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Cavli P-Series module + RUN mXTEND™: NB-IoT / LTE-M across bands 3/5/8

APPLICATION NOTE
RUN mXTEND™ (NN02-224)

RUN mXTEND™: High efficiency on global NB-IoT and LTE-CAT-M with a very compact module-antenna combo

- **Product:** P-Series Module by Cavli Wireless with embedded RUN mXTEND™ NN02-224
- **Antenna Dimensions:** 12.0 mm x 3.0 mm x 2.4 mm
- **Frequency regions:** 824-960 MHz and 1710-1880 MHz

Let´s enable cellular IoT for your Smart World!

As the Internet of Things is a priority for many companies now, all of them need help with the design process to be ready for this quick market. How can designers be ready in the shortest way?

IoT could **reduce its product development process** if designers get a compact and ready to use solution that simplifies the product development process: a **module-antenna combo**. Here we present to designers the **P-Series modules by Cavli Wireless with the RUN mXTEND™ embedded antenna by NN** that connects computing modules that enable IoT companies to these large-scale deployments.

Discover within this application note how to **adjust your P-Series module with the integrated antenna booster** to your device and easily cover the **NB IoT and LTE CAT-M bands** (824-960 MHz and 1710-1880 MHz) desired frequencies worldwide.

Use the P-Series module with embedded RUN mXTEND™ antenna for multiple use cases as Smart Factories and Smart City applications and its multiple possibilities: Smart Street lighting, Smart Parking, Smart Logistics etc.

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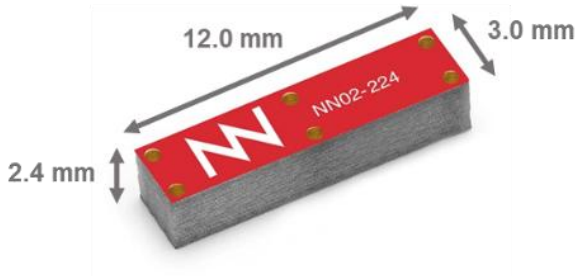
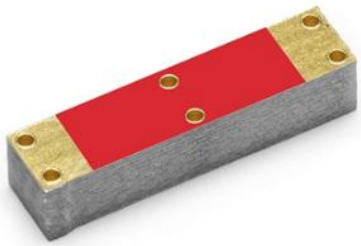
1. PRODUCT DESCRIPTION NN02-224

The RUN mXTEND™ antenna booster has been specifically designed for providing multiband performance in any wireless device enabling worldwide coverage, supporting 2G, 3G, 4G, NB-IoT, and LTE CAT-M. It is featured by a small form factor, that makes it ideal to be easily embedded in any IoT device with high size constraints. This is the case of the P32 series modules from CAVLI that integrate the RUN mXTEND™ antenna booster in a very compact module size of just 48 mm length by 20 mm width (section 2).

TOP



BOTTOM



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

APPLICATIONS

- Asset Tracking
- Fleet Management
- Smart Agriculture/Sensors
- Smart Home/Building/City
- Smart Metering
- IoT
- Smartphones, Handsets
- Tablets, Phablets, Laptop PCs
- Netbooks, eBook readers
- Modules
- Routers
- Data Loggers Gateways
- Smartwatches and Wearables

BENEFITS

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

The RUN mXTEND™ antenna booster belongs to a new generation of antenna solutions based on Virtual Antenna® technology owned by Ignion. This technology enables replacing conventional and custom antenna solutions by a new class of so-called antenna boosters, delivered in the form of a new range of miniature and off-the-shelf chip antenna components. These new chip antennas are by nature multiband and multipurpose, so 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, cheaper and easier***.

The fact of embedding the antenna in the P32 series modules from CAVLI implies significant advantages for the IoT world. It simplifies design and manufacturing processes and allow IoT designers to center their attention in their disruptive applications rather than in RF aspects.

Wireless data loggers or gateways are one of the most demanded IoT application nowadays. Any parameter position, temperature, humidity, acceleration, flow, etc… can be monitored by a super set of sensors present in any IoT device. All this huge quantity of data must be properly collected, stored, and transmitted through this wireless data loggers or gateways and they can apply to many different market segments, from smart factories with the control of logistics, smart cities with street lightning, up to smart agriculture, smart parking, etc…

This application note is intended to provide design recommendation to integrate the P32 series modules from CAVLI with the RUN mXTEND™ embedded antenna solution in the design of any wireless data logger device or gateway. Three different representative sizes from commercially available data loggers have been considered. The antenna performance is gathered for these three different platform sizes as well as when regarding the standalone module.

2. PRODUCT DESCRIPTION P32 SERIES MODULES FROM CAVLI

The P32 series modules from CAVLI are connected computing modules that enable IoT companies to mitigate the existing entry barriers to large scale deployment, and seamlessly carry out product development to global scale-up. P-Series modules with power EDGE computing capability supported state of the art Espressif ESP32 chipset and dual-core processor that can be used to run user applications. They provide the perfect IoT product development environment supporting ESP-IDF and Arduino programming console with WiFi and BLE support. P-Series offers flexible programming consoles and are integrated with eSIMs and preloaded with global connectivity.

The P32 series modules integrates the ESP32-D2WD with 520KB RAM, and 2MB Flash. Integrates a chip antenna, the RUN mXTEND™ (NN02-224) antenna booster for covering the band 3, 5, 8 (824-960MHz and 1710-1880MHz). Integrate an eSIM with Global Data Connectivity, with a programming Console with Arduino IDE and ESP-IDF. Presents a ultra-Low power modes for a longer battery life, and alternate radio: WIFI 2.4Ghz/Bluetooth 4.2/BLE.

(a) (b) (c)

Figure 1- P32 series modules. (a) P32 C1-RS, (b) P32 C31-QM and (c) P32 C1-RM.

P32 C1-RS is the connected compute module from P-Series family supporting LTE CAT NB-IoT connectivity (Figure 1a).

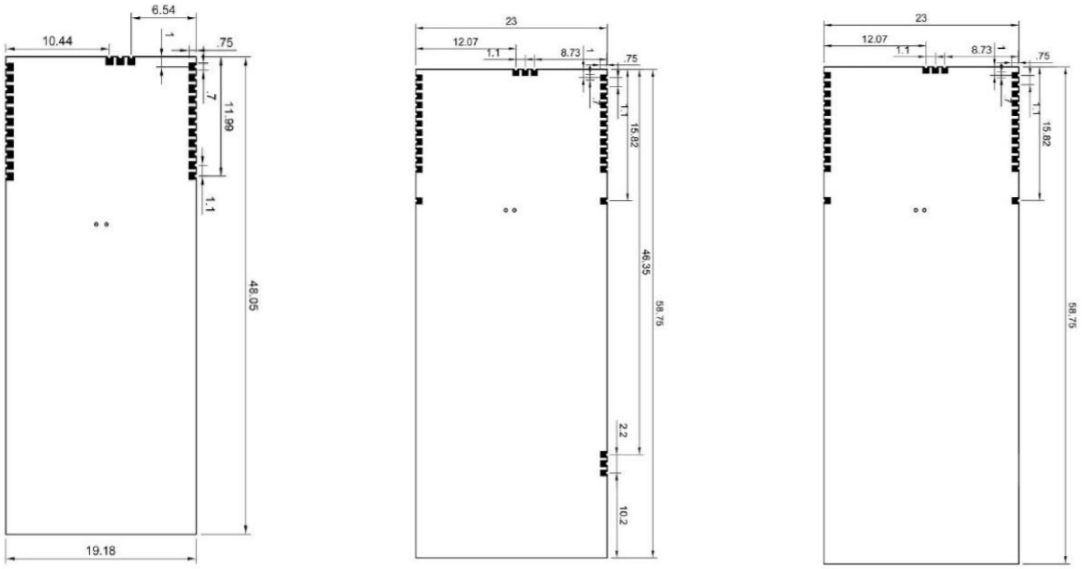
P32 C31-QM is the connected computed module from P-Series family supporting LTE CAT NB-IoT, CAT M1 with 2G fall back connectivity (Figure 1b).

P32 C1-RM is the connected compute module from P-Series family supporting LTE CAT NB-IoT with 2G fall back connectivity (Figure 1c).

Main CAVLI advantages are:

- Integrated eSIM and global connectivity through Cavli Hubble
- Intelligent/Automatic local eSIM provisioning
- Advanced firmware installation/update over-the-air
- PAYG global data subscription model

Each module presents different dimensions that must be considered during the integrations of the P32 module in the final design (Figure 2).

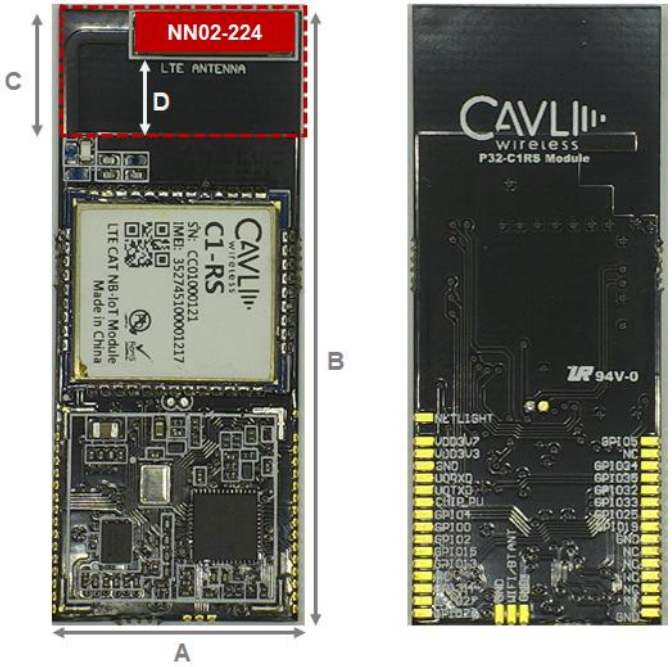


(a) (b) (c)

Figure 2- P32 series modules dimensions. (a) P32 C1-RS module, (b) P32 C31-QM module and (c) P32 C1-RM module.

3. P32-C1-RS Module

P32 C1-RS Module integrates the RUN mXTEND™ antenna booster to provide operation in bands 3, 5, 8, supporting LTE CAT NB-IoT connectivity in the frequency region from 824 to 960MHz, and from 1710MHz to 1880MHz. The P32 C1-RS Module presents a very compact size with a length of just 48.1mm and a width of 19.2mm. This section gathers the antenna performance results and the recommended matching network design in the P32 C1-RS (Figure 3).



Measure	mm
A	19.2
B	48.1
C	10.0
D	7.0

Tolerance: ±0.2 mm

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

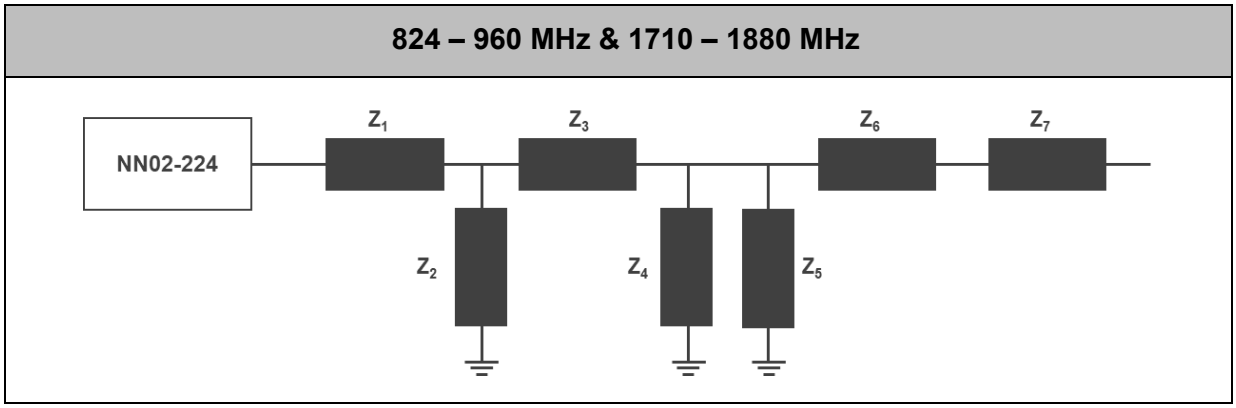
Material: The module is built on FR4 substrate. Thickness is 1 mm.

Clearance Area: 10 mm x 19.2 mm (C x A)

Figure 3 – P32 C1-RS Module integrates the RUN mXTEND™, providing operation from 824MHz to 960MHz, and from 1710MHz to 1880MHz. Top view in the left and bottom view in the right.

3.1. MATCHING NETWORK

RUN mXTEND™ antenna booster needs a matching network to connect to the C1-RS Module. This section describes the matching network used for RUN mXTEND™ (Figure 4) and the resulting product specs when measured in the P32 C1-RS Module (Table 1 and Figure 5). To ensure optimal results, the use of high-quality factor (Q) and tight tolerance components is highly recommended (e.g., Murata components with part numbers as in Figure 4).



Component	Value	Part Number
Z_1	0Ω	-
Z_2	7.0nH	LQW15AN7N0G80
Z_3	1.9pF	GJM1555C1H1R9WB01
Z_4	10nH	LQW15AN10NG80
Z_5	-	-
Z_6	4.3nH	LQW15AN4N3B80
Z_7	0Ω	

Figure 4 – Matching Network topology and components values implemented in the P32 C1-RS module (Figure 3)

3.2. VSWR AND TOTAL EFFICIENCY

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

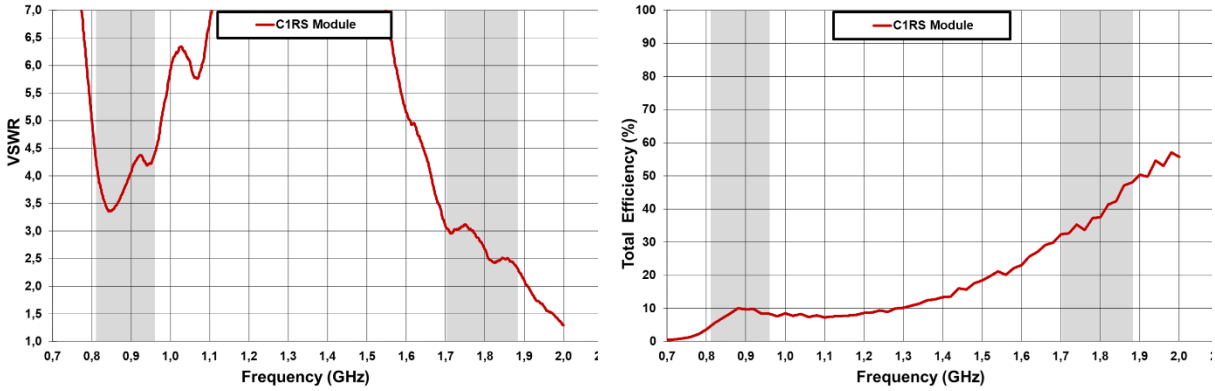


Figure 5 –VSWR and Antenna Efficiency in the C1-RS module, from 824MHz to 960MHz, and from 1710MHz to 1880MHz (Figure 4).

3.3. QUICK REFERENCE GUIDE FOR ANTENNA PERFORMANCE

Technical features	824 – 960 MHz	1710 – 1880 MHz
Average Efficiency	8.5 %	43.9 %
VSWR	< 4.4:1	< 3:1
Radiation Pattern	Omnidirectional	
Polarization	Linear	
Weight (approx.)	0.19 g	
Temperature	-40 to +125 ºC	
Impedance	50 Ω	
Dimensions (L x W x H)	12.0 mm x 3.0 mm x 2.4 mm	

Table 1 – Technical Features. Measures from the P32 C1-RS module (Figure 3).

4. RECOMMENDED P32 C1-RS INTEGRATION

P32 C1-RS module will simplify IoT product development since it provides a compact integration of all the required elements in a very small and reduced package.

Nevertheless, the antenna performance is always conditioned by its operating environment in such a way that different devices with different printed circuit board sizes, components nearby the antenna, LCD's, batteries, covers, connectors, etc. may need a different matching network to properly tune the operating frequencies. This section is intended to provide some guidelines and design recommendations to the IoT developers to allow them to ensure the most appropriate embedded cellular connectivity in their final products.

4.1. DESIGN RECOMMENDATIONS TO INTEGRATE P32 SERIES MODULES

See below the design recommendations to integrate the P32 C1-RS module in your device.

1. Chose the **optimum antenna placement**:

   Place the P32 C1-RS module aligned with the longest side of the PCB (Printed Circuit Board) in such a way that the feeding line, i.e., the line connecting the antenna with the RF module was also aligned with the longest side of the PCB. The RUN mXTEND™ should be as close as possible to a PCB corner.

2. Enlarge the **clearance area**:

   Enlarge the clearance area. Much better results are obtained if the clearance area is free from any electronic components, conductive traces, and ground plane in any PCB layers. It is important to maintain the recommended clearance in the main PCB where the P32 C1-RS is integrated (Figure 6).

3. Optimize **PCB inner layers**:

   Ensure a continuous ground plane layer in at least one inner layer of your design. Avoid any ground plane or trace layer underneath or over the pads area. Place them at a distance larger than 1 mm with respect to pads.

4. **Ground plane connection**:

   The P32 C1-RS ground layer must be properly connected to the ground plane layer of the main PCB.

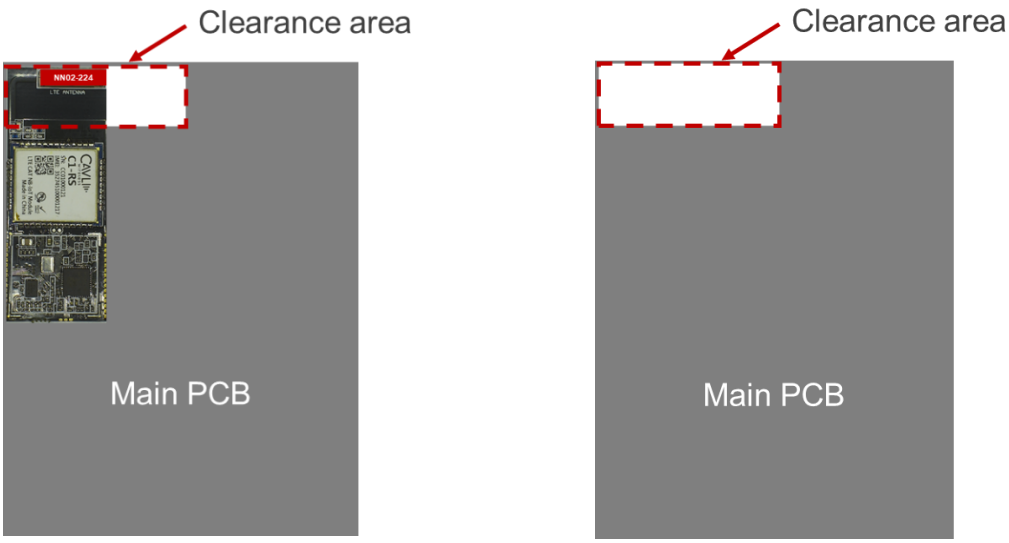


Figure 6 – On the left side, an example of the P32 C1-RS module integration in a particular device, and in the right side, an example of the main board ground plane and the required clearance area.

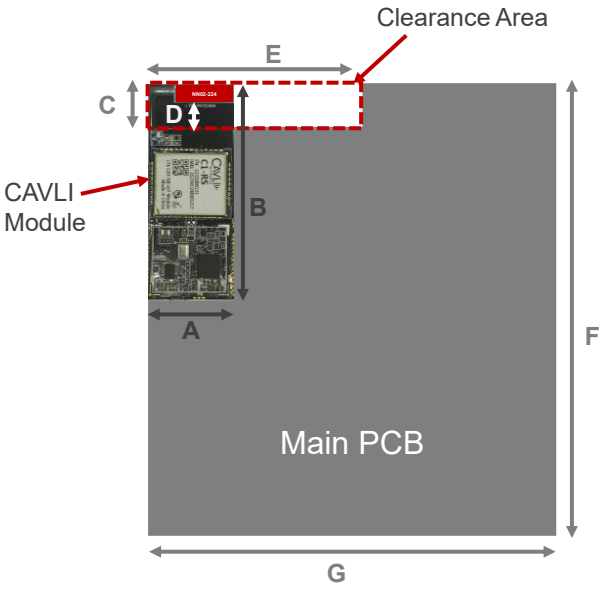
To follow these design recommendations will make the design experience and certification process of the IoT device much smoother and easier.

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 (Murata components).

If you need help designing your matching network beyond this application note, contact support@ignion.io or run your device through Oxion™ at https://oxion.ai, Ignion's free-of-charge[1] AI-powered antenna integration platform, for a custom matching network and a complete design report in 24h. Ignion's engineering services: https://ignion.io/design-center/engineering-support/

4.2. PERFORMANCE IN DIFFERENT PCB SIZES

This section is intended to illustrate how the antenna performance varies according to the PCB size and how the matching network could be tuned in each scenario. Three different representative sizes from commercially available wireless data loggers or gateways have been considered (Figure 7). The matching network has been designed in each case to provide operation in bands 3, 5, 8, supporting NB-IoT and LTE CAT-M frequencies, from 824MHz to 960MHz, and from 1710MHz to 1880MHz.



Measure	mm
A	19.2
B	48.1
C	10.0
D	7.0
E	50
F	80 - 100 - 160
G	60 - 90 - 120

Tolerance: ±0.2 mm

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

Material: The P32 C1-RS on FR4 substrate. Thickness is 1 mm.

Clearance Area: 10 mm x 50 mm (C x E)

Figure 7 – P32 C1-RS module integrated in a main board for providing operation from 824MHz to 960MHz, and from 1710MHz to 1880MHz.

1 See terms and conditions for the free-of-charge Oxion™ service at: https://oxion.ai

The antenna performance degrades as long as the PCB size is reduced (Figure 8). In this case the matching network used in all the cases is the same used in the P32 C1-RS module (Figure 4).

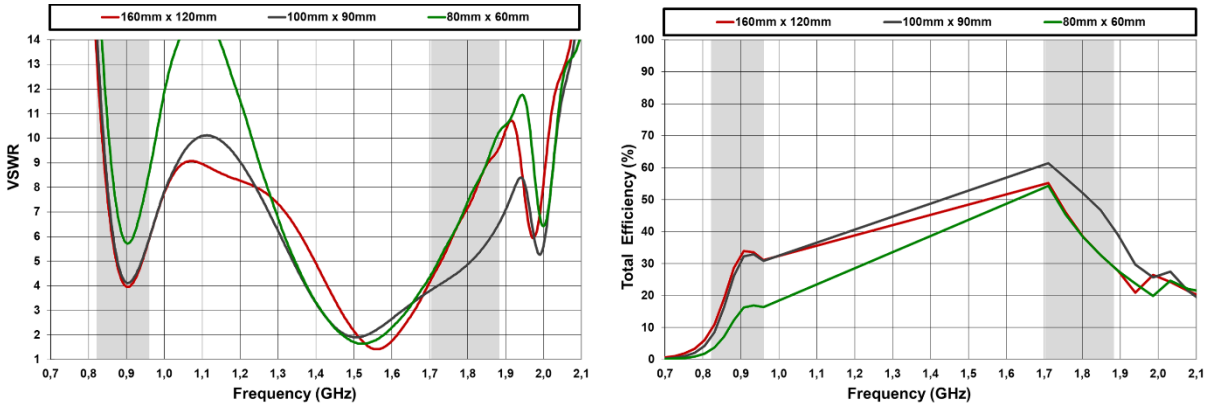


Figure 8 – Comparison VSWR and antenna efficiency for different PCB sizes (Figure 7) considering the **same matching network considered in the C1-RS module in all the platforms**, from 824MHz to 960MHz, and from 1710MHz to 1880MHz (Figure 4).

	LFR (824 – 960MHz)					HFR (1710 – 1880MHz)				
F x G (mm)	**$\eta_{a\ 824MHz}$**	**$\eta_{a\ 960MHz}$**	**Min**	**Max**	**Av. η_a**	**$\eta_{a\ 1710MHz}$**	**$\eta_{a\ 1880MHz}$**	**Min**	**Max**	**Av. η_a**
80mm x 60mm	3.3	16.4	3.3	17.0	12.2	54.3	29.2	29.2	54.3	39.7
100mm x 90mm	7.5	30.8	7.5	33.0	24.5	61.4	41.4	41.4	61.4	51.2
160mm x 120mm	9.9	31.1	9.9	34.0	26.2	55.3	29.2	29.2	55.3	40.0

Table 2 – Antenna efficiency comparison regarding the **same matching network considered in the C1-RS module in all the** PCB sizes (Figure 4).

The antenna performance can be improved by properly adjusting the matching network in each case (Figure 9 and Figure 10).

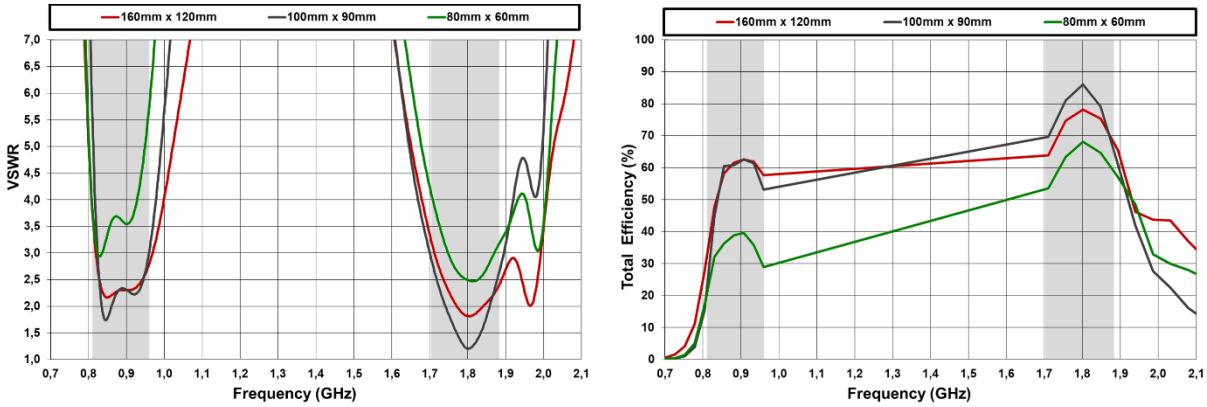
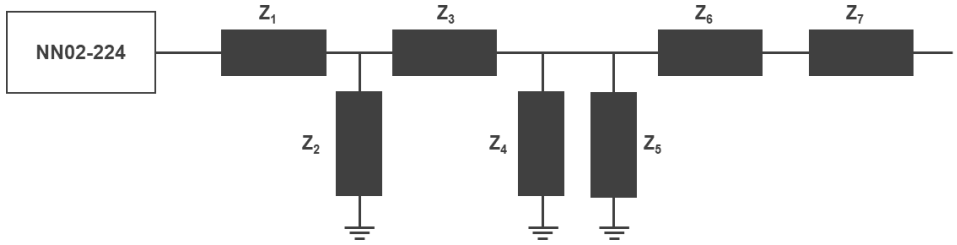


Figure 9 – Comparison VSWR and Antenna Efficiency by changing the Main PCB dimensions considering the **optimized matching network for each platform**, for 824MHz to 960MHz, and from 1710MHz to 1880MHz (Figure 4).

	LFR (824 – 960MHz)					HFR (1710 – 1880MHz)				
F x G (mm)	**$\eta_{a\ 824MHz}$**	**$\eta_{a\ 960MHz}$**	**Min**	**Max**	**Av. η_a**	**$\eta_{a\ 1710MHz}$**	**$\eta_{a\ 1880MHz}$**	**Min**	**Max**	**Av. η_a**
80mm x 60mm	28.7	29.0	28.7	39.6	35.3	53.6	59.4	53.6	68.1	61.4
100mm x 90mm	38.1	53.2	38.1	62.7	57.3	69.7	66.5	66.5	86.0	75.4
160mm x 120mm	43.2	57.6	43.2	62.6	58.3	63.9	68.5	63.9	78.2	71.5

Table 3 – Antenna efficiency comparison considering the **optimized matching network for each platform** (Figure 10).

824 – 960 MHz & 1710 – 1880 MHz



	Components						
PCB Dimensions	**Z_1**	**Z_2**	**Z_3**	**Z_4**	**Z_5**	**Z_6**	**Z_7**
MN for 60mm x 80mm	10nH	13nH	0.6pF	15nH	-	1.1pF	8.7nH
MN for 90mm x 100mm	4.3nH	15nH	0.5pF	15nH	-	0.8pF	17nH
MN for 120mm x 160mm	5.8nH	13nH	0.7pF	12nH	-	1.3pF	7.5nH

Figure 10 – Matching Network topology and the proposed matching network for each PCB size (Figure 7)

Value		Part Number
Z1	10 nH	LQW18AN10NG80
	4.3 nH	LQW15AN4N3G80
	5.8 nH	LQW15AN5N8G80
Z2	13 nH	LQW18AN13NG80
	15 nH	LQW18AN15NG80
Z3	0.6 pF	GJM1555C1HR60WB01
	0.5 pF	GJM1555C1HR50WB01
	0.7 pF	GJM1555C1HR70WB01
Z4	15 nH	LQW18AN15NG80
	12 nH	LQW18AN12NG80
Z6	1.1 pF	GJM1555C1H1R1WB01
	0.8 pF	GJM1555C1HR80WB01
	1.3 pF	GJM1555C1H1R3WB01
Z7	8.7 nH	LQW15AN8N7B80
	17 nH	LQW18AN17NG80
	7.5 nH	LQW18AN7N5G80

Table 4 – Values and part numbers of the components used for the matching networks for the different PCB sizes analyzed in the integration of the C1-RS module in a main Board (Figure 10).

Product Change Notification

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PCN Number: NN19100011

Notification Date: October 07th, 2019

Part Number identification:

Part Number changes, it will be applied in all the document of the company (User Manual, Data Sheet, …)

Previous Part Number	New Part Number
FR01-S4-224	NN02-224

Reason for change:

	Specs (electrical/mechanical)		Manufacturing location
	User Manual/Data Sheet		Quality/Reliability
	Material/Composition		Logistics
	Processing/Manufacturing	X	Other: Part Number

Change description

1.- Part Number: From FR01-S4-224 FRACTUS to NN02-224 Ignion in the User Manual

OLD

NEW

Comments:

1.- Electrical and Mechanical specs remain the same

2.- Footprint in the PCB to solder the chip antenna remains the same

Identification method

1.- The part number on the antenna is different

User Manual	X	Available from: January 2020
Samples	X	Available from: January 2020

Ignion Contact:

	Sales	Supply Chain
Name:	Josep Portabella	Albert Vidal
Email:	josep.portabella@ignion.io	albert.vidal@ignion.io

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

ISO 9001: 2015 Certified

ignion

Your innovation.
Accelerated.

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

Barcelona

Carrer Jesús Serra Santamans, 2
Building 2, 3rd Floor, 08174
Sant Cugat del Vallès, Barcelona,
Spain
+34 935 660 710

Shenzhen

Keyan Road 9, Nanshan District
BAK Science and Technology Building,
Room 1301E, Shenzhen, GD 518057
China
+86 138 2653 8470

Tampa

8875 Hidden River Parkway, Suite 300,
Tampa, FL 33637,
USA
+1 407-902-9278
+1 888 726 8366