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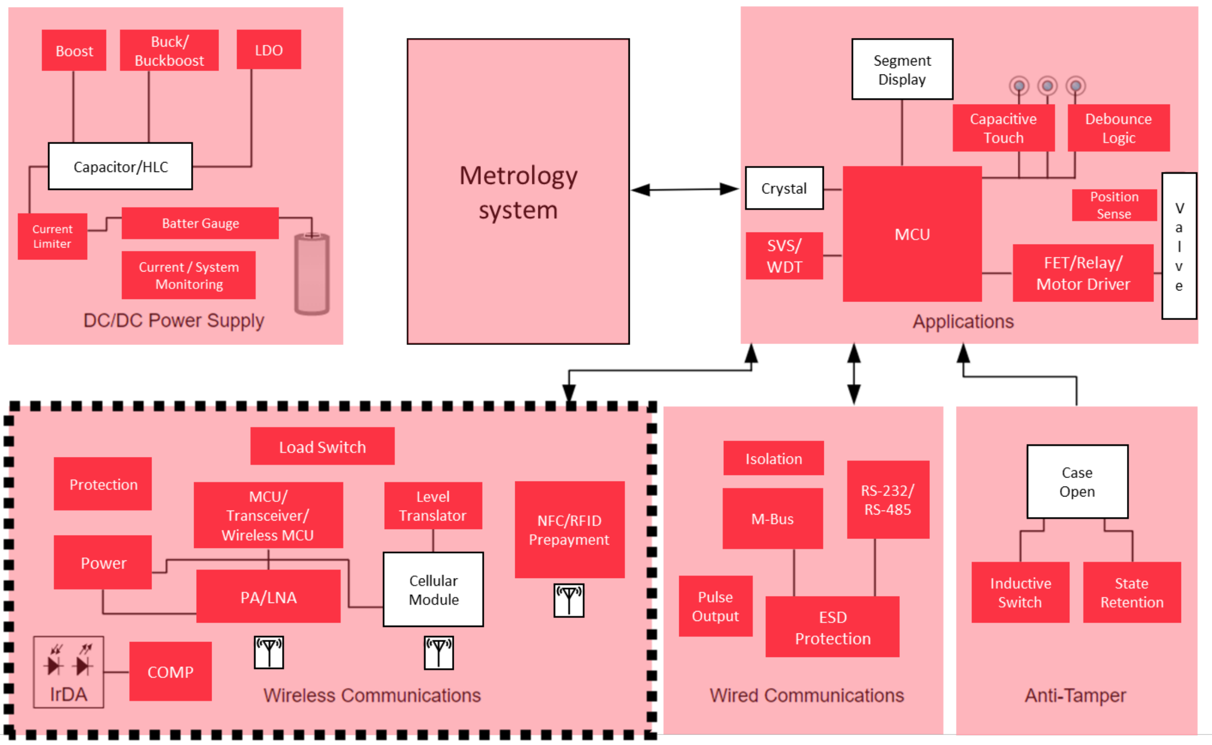
Smart meter antenna design guidelines

APPLICATION NOTE
RUN mXTEND^{TM} (NN02-224)

SMART METERING

Nowadays, the main challenges faced by smart meter manufacturers, when designing a new metering device, are price, size, global coverage, long range and considering surrounding environments that could affect the overall performance.
Any wireless smart metering device's data transmission has to be completely reliable, therefore, the antenna is a critical component in such device.
First, chip antenna technology is perfect for providing cost savings in your smart meter production. It is often a lower cost component than an external antenna or FPC, and, by being SMD pick and place, it provides savings on assembly costs.
The internally mounted chip antenna provides the benefit of increased protection against environmental factors and vandalism compared to an external antenna. Our patented technology, Virtual antenna® allows for the same antenna part to cover multiple frequency bands simultaneously and offers any device designer the flexibility of selecting and tuning the frequency bands simply through adjustment of the matching network. Virtual Antenna offers a predictable and optimized performance ensuring metering devices easily comply with cellular certifications.
Second, Virtual Antenna® components use the PCB to resonate, which enables high performance in space constrained device designs. Even with a small size Virtual Antenna® component, the metering device will perform with optimal efficiency and high gain in all the bands, helping with long-range communications.
Smart meters are subject to long product development cycles and massive deployment and installation. Altogether, this can span to several years. And it might happen that in the midst of the deployment, a new connectivity standard arises that improves the business model of the utility provider: e.g., using 5G instead of 4G or older 3G, 2G. A fast upgrade of the smart meter design becomes then very convenient and Virtual Antenna® ensures that the same component used for 3G will be capable of upgrading to 4G, 5G or any "G" with just a minimum change of the matching network. Even the same antenna can be used with non-cellular LPWAN standards such as LoRa and Sigfox.



Block Diagram of a Smart Meter

In the Block Diagram above, we see an example of a Smart Metering Application. Some of the main components within a device like this, are:

Microcontroller unit (MCU):
An MCU or MPU is an intelligent semiconductor and the main component in any device. It is what allows for the entire system to function, by translating the data programmed in it to commands that all the other components will understand an execute to deliver results. It is the brains of the module.
Choosing the best performing antenna will allow for a faster data transmission, which will lead the MPU to perform at its full capacity.

Metrology system:
Another especially important unit in a Smart Meter is the metrology system as the devices needs to constantly measure the gas flow rate within an installation in a fully accurate way in order to be able to collect data, to be sent afterwards. In the next bullet point you can read how important the antenna is for the data collected by the metrology system to be correctly sent.

Antenna (Wireless Communications):
For optimal communication efficiency, the antenna's placement is crucial, therefore, its implementation within the device's design has to be in an early stage. That early implementation has to be done also because, usually, an antenna needs a clearance area in the PCB.
At this point, Virtual Antenna® technology becomes the best solution for any metering device. It gives the customer the ability to design the antenna set-up, in-house, with no expertise required. Furthermore, the customer will also be able to fine tune the performance given its overall product's structure from the beginning.

In summary, when designing a Smart Meter Device, the customer should think about the antenna at the early stage of the design process, as the location, PCB dimension and overall mechanics of the product will all determine/impact the overall performance of the antenna. Ignion can help and guide/advise the customer, using our Antenna Services.-By choosing Virtual Antenna® technology as your antenna solution, thanks to its high RF efficiency and adaptability, you will ensure best performance in your Smart Metering Device.

Moreover, Virtual Antenna® components, by being off-the-shelf, tunable, and versatile antennas, will allow for faster development times, predictability of design from minute one and a fast and flexible adaptation to different tracking forms.
In this application note, we will review the best design practices, performance and different metrics of the RUN mXTEND™ (NN02-224) and TRIO mXTEND, our top performing multiband antennas for Smart Metering.

RUN mXTEND^{TM} – SAVING TIME AND COST: Virtual antenna^{tm} for smart meters

Forget the troubles with your meter connectivity. **Turn into smart** by using a tiny antenna booster and obtain an **accurate read on your smart meter** device **everywhere** and without troubling connection problems. Achieve a perfect **cellular communication** of your meter through an internal antenna component that is concealed and protected inside your device.

Discover in this application note how to tune the main mobile communication standards (NB-IoT, LTE-M, Sigfox, ZigBee, GSM, UMTS, LoRa, LoRaWAN, ISM, WiFi) inside any smart meter, **regardless of the meter type, form, size or frequency band (698 MHz - 2690 MHz): one single antenna component fits all.**

Either with the RUN mXTEND^{TM} or the TRIO mXTEND^{TM} antenna components, no more complications with environmental factors, the antenna is now assembled in the PCB just like another chip so, avoid the traditional external antennas problem regarding protection issues.

In addition, this surface mount nature chip components can be assembled in production using conventional pick-and-place machinery, **saving production costs,** and **increasing quality** and **reliability** to the final device.

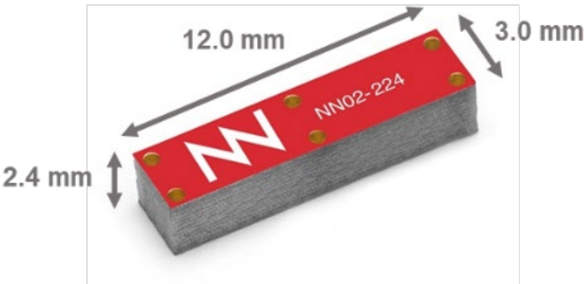
Get your meter smart ready today.

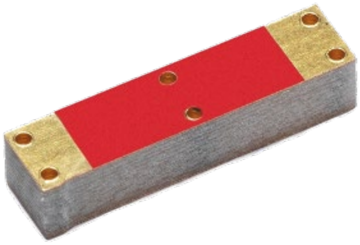
TABLE OF CONTENTS

1. PRODUCT DESCRIPTION NN02-224 AND NN03-310

In this application note we illustrate how to use the RUN mXTEND™ antenna booster (NN02-224) for operating 824-960MHz and 1710-2690MHz frequency range, or alternatively the TRIO mXTEND™ chip antenna component (NN03-310) for operating the 698-960MHz and 1710-2690MHz frequency range, which are the typically frequency ranges used in smart meters for providing cellular communication. One of the main differences between both antenna parts is that the TRIO mXTEND™ chip antenna component (NN03-310) allows operating the LTE low frequency standards, such as LTE700, with a higher antenna performance. On the other hand, RUN mXTEND™ offers a smaller footprint for meters where component size is a constrain. The tests in both cases have been performed regarding an evaluation board having the typical size of the connectivity board used in current smart meters. The results will consider the connectivity board standalone performance as well as the impact of its integration inside the main board to provide the most relevant results possible for those who design smart meters.

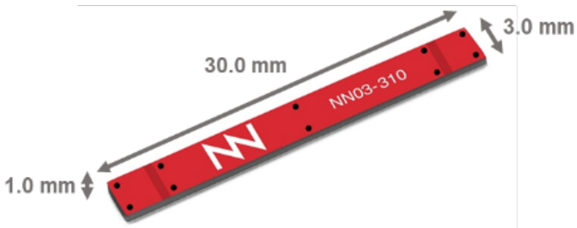
TOP **BOTTOM**





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

TOP **BOTTOM**



Material: The TRIO mXTEND™ chip antenna component is built on glass epoxy substrate.

The RUN mXTEND™ and the TRIO mXTEND™ are perfect for providing cost savings in your smart meter production. They are often a lower cost component than an external antenna and being SMD pick and place, they provide savings on assembly labor costs. Additionally, as these antennas are mounted internally, they provide the further benefit of increased protection against environmental factors compared to an external antenna. The same antenna part can be used to cover different frequency ranges, thus offering the antenna designer the flexibility of selecting the frequency regions to operate through just the customization of the matching network.

This application note helps on:

1) How to connect the connectivity board to the main board for best performance.
2) How the matching network should be configured for multiband operation at LTE bands.

APPLICATIONS

- Smart meters
- IoT devices
- Modules
- Routers
- Remote sensors

BENEFITS

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

Based on Ignion' proprietary Virtual Antenna™ technology, the RUN mXTEND™ and the TRIO mXTEND™ belong to a new generation of antenna products focused on replacing conventional antenna solutions with miniature, off-the-shelf components that drive a fast and effective design process. This breakthrough technology has been specifically designed to fit a diverse set of wireless applications – smart meters are just one of the many environments where this tiny antenna can be transformational.

2. CONNECTIVITY BOARD FOR SMART METERS – RUN mXTEND™

2.1. CONNECTIVITY BOARD ASSEMBLED TO THE MAIN BOARD

Usually, smart meters integrate a main board with all the electronics required for the electricity management as well as an adjacent connectivity board containing all the RF parts needed to transmit and receive data from/to the cellular network (Figure 1).

Measure	mm
A	131
B	60
C	190
D	10

Tolerance: ±0.2 mm

D: Distance between the main board and the connectivity board.

Clearance area: 60 mm x 11 mm

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

Figure 1 – Connectivity board (A x B) connected to the main board (A x C).

The connectivity board is connected to the main board and this connection can introduce variations in the antenna performance. This section shows the recommended case and two other alternatives set-ups in case you cannot implement the best one. In this case, the connectivity board EB_NN02-224-1B-2RJ-1P integrates a UFL cable to connect the RUN mXTEND™ antenna booster with the SMA connector. It also includes a pin connector to make the connection to the main board, whose location is marked with a red rectangle in the image above (Figure 3).

2.1.1. Recommended case

The following set-up shows the recommended case in order to maximize efficiency in your device (Figure 2). The red area shows the connection between the connectivity and main board which can be achieved by any kind of connection such as for example multi-pin connectors or flex-film. At least one ground line should connect connectivity and main board.

Connectivity board | Main board | 3D view. Connectivity board: A x B. Main board A x C

Figure 2 – Best case to connect the main and connectivity board.

Other cases: In case you cannot follow the recommended guideline shown above, there are other cases that can be used (Figure 3). However, it should be considered that the recommended case is the preferred one in order to maximize the efficiency in your device.

Figure 3 – Placement of the connection pins on the connectivity board (from left to right: set-up 1 (corner long edge), set-up 2 (corner short edge).

2.1.2. VWSR AND TOTAL EFFICIENCY

VSWR (Voltage Standing Wave Ratio) and Total Efficiency versus Frequency (GHz).

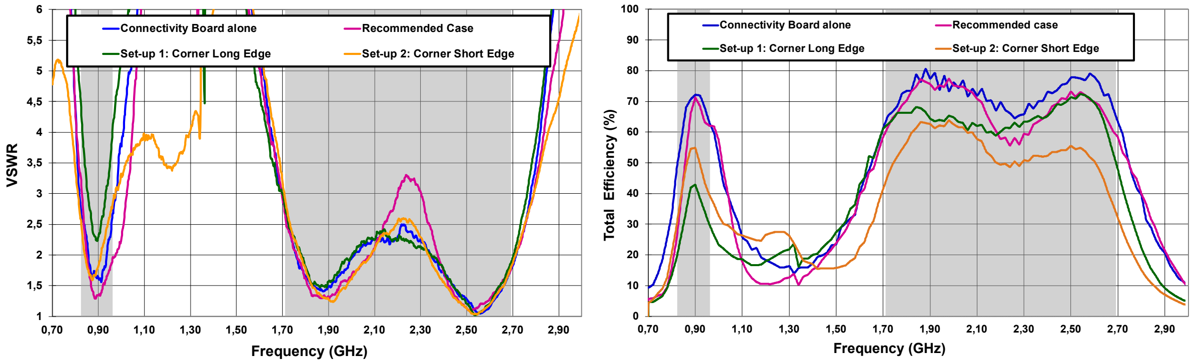


Figure 4 – VSWR and Total Efficiency for the 824 – 960 MHz frequency range and for the 1710 – 2690 MHz frequency range (the connectivity board alone; the connectivity board connected to the main board for the recommended case and two other scenarios).

	LFR (824 – 960 MHz)					HFR (1710 – 2690 MHz)				
Set-up	η_a 824MHz	η_a 960MHz	**Min**	**Max**	**Av. η_a**	η_a 1710MHz	η_a 2690MHz	**Min**	**Max**	**Av. η_a**
Connectivity board alone	49.4	63.1	49.4	72.1	66.5	63.3	65.3	63.3	80.6	72.7
Recommended case	33.1	55.8	33.1	65.8	57.3	68.8	63.7	47.6	77.4	63.5
Set-up 1: Corner Long Edge	20.6	30.0	20.3	42.9	35.0	61.9	50.5	50.7	72.4	64.7
Set-up 2: Corner Short Edge	30.9	39.6	30.5	54.9	46.7	43.6	34.3	34.5	63.8	54.2

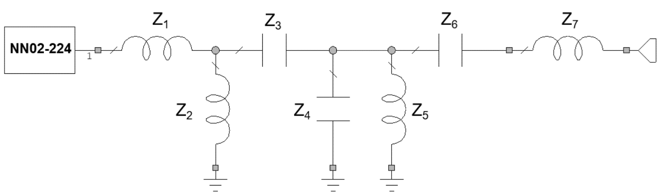
Table 1 – Total efficiency (%) comparison considering the different connection pins location between connectivity board and main board.

2.2. MATCHING NETWORK

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. affect the antenna performance. 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. Do it in the ground plane area, not in the clearance area. This provides a degree of freedom to tune the RUN mXTEND™ antenna booster once the design is finished considering elements of the system (batteries, displays, covers, etc.).

This section presents the proposed matching network and specs measured in the corresponding evaluation board (Figure 2), which is an ideal case. Accordingly, this matching network applies to this evaluation board. Please note that different devices with different ground planes and different components nearby the RUN mXTEND™ antenna booster may need a different matching network. To ensure optimal results, the use of high Q and tight tolerance components is highly recommended (e.g., Murata components (Table 2)). 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, 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/

824 – 960 MHz and 1710 – 2690 MHz



Label	Recommended case	Set-up 1	Set-up 2
Z_1	4.3nH	4.3nH	4.3nH
Z_2	18nH	18nH	18nH
Z_3	0.9pF	0.9pF	0.9pF
Z_4	0.6pF	1.0pF	1.0pF
Z_5	23nH	13nH	13nH
Z_6	2.1pF	2.0pF	2.0pF
Z_7	4.8nH	4.5nH	4.5nH

Table 2 – Topology and values of the matching network components for the three considered set-ups (Figure 3).

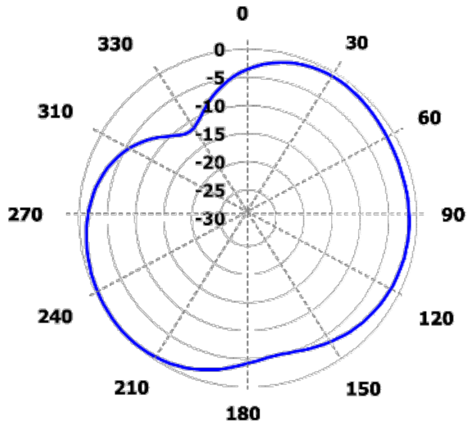
[1] See terms and conditions for a free Antenna Intelligence Cloud service in 24h at: https://www.ignion.io/antenna-intelligence/

Label	Value	Part Number
Z_1	4.3 nH	LQW15AN4N3B80
Z_2	18 nH	LQW18AN18NG10
Z_3	0.9 pF	GJM1555C1HR90WB01
	1.0 pF	GJM1555C1H1R0WB01
Z_4	1.0 pF	GJM1555C1H1R0WB01
	0.6 pF	GJM1555C1HR60WB01
Z_5	13 nH	LQW15AN13NG00
	23 nH	LQW18AN23NG80
Z_6	2.0 pF	GJM1555C1H2R0WB01
	2.1 pF	GJM1555C1H2R1WB01
Z_7	4.5 nH	LQW15AN4N5B80
	4.8 nH	LQW15AN4N8G80

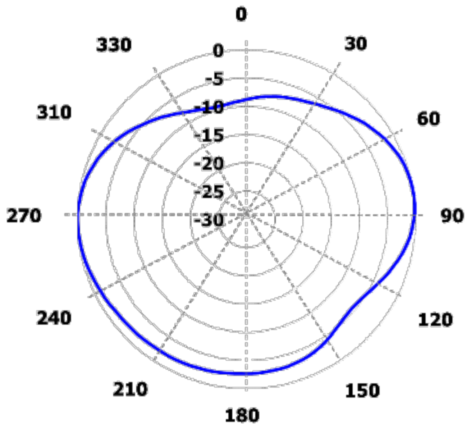
Table 3 – Values and part numbers of the matching network components used for the matching networks for the three considered set-ups.

2.2.1. RADIATION PATTERNS (824-960 MHz), GAIN AND EFFICIENCY

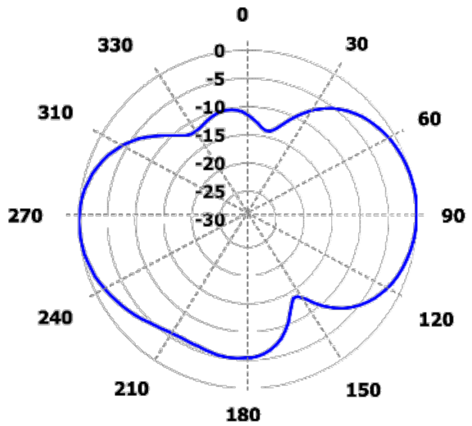
Measurement System Set-Up
Evaluation Board in Plane XY



θ = 90º Plane XY at 890 MHz



ϕ = 0º Plane XZ at 890 MHz



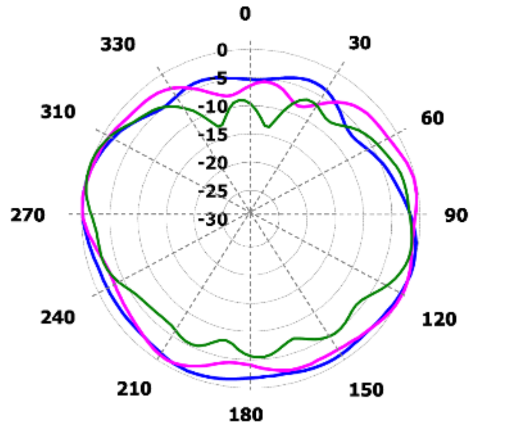
ϕ = 90º Plane YZ at 890 MHz

Gain	**Peak Gain**	1.5 dBi
	Average Gain across the band	-3.9 dBi
	Gain Range across the band (min, max)	-12.5 **<–>** 1.8 dBi
Efficiency	**Peak Efficiency**	65.8 %
	Average Efficiency across the band	57.3 %
	Efficiency Range across the band (min, max)	33.1 – 65.8 %

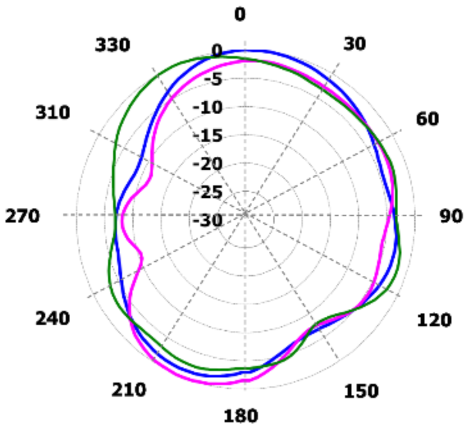
Table 4 – Antenna Gain and Total Efficiency associated to recommended case (Figure 3) within the 824 – 960 MHz frequency range. Measurements made in the Satimo STARGATE 32 anechoic chamber. No significant changes in the radiation pattern shape are appreciated for the rest of the set-ups. Accordingly, the best case is shown herein.

2.2.2. RADIATION PATTERNS (1710-2690 MHz), GAIN AND EFFICIENCY

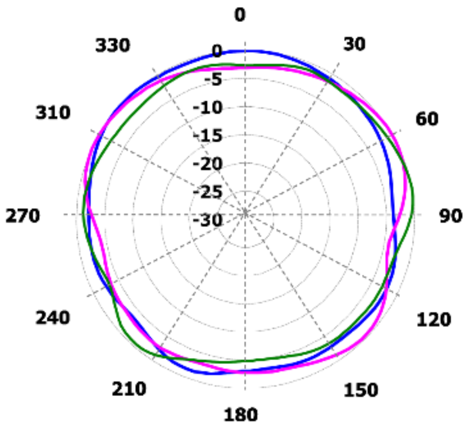
Measurement System Set-Up
Evaluation Board in Plane XY



θ = 90º Plane XY at 1.71GHz, 2.2GHz and 2.69GHz



ϕ = 0º Plane XZ at 1.71GHz, 2.2GHz and 2.69GHz



ϕ = 90º Plane YZ at 1.71GHz, 2.2GHz and 2.69GHz

Gain	**Peak Gain**	1.2 dBi
	Average Gain across the band	-3 dBi
	Gain Range across the band (min, max)	-11.5 <–> 1.2 dBi
Efficiency	**Peak Efficiency**	77.4 %
	Average Efficiency across the band	63.5 %
	Efficiency Range across the band (min, max)	47.6 – 77.4 %

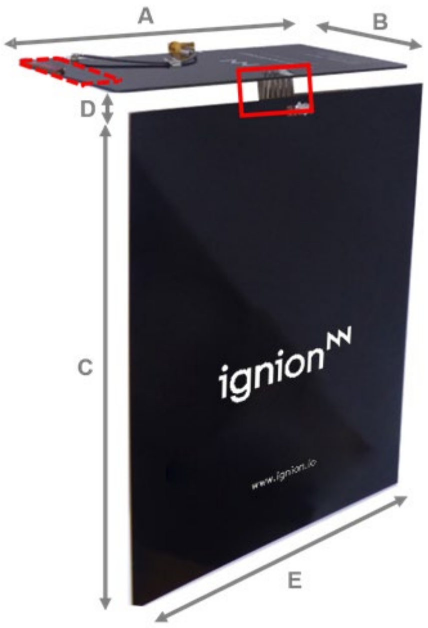
Table 5 – Antenna Gain and Total Efficiency associated to the recommended case (Figure 3) within the 1710 – 2690 MHz frequency range. Measurements made in the Satimo STARGATE 32 anechoic chamber. No significant changes in the radiation pattern shape are appreciated for the rest of the set-ups. Accordingly, the best case is shown herein.

3. CONNECTIVITY BOARD FOR SMART METERS – TRIO mXTEND™

3.1. CONNECTIVITY BOARD ASSEMBLED TO THE MAIN BOARD

This connectivity board EB_NN03-310-M integrates a UFL cable to connect the TRIO mXTEND™ chip antenna component with the SMA connector. It also includes a pin connector to make the connection to the main board.

The following set-up shows the **recommended case** in order to maximize efficiency in your device (Figure 5). The red area shows the connection between the connectivity and main board which can be achieved by any kind of connection such as for example multi-pin connectors or flex-film. At least one ground line should connect connectivity and main board.



Measure	mm
A	142
B	60
C	190
D	10
E	131

Tolerance: ±0.2 mm

D: Distance between the main board and the connectivity board.

Clearance Area: 40 mm x 12 mm

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

Figure 5 – Connectivity board (A x B) connected to the main board (C x E)

3.1.1. VSWR AND TOTAL EFFICIENCY

VSWR (Voltage Standing Wave Ratio) and Total Efficiency versus Frequency (GHz).

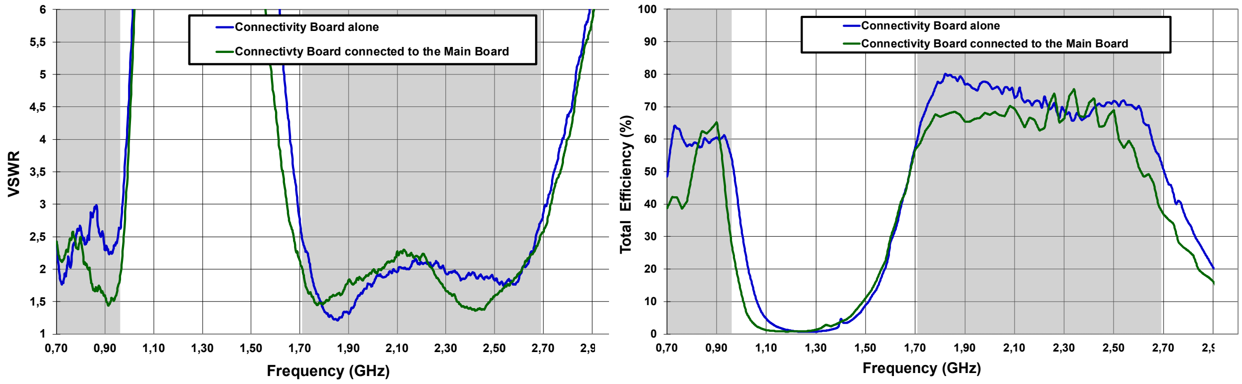


Figure 6 – VSWR and Total Efficiency for the 698 - 960 MHz and 1710 - 2690 MHz frequency range (the connectivity board alone and the connectivity board connected to the main board).

	LFR (824 – 960 MHz)					HFR (1710 – 2690 MHz)				
Set-up	**ηa 698MHz**	**ηa 960MHz**	**Min**	**Max**	**Av. ηa**	**ηa 1710MHz**	**ηa 2690MHz**	**Min**	**Max**	**Av. ηa**
Connectivity board alone	48.5	54.3	57.5	60.5	59.3	60.4	53.0	51.7	80.2	71.4
Connectivity board connected to the main board	38.8	27.5	27.5	65.2	49.9	57.9	38.2	38.2	75.4	64.4

Table 6 – Total efficiency (%) comparison considering the connectivity board alone and the connectivity board connected to the main board.

3.2. MATCHING NETWORK

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. affect the antenna performance. 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. Do it in the ground plane area, not in the clearance area. This provides a degree of freedom to tune the TRIO mXTEND™ chip antenna component once the design is finished and considering all elements of the system (batteries, displays, covers, etc.).

This section presents the proposed matching network and specs measured in the corresponding evaluation board (Figure 5), which is an ideal case. Accordingly, this matching network applies to this evaluation board. Other configurations would require a matching network adjustment. Please note that different devices with different ground planes and different components nearby the TRIO mXTEND™ chip antenna component may need a different matching network. To ensure optimal results, the use of high Q and tight tolerance components is highly recommended (e.g. Murata components (Figure 8)). 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, which will get you a complete antenna design report including a custom matching network for your device in 24h[2]. Additional information related to Ignion's range of R&D services is available at: https://ignion.io/rdservices/

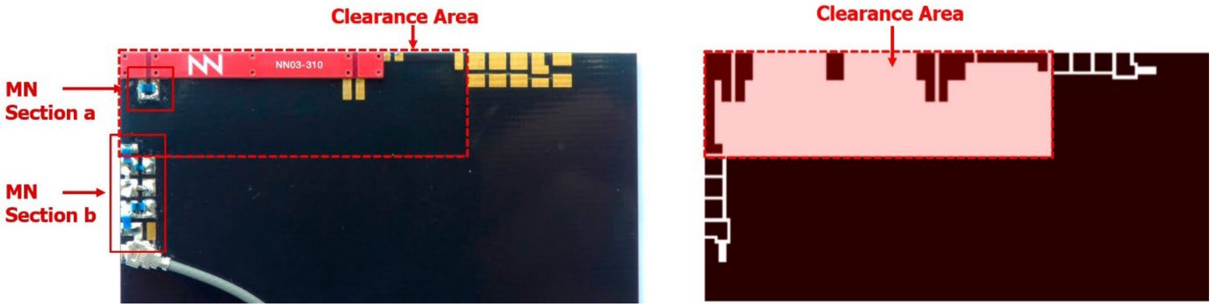
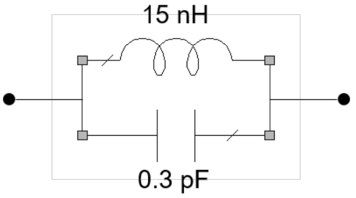


Figure 7 – Matching network distribution

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

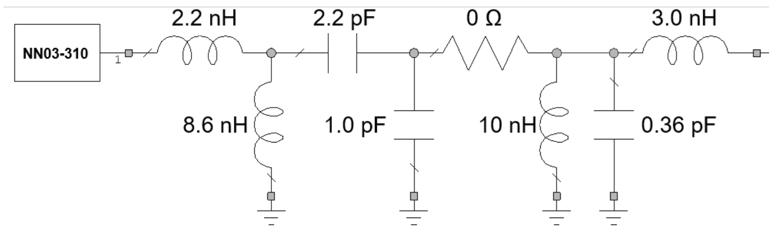
698 MHz – 960 MHz and 1710 MHz – 2690 MHz

MN Section a



Value	Part Number
15 nH	LQW18AN15NG80
0.3 pF	GJM1555C1HR30WB01

MN Section b

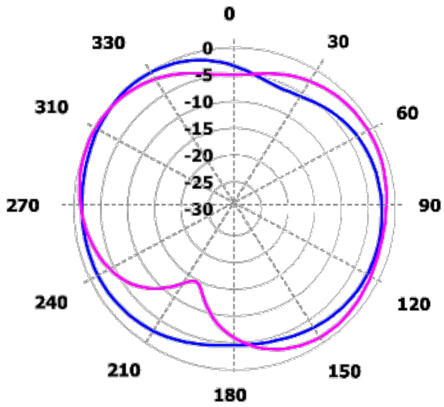


Value	Part Number
2.2 nH	LQW18AN2N2C80
8.6 nH	LQW15AN8N6G80
2.2 pF	GJM1555C1H2R2WB01
1.0 pF	GJM1555C1H1R0WB01
10 nH	LQW18AN10NG80
0.36 pF	GJM1555C1HR36WB01
3.0 nH	LQW18AN3N0C80

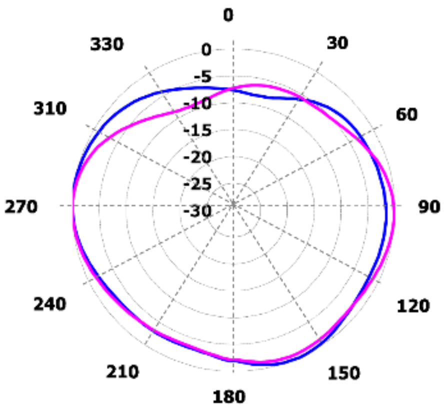
Figure 8 – Matching network implemented in the connectivity board (**Figure** 5).

3.2.1. RADIATION PATTERNS (698-960 MHz), GAIN AND EFFICIENCY

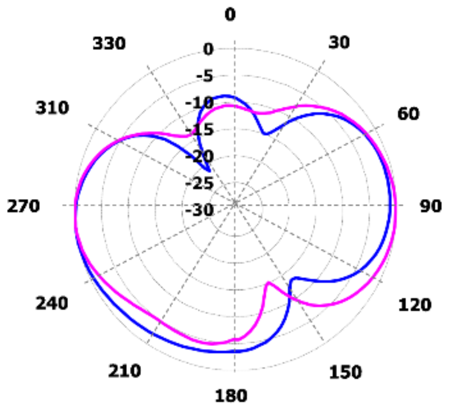
Measurement System Set-Up
Evaluation Board in Plane XY



θ = 90º Plane XY at 750 MHz and 890 MHz



ϕ = 0º Plane XZ at 750 MHz and 890 MHz



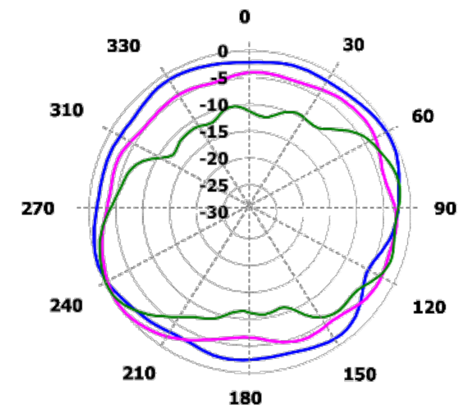
ϕ = 90º Plane YZ at 750 MHz and 890 MHz

Gain	**Peak Gain**	1.5 dBi
	Average Gain across the band	-4.1 dBi
	Gain Range across the band (min, max)	-22.6 dBi – 1.5 dBi
Efficiency	**Peak Efficiency**	65.2 %
	Average Efficiency across the band	49.9 %
	Efficiency Range across the band (min, max)	27.5 – 65.2 %

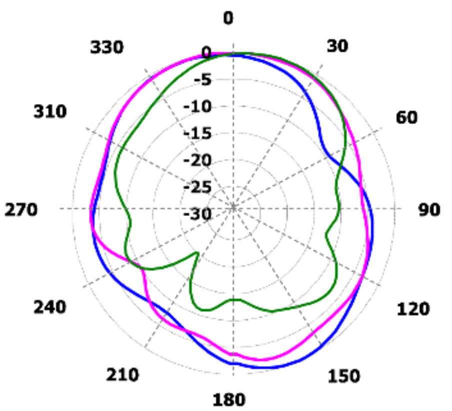
Table 7 – Antenna Gain and Total Efficiency when regarding the connectivity board connected to the main board (Figure 5) within the 698 – 960 MHz frequency range. Measurements made in the Satimo STARGATE 32 anechoic chamber.

3.2.2. RADIATION PATTERNS (1710-2690 MHz) GAIN AND EFFICIENCY

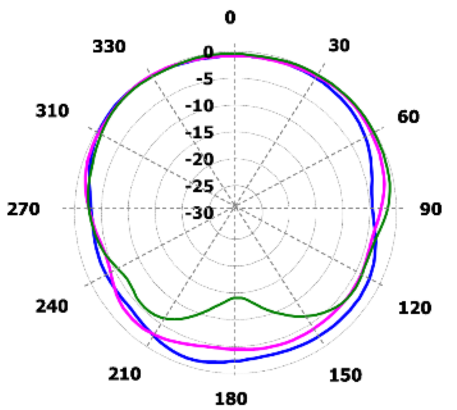
Measurement System Set-Up
Evaluation Board in Plane XY



θ = 90º Plane XY at 1.71 GHz, 2.2 GHz and 2.69 GHz



ϕ = 0º Plane XZ at 1.71 GHz, 2.2 GHz and 2.69 GHz



ϕ = 90º Plane YZ at 1.71 GHz, 2.2 GHz and 2.69 GHz

Gain	**Peak Gain**	0.8 dBi
	Average Gain across the band	-3.9 dBi
	Gain Range across the band (min, max)	-20.5 dBi – 0.8 dBi
Efficiency	**Peak Efficiency**	75.4 %
	Average Efficiency across the band	64.4 %
	Efficiency Range across the band (min, max)	38.2 – 75.4 %

Table 8 – Antenna Gain and Total Efficiency when regarding the connectivity board connected to the main board (Figure 5) within the 1710 – 2690 MHz frequency range. Measurements made in the Satimo STARGATE 32 anechoic chamber.

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Contact:
support@ignion.io
+34 935 660 710

Barcelona

Av. Alcalde Barnils, 64-68 Modul C, 3a pl.
Sant Cugat del Vallés
08174 Barcelona
Spain

Shanghai

Shanghai Bund Centre
18/F Bund Centre, 222 Yan'an Road East,
Huangpu District
Shanghai, 200002
China

New Dehli

New Delhi, Red Fort Capital Parsvnath Towers
Bhai Veer Singh Marg, Gole Market,
New Delhi, 110001
India

Tampa

8875 Hidden River Parkway
Suite 300
Tampa, FL 33637
USA