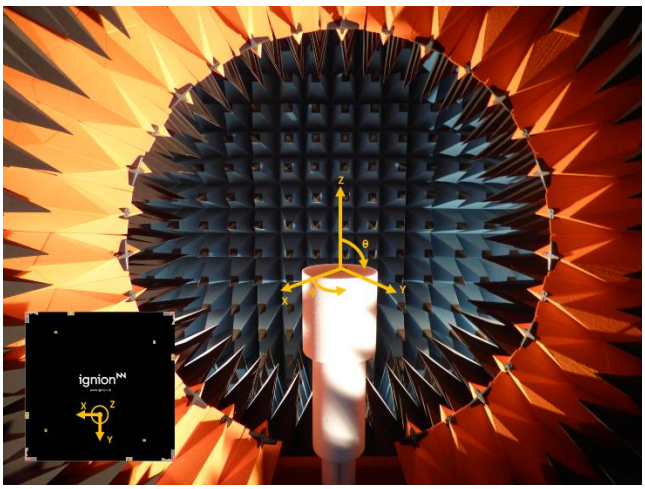
LFR Wi-Fi 6E 2.400-2.483GHz	**Gain**	**Peak Gain**	4.8 dBi
		Average Gain across the band	4.8 dBi
		Gain Range across the band (min, max)	4.7 **<–>** 4.8 dBi
	Efficiency	**Peak Efficiency**	77.7 %
		Average Efficiency across the band	76.4 %
		Efficiency Range across the band (min, max)	73.6 – 77.7 %

Table 7 – Antenna gain and total efficiency from the Evaluation Board of ONE mXTEND™ port 3 (Figure 1) for 2.400 GHz – 2.483 GHz with the matching network of Figure 5. Simulated results obtained with CST.

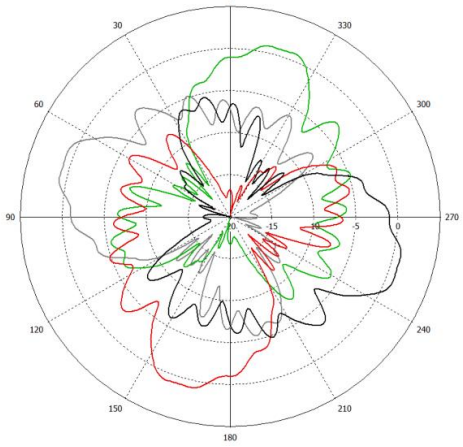
LFR Wi-Fi 6E 2.400-2.483GHz	**Gain**	**Peak Gain**	4.9 dBi
		Average Gain across the band	4.8 dBi
		Gain Range across the band (min, max)	4.7 **<–>** 4.9 dBi
	Efficiency	**Peak Efficiency**	78.0 %
		Average Efficiency across the band	76.7 %
		Efficiency Range across the band (min, max)	74.4 – 78.0 %

Table 8 – Antenna gain and total efficiency from the Evaluation Board of ONE mXTEND™ port 4 (Figure 1) for 2.400 GHz – 2.483 GHz with the matching network of Figure 5. Simulated results obtained with CST.

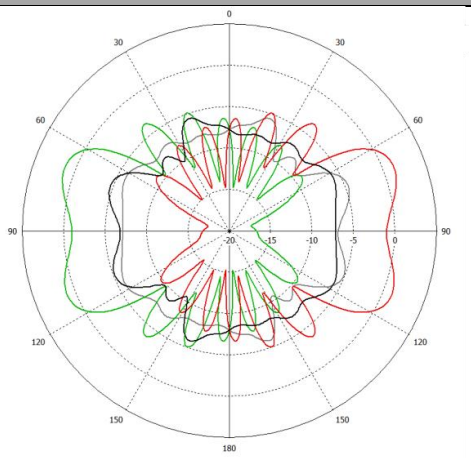
2.1.7 RADIATION PATTERNS (5.170 - 5.835 GHz), GAIN, AND EFFICIENCY



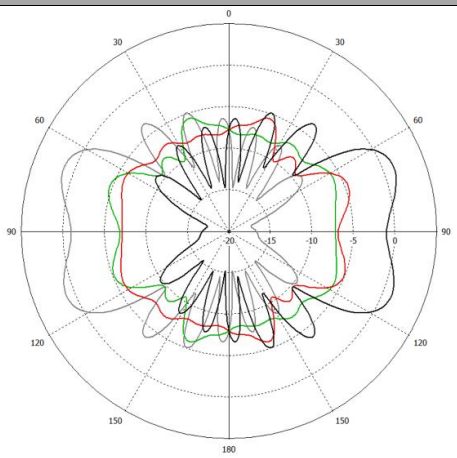
Measurement System Set-Up
Evaluation Board in Plane XY



θ = 90º Plane XY at 5.5 GHz
(ONE Port 1, ONE Port 2, ONE Port 3, ONE Port 4)



ϕ = 0º Plane XZ at 5.5 GHz
(ONE Port 1, ONE Port 2, ONE Port 3, ONE Port 4)



ϕ = 90º Plane YZ at 5.5 GHz
(ONE Port 1, ONE Port 2, ONE Port 3, ONE Port 4)

HFR Wi-Fi 6E 5.170-5.835 GHz	**Gain**	**Peak Gain**	7.7 dBi
		Average Gain across the band	7.4 dBi
		Gain Range across the band (min, max)	7.1 **<–>** 7.7 dBi
	Efficiency	**Peak Efficiency**	90.7 %
		Average Efficiency across the band	88.4 %
		Efficiency Range across the band (min, max)	86.9 – 90.7 %

Table 9 - Antenna gain and total efficiency from the Evaluation Board of ONE mXTEND™ port 1 (Figure 1) for 5.170 GHz **–** 5.835 GHz with the matching network of Figure 5. Simulated results obtained with CST.

HFR Wi-Fi 6E 5.170-5.835 GHz	**Gain**	**Peak Gain**	7.7 dBi
		Average Gain across the band	7.4 dBi
		Gain Range across the band (min, max)	7.1 **<–>** 7.7 dBi
	Efficiency	**Peak Efficiency**	90.7 %
		Average Efficiency across the band	88.4 %
		Efficiency Range across the band (min, max)	86.9 – 90.7 %

Table 10 - Antenna gain and total efficiency from the Evaluation Board of ONE mXTEND™ port 2 (Figure 1) for 5.170 GHz **–** 5.835 GHz with the matching network of Figure 5. Simulated results obtained with CST.

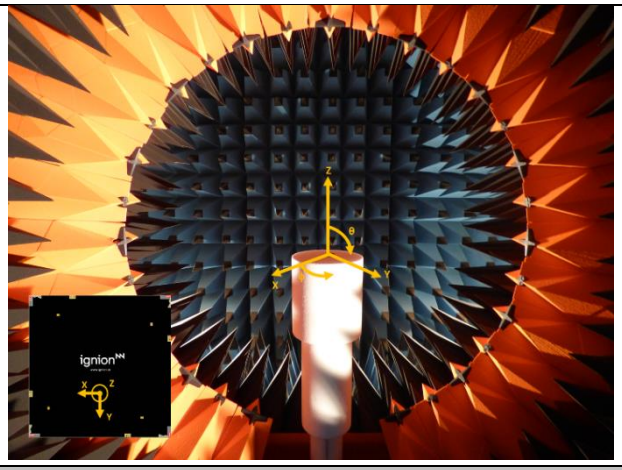
HFR Wi-Fi 6E 5.170-5.835 GHz	**Gain**	**Peak Gain**	7.7 dBi
		Average Gain across the band	7.4 dBi
		Gain Range across the band (min, max)	7.1 **<–>** 7.7 dBi
	Efficiency	**Peak Efficiency**	90.8 %
		Average Efficiency across the band	88.5 %
		Efficiency Range across the band (min, max)	86.9 – 90.8 %

Table 11 - Antenna gain and total efficiency from the Evaluation Board of ONE mXTEND™ port 3 (Figure 1) for 5.170 GHz **–** 5.835 GHz with the matching network of Figure 5. Simulated results obtained with CST.

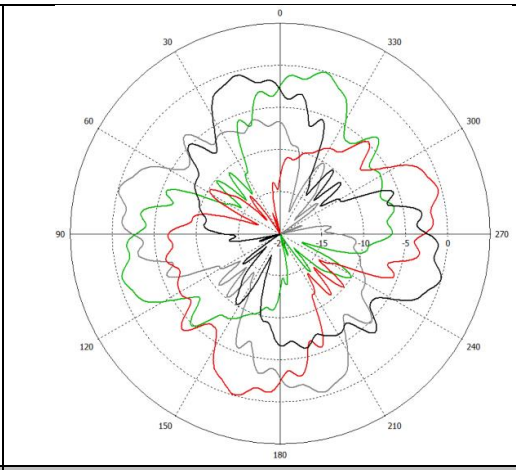
HFR Wi-Fi 6E 5.170-5.835 GHz	**Gain**	**Peak Gain**	7.7 dBi
		Average Gain across the band	7.4 dBi
		Gain Range across the band (min, max)	7.1 **<–>** 7.7 dBi
	Efficiency	**Peak Efficiency**	90.7 %
		Average Efficiency across the band	88.4 %
		Efficiency Range across the band (min, max)	86.9 – 90.7 %

Table 12 - Antenna gain and total efficiency from the Evaluation Board of ONE mXTEND™ port 4 (Figure 1) for 5.170 GHz **–** 5.835 GHz with the matching network of Figure 5. Simulated results obtained with CST.

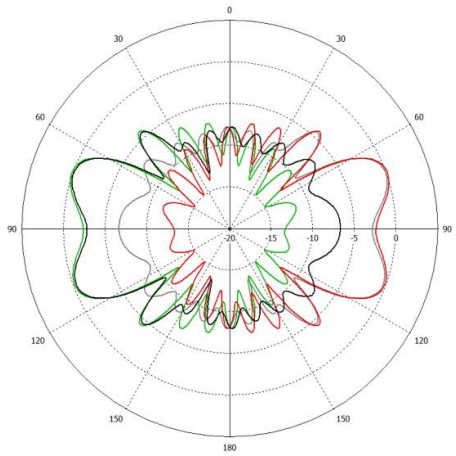
2.1.8 RADIATION PATTERNS (5.925 - 7.125 GHz), GAIN, AND EFFICIENCY



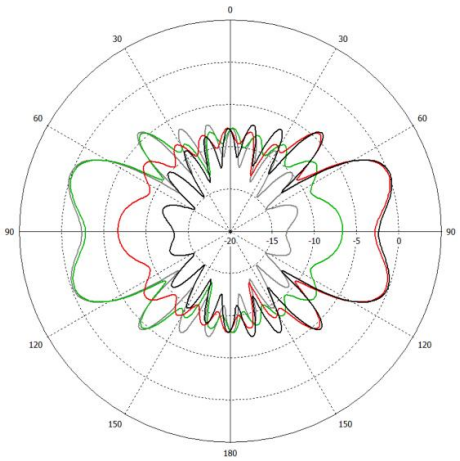
Measurement System Set-Up
Evaluation Board in Plane XY



θ = 90º Plane XY at 6.5 GHz
(ONE Port 1, ONE Port 2, ONE Port 3, ONE Port 4)



ϕ = 0º Plane XZ at 6.5 GHz
(ONE Port 1, ONE Port 2, ONE Port 3, ONE Port 4)



ϕ = 90º Plane YZ at 6.5 GHz
(ONE Port 1, ONE Port 2, ONE Port 3, ONE Port 4)

HFR Wi-Fi 6E 5.925-7.125 GHz	**Gain**	**Peak Gain**	7.0 dBi
		Average Gain across the band	6.4 dBi
		Gain Range across the band (min, max)	6.1 **<–>** 7.0 dBi
	Efficiency	**Peak Efficiency**	87.8 %
		Average Efficiency across the band	85.6 %
		Efficiency Range across the band (min, max)	77.0 – 87.8 %

Table 13 - Antenna gain and total efficiency from the Evaluation Board of ONE mXTEND™ port 1 (Figure 1) 5.925 GHz **–** 7.125 GHz with the matching network of Figure 5. Simulated results obtained with CST.

HFR Wi-Fi 6E 5.925-7.125GHz	**Gain**	**Peak Gain**	7.0 dBi
		Average Gain across the band	6.4 dBi
		Gain Range across the band (min, max)	6.1 **<–>** 7.0 dBi
	Efficiency	**Peak Efficiency**	87.9 %
		Average Efficiency across the band	85.6 %
		Efficiency Range across the band (min, max)	77.0 – 87.9 %

Table 14 - Antenna gain and total efficiency from the Evaluation Board of ONE mXTEND™ port 2 (Figure 1) 5.925 GHz **–** 7.125 GHz with the matching network of Figure 5. Simulated results obtained with CST.

HFR Wi-Fi 6E 5.925-7.125 GHz	**Gain**	**Peak Gain**	6.9 dBi
		Average Gain across the band	6.4 dBi
		Gain Range across the band (min, max)	6.1 **<–>** 6.9 dBi
	Efficiency	**Peak Efficiency**	87.9 %
		Average Efficiency across the band	85.4 %
		Efficiency Range across the band (min, max)	76.4 – 87.8 %

Table 15 – Antenna gain and total efficiency from the Evaluation Board of ONE mXTEND™ port 3 (Figure 1) 5.925 GHz – 7.125 GHz with the matching network of Figure **5**. Simulated results obtained with CST.

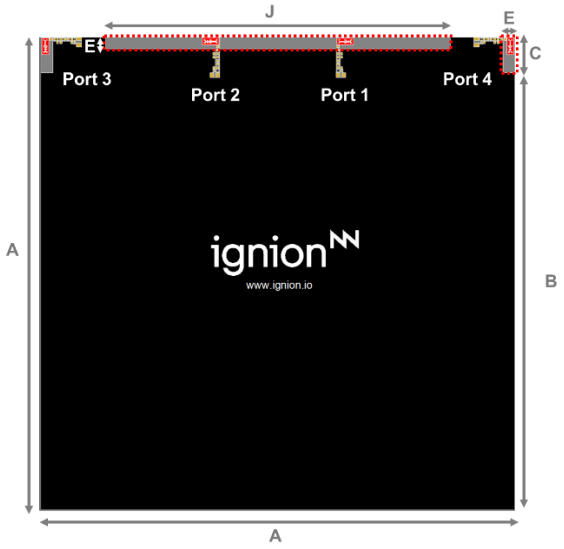
HFR Wi-Fi 6E 5.925-7.125 GHz	**Gain**	**Peak Gain**	6.9 dBi
		Average Gain across the band	6.4 dBi
		Gain Range across the band (min, max)	6.1 **<–>** 6.9 dBi
	Efficiency	**Peak Efficiency**	87.8 %
		Average Efficiency across the band	85.4 %
		Efficiency Range across the band (min, max)	76.5 – 87.8 %

Table 16 - Antenna gain and total efficiency from the Evaluation Board of ONE mXTEND™ port 4 (Figure 1) 5.925 GHz **–** 7.125 GHz with the matching network of Figure 5. Simulated results obtained with CST.

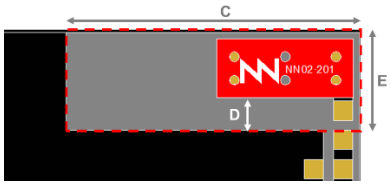
2.2 CONFIGURATION 2: ANTENNAS ON THE SAME EDGE

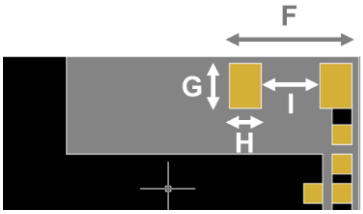
2.2.1 EVALUATION BOARD

The performance of the ONE mXTEND™ antenna boosters in MIMO 4x4 configuration operating in the Wi-Fi 6E frequency bands is measured in an access point size Evaluation Board (200 mm x 200 mm). In this section, the 4 ONE mXTEND™ are placed on the same edge of the PCB. The antenna part remains the same and the operating frequencies can be easily tuned by simply adjusting the matching network.



200mm x 200mm (AxA)





Measure	mm	Measure	mm
A	200	**F**	6.3
B	185	**G**	2.3
C	15	**H**	1.65
D	2.0	**I**	3.0
E	5.0	**J**	150

Tolerance: ±0.2 mm

D: Distance between the antenna booster and the ground plane.

Material: The evaluation board is built on FR4 substrate. Thickness is 1 mm.

Clearance Area: 15 mm x 5.0 mm (CxE) and 150 mm x 5.0 mm (JxE) (indicated in dashed red line)

Figure 6 – Evaluation board used for MIMO 4x4 with 4 ONE mXTEND™ antenna boosters placed in the same edge of the PCB.

Please note that the ONE mXTEND™ is a versatile antenna solution that can cover other frequency ranges besides those covered in this document. If your device is to operate in any other band, please contact to support@ignion.io for assistance. We are here to help.

2.2.2 VSWR AND EFFICIENCY

This section explains the antenna performance in terms of VSWR (Voltage Standing Wave Ratio) and Total Efficiency results versus frequency (GHz) for the Wi-Fi 6E frequency bands.

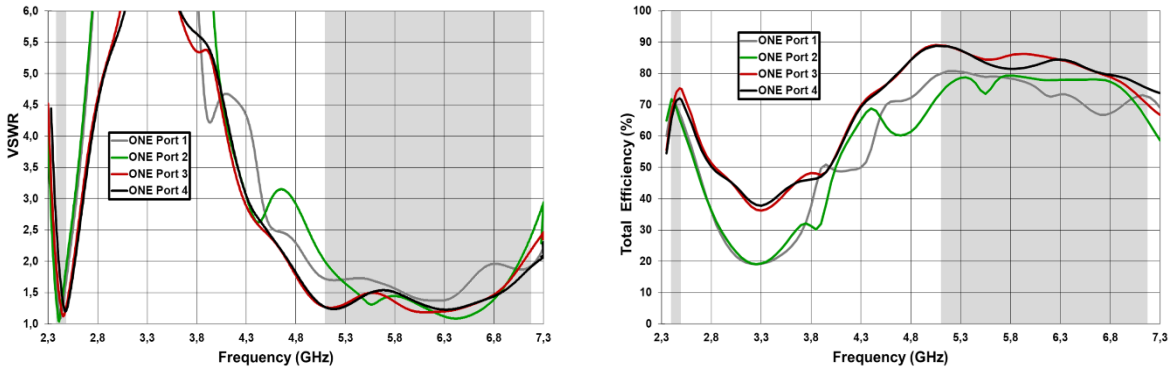


Figure 7 – VSWR and Total Efficiency for the 2.400 – 2.483 GHz frequency range and for the 5.170 – 7.125 GHz frequency range considering all the ONE mXTEND™ implemented (Figure 6).

	2.400 – 2.483GHz				
200mm x 200mm	**$\eta_{a\ 2400MHz}$**	**$\eta_{a\ 2483MHz}$**	**Min**	**Max**	**Av. η_a**
ONE Port 1	69.3	67.2	67.2	70.3	69.1
ONE Port 2	71.8	65.3	65.3	71.8	69.0
ONE Port 3	67.6	75.2	67.6	75.2	72.4
ONE Port 4	65.6	72.0	65.6	72.0	69.8

Table 17 – Antenna efficiency for 2.400 – 2.483 GHz frequency range (Figure 6).

	5.170 – 5.835GHz					5.925 – 7.125GHz				
200mm x 200mm	**$\eta_{a\ 5170MHz}$**	**$\eta_{a\ 5835MHz}$**	**Min**	**Max**	**Av. η_a**	**$\eta_{a\ 5925MHz}$**	**$\eta_{a\ 7125MHz}$**	**Min**	**Max**	**Av. η_a**
ONE Port 1	80.6	78.2	78.2	80.7	79.5	77.5	73.1	66.8	77.5	71.8
ONE Port 2	76.2	79.2	73.4	79.3	77.4	78.9	67.2	67.2	78.9	76.5
ONE Port 3	88.6	86.1	84.4	88.6	86.0	86.3	71.5	71.5	86.3	81.1
ONE Port 4	88.7	81.5	81.5	88.7	84.6	81.7	76.0	76.0	84.5	81.1

Table 18 - Antenna efficiency for 5.170 - 5.835 GHz and 5.925 – 7.125 GHz frequency ranges (Figure 6).

ONE mXTEND™ operates the required Wi-Fi 6E frequency spectrum with high efficiency values.

2.2.3 TRANSMISSION COEFFICIENTS

This section explains transmission coefficient results versus frequency (GHz) for each of the antenna boosters for the Wi-Fi 6E frequency bands.

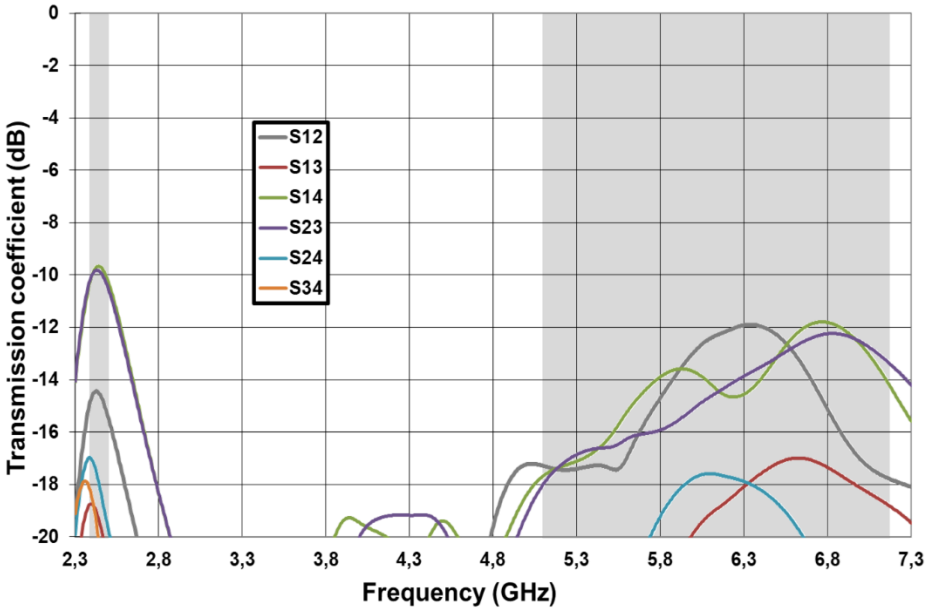


Figure 8 – Transmission coefficients for the 2.400 – 2.483 GHz frequency range and for the 5.170 – 7.125 GHz frequency range considering all the ONE mXTEND™ implemented (Figure 6).

2.2.4 ENVELOPE CORRELATION COEFFICIENT (ECC) AND MULTIPLEXING EFFICIENCY

Envelope Correlation Coefficient (ECC) tells us how independent two antennas radiation patterns are. In MIMO systems, the ECC should be as low as possible, since this implies that the signals from both antennas are independent and, therefore, it is possible to increase the data transmission capacity. Multiplexing efficiency is a figure of merit that considers both correlation effects and those associated with the antenna efficiencies of each of the antennas that make up the MIMO system. This section explains ECC and Multiplexing Efficiency results versus frequency (GHz) for each of the antenna boosters for the Wi-Fi 6E frequency bands.

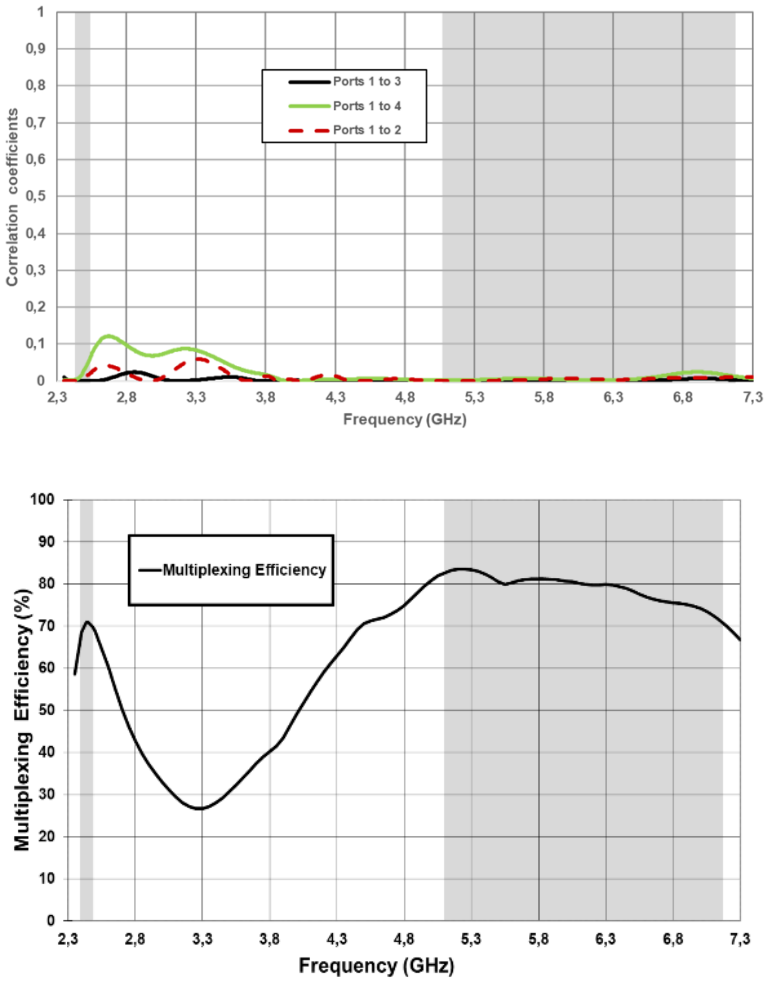


Figure 9 – Envelope Correlation Coefficient and Multiplexing efficiency for the 2.400 – 2.483 GHz frequency range and for the 5.170 – 7.125 GHz frequency range considering all the ONE mXTEND™ implemented (Figure 6).

2.2.5 MATCHING NETWORK

The ONE mXTEND™ antenna booster needs a matching network to connect to your Wi-Fi 6E transceiver. This section describes the recommended matching network topologies and values (Figure 10, Table 19 and Table 20) for each of the ONE mXTEND™ implemented (Figure 6).

Thanks to its versatility, the ONE mXTEND™ antenna booster can be easily tuned to cover Wi-Fi 6E spectrum through just the proper adjustment of the matching network. The excellent tuning capabilities of the ONE mXTEND™ makes it ideal to avoid unnecessary product redesigns each time your product specifications and operating frequencies vary. It allows you to easily adapt your design to different applications, market segments, and devices through just the proper design of the matching network whilst maintaining the same antenna.

Recommended Matching Network Topology for EB 200mm x 200mm

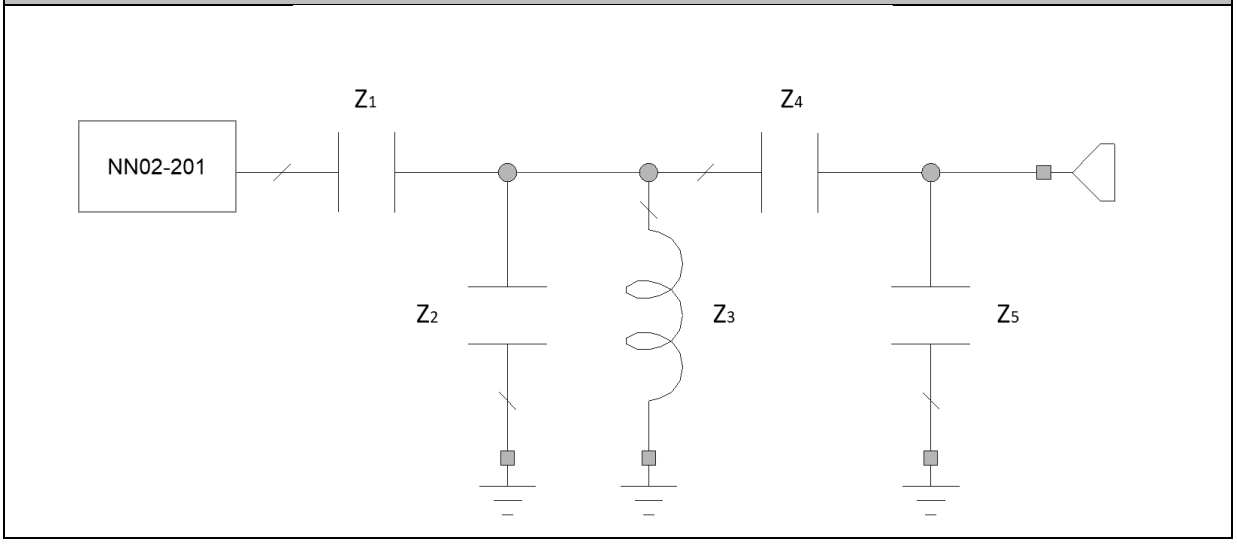


Figure 10 – Topology of the matching networks for each of the antennas (Figure 6).

The matching network topology (Figure 10) remains equal for each of the implemented ONE mXTEND™ antenna boosters and just the values of the matching network components must be adjusted to tune the antenna performance to the required operating frequency bands. The recommended matching network component values for operating the Wi-Fi 6E standards ranging from 2.400 – 2.483 GHz and 5.170 – 7.125 GHz are shown in Table 19 and Table 20.

A x A (mm)	Z_1	Z_2	Z_3	Z_4	Z_5
ONE Port 1	1.3nH	1.2pF	13pF	0.7pF	0.2pF
ONE Port 2	1.3nH	0.8pF	15pF	0.7pF	0.2pF
ONE Port 3	5.0pF	0.3pF	2.3nH	0.4pF	0.3pF
ONE Port 4	5.0pF	0.3pF	2.3nH	0.4pF	0.3pF

Table 19 - Values of the matching network components for the different antennas (Figure 6).

Value		Part Number
Z1	1.3nH	LQW15AN1N3C80
	1.3nH	LQW15AN1N3C80
	5.0pF	GJM1555C1H5R0WB01
	5.0pF	GJM1555C1H5R0WB01
Z2	1.2pF	GJM1555C1H1R2WB01
	0.8pF	GJM1555C1HR80WB01
	0.3pF	GJM1555C1HR30WB01
	0.3pF	GJM1555C1HR30WB01
Z3	13 pF	GJM1555C1H130GB01
	15 pF	GJM1555C1H150FB01
	2.3nH	LQW15AN2N3G80
	2.3nH	LQW15AN2N3G80
Z4	0.7pF	GJM1555C1HR70WB01
	0.7pF	GJM1555C1HR70WB01
	0.4pF	GJM1555C1HR40WB01
	0.4pF	GJM1555C1HR40WB01
Z5	0.2pF	GJM1555C1HR20WB01
	0.2pF	GJM1555C1HR20WB01
	0.3pF	GJM1555C1HR30WB01
	0.3pF	GJM1555C1HR30WB01

Table 20 - Values and part numbers of the components used for the matching networks.

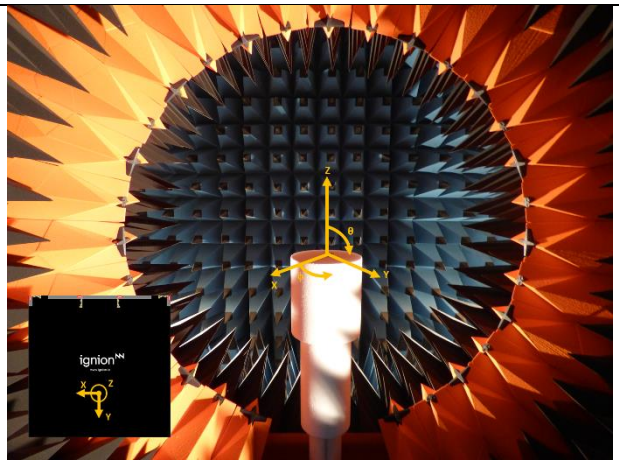
The antenna performance is always conditioned by its operating environment. Different devices with different printed circuit board sizes, components nearby the antenna, LCD's, batteries, covers, connectors, etc. may need a different matching network. Accordingly, it is highly recommended placing pads compatible with 0402 and 0603 SMD components for a matching network as close as possible to the feeding point of the antenna element in the ground plane area, not in the clearance area. This provides a degree of freedom to tune the ONE mXTEND™ antenna booster once the design is finished and takes into account all elements of the system (batteries, displays, covers, etc.). To ensure optimal results, the use of high-quality factor (Q) and tight tolerance components is highly recommended (e.g. Murata components (Table 20)).

If you need assistance to design your matching network beyond this application note, please contact support@ignion.io, or if you are designing a **different device size** or a **different frequency band**, **we can assist you** in less than 24 hours. Please, try our free-of-charge[1] **Antenna Intelligence Cloud** design service (https://ignion.io/antenna-intelligence/), you will get your complete design report including a custom matching network for your device in 24h[2]. Additional information related to NN's range of R&D services is available at: https://ignion.io/rdservices/

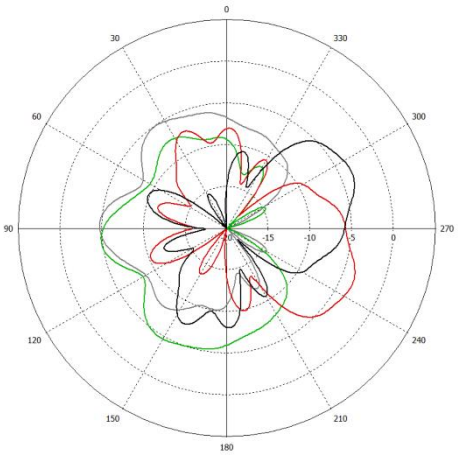
[2] See terms and conditions for a free Antenna Intelligence Cloud service in 24h at: https://www.ignion.io/antenna-intelligence/

2.2.6 RADIATION PATTERNS (2.400 - 2.483 GHz), GAIN, AND EFFICIENCY

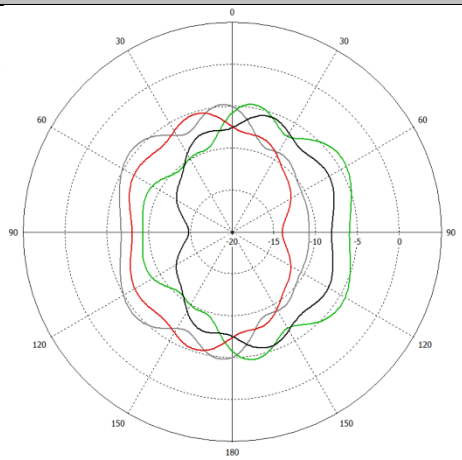
This section describes the different radiation patterns, gain and efficiency for each of the ONE mXTEND™ antenna boosters implemented in the MIMO 4x4 system.



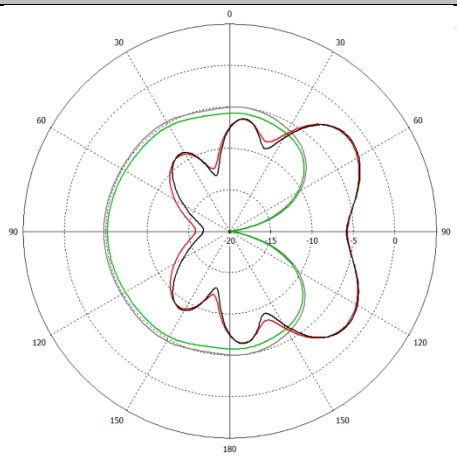
Measurement System Set-Up Evaluation Board in Plane XY



θ = 90º Plane XY at 2.450 GHz (ONE Port 1, ONE Port 2, ONE Port 3, ONE Port 4)



ϕ = 0º Plane XZ at 2.45 GHz (ONE Port 1, ONE Port 2, ONE Port 3, ONE Port 4)



ϕ = 90º Plane YZ at 2.45 GHz (ONE Port 1, ONE Port 2, ONE Port 3, ONE Port 4)

LFR Wi-Fi 6E 2.400-2.483 GHz	**Gain**	**Peak Gain**	1.7 dBi
		Average Gain across the band	1.6 dBi
		Gain Range across the band (min, max)	1.4 **<–>** 1.7 dBi
	Efficiency	**Peak Efficiency**	70.3 %
		Average Efficiency across the band	69.1 %
		Efficiency Range across the band (min, max)	67.2 – 70.3 %

Table 21 - Antenna gain and total efficiency from the Evaluation Board of ONE mXTEND™ port 1 (Figure 6) for 2.400 GHz – 2.483 GHz with the matching network of Figure 10. Simulated results obtained with CST.

LFR Wi-Fi 6E 2.400-2.483 GHz	**Gain**	**Peak Gain**	2.0 dBi
		Average Gain across the band	1.8 dBi
		Gain Range across the band (min, max)	1.7 **<–>** 2.0 dBi
	Efficiency	**Peak Efficiency**	71.8 %
		Average Efficiency across the band	69.0 %
		Efficiency Range across the band (min, max)	65.3 – 71.8 %

Table 22 - Antenna gain and total efficiency from the Evaluation Board of ONE mXTEND™ port 2 (Figure 6) for 2.400 GHz – 2.483 GHz with the matching network of Figure 10. Simulated results obtained with CST.

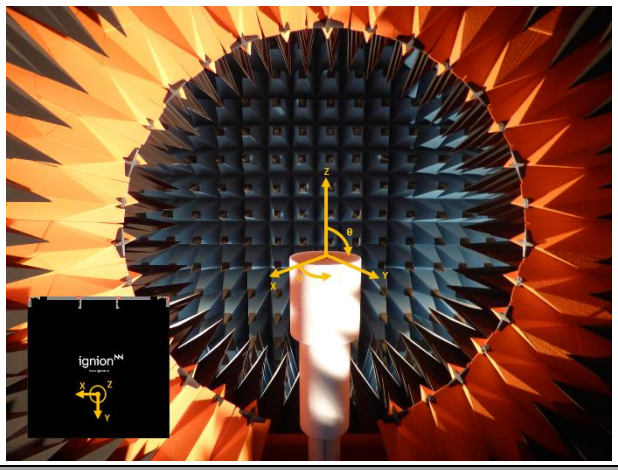
LFR Wi-Fi 6E 2.400-2.483 GHz	**Gain**	**Peak Gain**	5.7 dBi
		Average Gain across the band	5.6 dBi
		Gain Range across the band (min, max)	5.5 **<–>** 5.7 dBi
	Efficiency	**Peak Efficiency**	75.2 %
		Average Efficiency across the band	72.4 %
		Efficiency Range across the band (min, max)	67.6 – 75.2 %

Table 23 – Antenna gain and total efficiency from the Evaluation Board of ONE mXTEND™ port 3 (Figure 6) for 2.400 GHz – 2.483 GHz with the matching network of Figure 10. Simulated results obtained with CST.

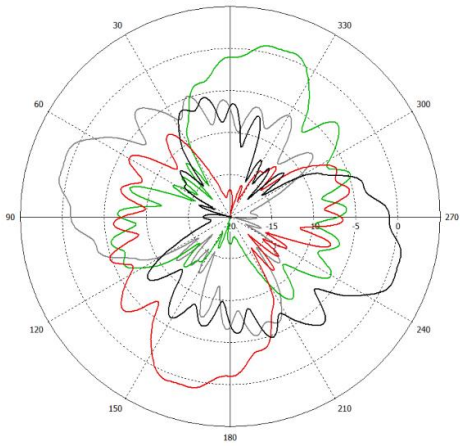
LFR Wi-Fi 6E 2.400-2.483 GHz	**Gain**	**Peak Gain**	5.6 dBi
		Average Gain across the band	5.5 dBi
		Gain Range across the band (min, max)	5.4 **<–>** 5.6 dBi
	Efficiency	**Peak Efficiency**	72.0 %
		Average Efficiency across the band	69.8 %
		Efficiency Range across the band (min, max)	65.6 – 72.0 %

Table 24 – Antenna gain and total efficiency from the Evaluation Board of ONE mXTEND™ port 4 (Figure 6) for 2.400 GHz – 2.483 GHz with the matching network of Figure 10. Simulated results obtained with CST.

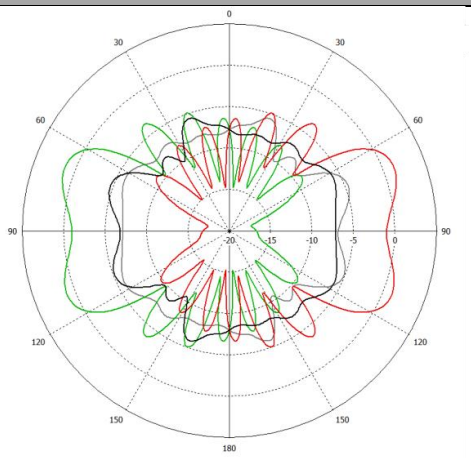
2.2.7 RADIATION PATTERNS (5.170 - 5.835 GHz), GAIN, AND EFFICIENCY



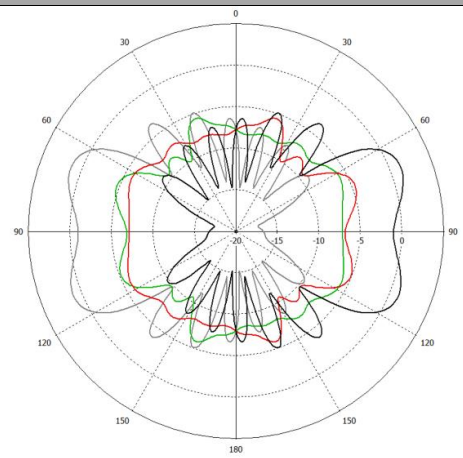
Measurement System Set-Up
Evaluation Board in Plane XY



θ = 90º Plane XY at 5.5 GHz
(ONE Port 1, ONE Port 2, ONE Port 3, ONE Port 4)



ϕ = 0º Plane XZ at 5.5 GHz
(ONE Port 1, ONE Port 2, ONE Port 3, ONE Port 4)



ϕ = 90º Plane YZ at 5.5 GHz
(ONE Port 1, ONE Port 2, ONE Port 3, ONE Port 4)

HFR Wi-Fi 6E 5.170-5.835 GHz	**Gain**	**Peak Gain**	4.9 dBi
		Average Gain across the band	4.8 dBi
		Gain Range across the band (min, max)	4.4 **<–>** 4.9 dBi
	Efficiency	**Peak Efficiency**	80.7 %
		Average Efficiency across the band	79.5 %
		Efficiency Range across the band (min, max)	78.2 – 80.7 %

Table 25 - Antenna gain and total efficiency from the Evaluation Board of ONE mXTEND™ port 1 (Figure 6) for 5.170 GHz **–** 5.835 GHz with the matching network of Figure 10. Simulated results obtained with CST.

HFR Wi-Fi 6E 5.170-5.835 GHz	**Gain**	**Peak Gain**	5.6 dBi
		Average Gain across the band	5.2 dBi
		Gain Range across the band (min, max)	4.5 **<–>** 5.6 dBi
	Efficiency	**Peak Efficiency**	79.3 %
		Average Efficiency across the band	77.4 %
		Efficiency Range across the band (min, max)	73.4 – 79.3 %

Table 26 - Antenna gain and total efficiency from the Evaluation Board of ONE mXTEND™ port 2 (Figure 6) for 5.170 GHz **–** 5.835 GHz with the matching network of Figure 10. Simulated results obtained with CST.

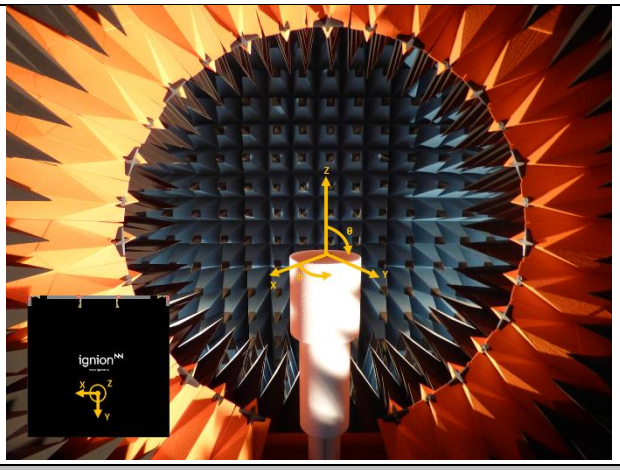
HFR Wi-Fi 6E 5.170-5.835 GHz	**Gain**	**Peak Gain**	7.3 dBi
		Average Gain across the band	7.1 dBi
		Gain Range across the band (min, max)	6.9 **<–>** 7.3 dBi
	Efficiency	**Peak Efficiency**	88.6 %
		Average Efficiency across the band	86.0 %
		Efficiency Range across the band (min, max)	84.4 – 88.6 %

Table 27 - Antenna gain and total efficiency from the Evaluation Board of ONE mXTEND™ port 3 (Figure 6) for 5.170 GHz **–** 5.835 GHz with the matching network of Figure 10. Simulated results obtained with CST.

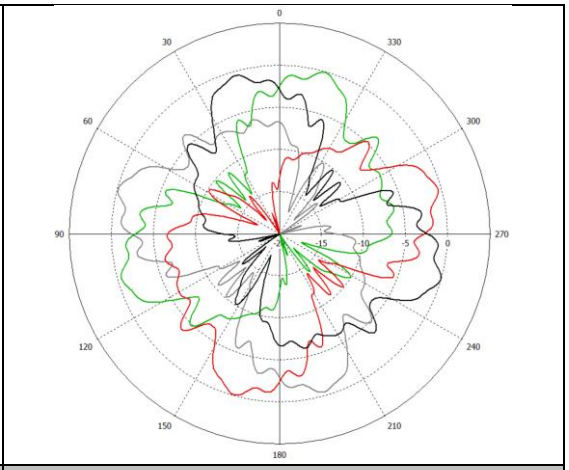
HFR Wi-Fi 6E 5.170-5.835 GHz	**Gain**	**Peak Gain**	7.6 dBi
		Average Gain across the band	7.2 dBi
		Gain Range across the band (min, max)	6.7 **<–>** 7.6 dBi
	Efficiency	**Peak Efficiency**	88.7 %
		Average Efficiency across the band	84.6 %
		Efficiency Range across the band (min, max)	81.5 – 88.7 %

Table 28 - Antenna gain and total efficiency from the Evaluation Board of ONE mXTEND™ port 4 (Figure 6) for 5.170 GHz **–** 5.835 GHz with the matching network of Figure 10. Simulated results obtained with CST.

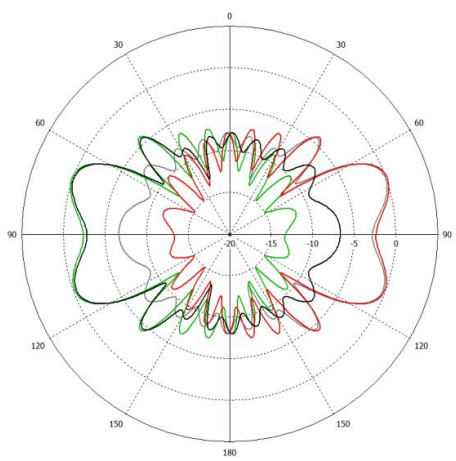
2.2.8 RADIATION PATTERNS (5.925 - 7.125 GHz), GAIN, AND EFFICIENCY



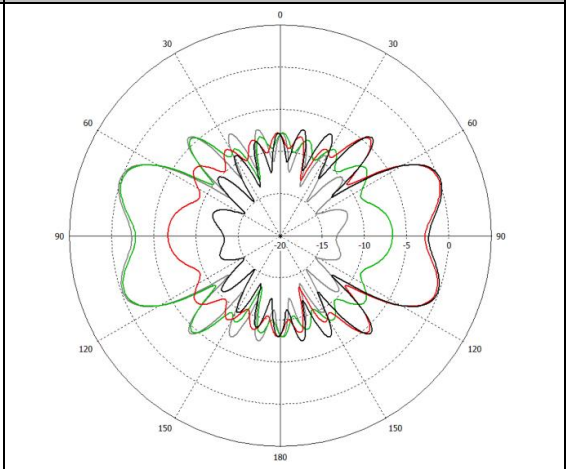
Measurement System Set-Up Evaluation Board in Plane XY



θ = 90º Plane XY at 6.5 GHz (ONE Port 1, ONE Port 2, ONE Port 3, ONE Port 4)



ϕ = 0º Plane XZ at 6.5 GHz (ONE Port 1, ONE Port 2, ONE Port 3, ONE Port 4)



ϕ = 90º Plane YZ at 6.5 GHz (ONE Port 1, ONE Port 2, ONE Port 3, ONE Port 4)

HFR Wi-Fi 6E 5.925-7.125 GHz	**Gain**	**Peak Gain**	5.4 dBi
		Average Gain across the band	4.8 dBi
		Gain Range across the band (min, max)	3.6 **<–>** 5.4 dBi
	Efficiency	**Peak Efficiency**	77.5 %
		Average Efficiency across the band	71.8 %
		Efficiency Range across the band (min, max)	66.8 – 77.5 %

Table 29 - Antenna gain and total efficiency from the Evaluation Board of ONE mXTEND™ port 1 (Figure 6) for 5.925 GHz **–** 7.125 GHz with the matching network of Figure 10. Simulated results obtained with CST.

HFR Wi-Fi 6E 5.925-7.125 GHz	**Gain**	**Peak Gain**	5.3 dBi
		Average Gain across the band	4.9 dBi
		Gain Range across the band (min, max)	4.4 **<–>** 5.3 dBi
	Efficiency	**Peak Efficiency**	78.9 %
		Average Efficiency across the band	76.5 %
		Efficiency Range across the band (min, max)	67.2 – 78.9 %

Table 30 - Antenna gain and total efficiency from the Evaluation Board of ONE mXTEND™ port 2 (Figure 6) for 5.925 GHz **–** 7.125 GHz with the matching network of Figure 10. Simulated results obtained with CST.

HFR Wi-Fi 6E 5.925-7.125 GHz	**Gain**	**Peak Gain**	7.0 dBi
		Average Gain across the band	6.1 dBi
		Gain Range across the band (min, max)	5.2 **<–>** 7.0 dBi
	Efficiency	**Peak Efficiency**	86.3 %
		Average Efficiency across the band	81.1 %
		Efficiency Range across the band (min, max)	71.5 – 86.3 %

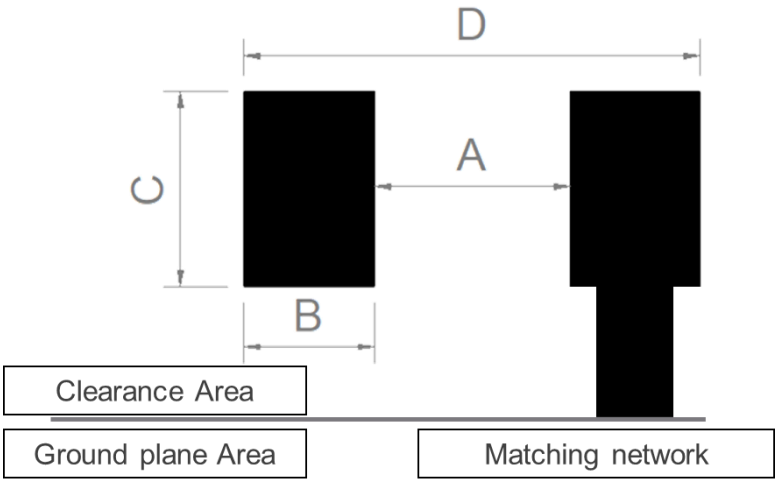
Table 31 – Antenna gain and total efficiency from the Evaluation Board of ONE mXTEND™ port 3 (Figure 6) for 5.925 GHz **–** 7.125 GHz with the matching network of Figure 10. Simulated results obtained with CST.

HFR Wi-Fi 6E 5.925-7.125 GHz	**Gain**	**Peak Gain**	6.8 dBi
		Average Gain across the band	6.3 dBi
		Gain Range across the band (min, max)	5.8 **<–>** 6.8 dBi
	Efficiency	**Peak Efficiency**	84.5 %
		Average Efficiency across the band	81.1 %
		Efficiency Range across the band (min, max)	76.0 – 84.5 %

Table 32 – Antenna gain and total efficiency from the Evaluation Board of ONE mXTEND™ port 4 (Figure 6) for 5.925 GHz **–** 7.125 GHz with the matching network of Figure 10. Simulated results obtained with CST.

2.3 RECOMMENDED ANTENNA FOOTPRINT FOR NN02-201

The ONE mXTEND™ antenna booster (NN02-201) must be placed as close as possible to a corner of the PCB. See below the recommended footprint dimensions when it is placed close to a corner of the PCB with the feeding line aligned with the longest side of the board according to the Evaluation Board (Figure 1).



Measure	mm
A	3.0
B	1.65
C	2.3
D	6.3

Tolerance: ±0.05mm

Figure 11 - Footprint dimensions for the ONE mXTEND™ (NN02-201) antenna booster.

Do you need further assistance with your antenna for your device?

Use our **Antenna Intelligence Cloud service** and get your ready-to-test antenna design especially simulated for your project **free of charge**[1], and in **24 hours**.

https://ignion.io/antenna-intelligence/

The ONE mXTEND™ antenna booster and other Ignion products are based upon proprietary Virtual Antenna™ technology that are protected by one or more of the following https://ignion.io/files/PL_NN02-201.pdf

Ignion is an ISO 9001:2015 certified company. All our antennas are lead-free and RoHS and REACH compliant.

ISO 9001: 2015 Certified

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