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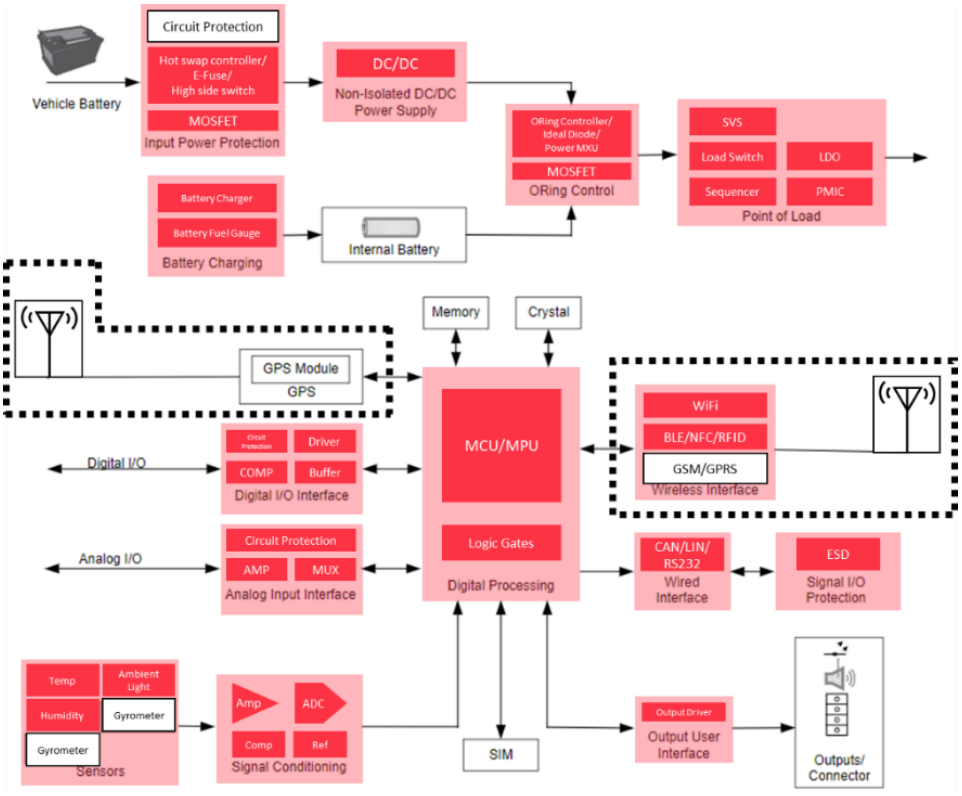
How PCB clearance and ground-plane size affect a 4G antenna in asset trackers

APPLICATION NOTE
RUN mXTEND™ (NN02-224)

ASSET TRACKING – Asset Tracker

Some of the most important challenges that manufacturers face when designing and prototyping an asset tracker, are performance, battery life, accuracy and so on.
Any asset tracking device's data transmission has to be completely reliable, therefore, the antenna is a critical component in such device.
First, chip antenna technology has been proven to deliver top GNSS (GPS, GLONASS, GALILEO, BeiDou…) performance in a variety of tracking devices and fleet management applications. Usually, a ceramic patch antenna is the option of choice for its traditional connection with satellite systems applications in terms of a good reception if the receiver is reasonably stable with respect to the GNSS satellite constellation and if the application has no relevant space and cost constrains. Nowadays, the range of different types of tracking devices is very large, and all of them have different sizes and requirements. These have to consider one important fact: they are located everywhere and not always stable and facing to the satellite reception. As modern smartphones proved that an omnidirectional, linearly polarized antenna can deliver an optimal GNSS performance for the vast majority of applications, such antenna to integrate into your tracking device will ensure the best GNSS signal regardless of the satellite location and/or the distance from the data receiver. At this point, with the endless diversity of new devices requiring versatile GNSS connection, Virtual Antenna™ components, being omnidirectional antennas, become the perfect choice where also, size, weight, portability, and cost are a priority.
Second, Virtual Antenna® technology allows for a single antenna to use multiple RF protocols with a single antenna component, letting your tracking device to broadcast a location via GPS while using Bluetooth or Cellular to receive or transmit data with an external device for configuration or managing purposes apart from location. This antenna versatility can be determining when deciding which is the best fit for your device, as you might have multiple solutions within only just one antenna component.
Furthermore, thanks to the use of the PCB for radiating, Virtual Antenna® technology allows for de-tuning to be easily solved by minor adjustments of the matching network, to adapt with the device's environment, such as close proximity to biological tissue, metal casings, concrete and so on. Also, the optimal use of the PCB to radiate the RF signal, ensures a top performance as the full size of the device is used as part of the antenna system. This will have an impact on how accurate and reliable a tracking device is.



Block Diagram: Asset Tracking – Asset Tracker

In the Block Diagram above, we see an example of an Asset Tracker 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 whole 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 essentially 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.

Battery system:
Whether if it's a rechargeable battery or a regular one, it's the main power unit for any Asset Tracker. All this system, engineered to manage the power transmission, is essential for the proper function of the device. For a sensor tag, the battery will be the factor that defines the life of the device (until recharging or changing the battery).
Chip antenna technology ensures a lower consumption than other types of antennas, such as an external one, bringing the overall device consumption to its lowest, which translates into longer battery life. Also, if the device doesn't have the right antenna, the transceiver will have to consume more power, reducing the battery life.

Antenna/s (wireless interface and GPS):
Any tracking device needs to have a reliable transmission of data to both satellites and gateways or other devices in other to do its function properly. That is why the antenna is one of the most important components within any tracking device. For an optimal antenna efficiency (and clearance area), the component's placement is crucial, therefore, its implementation within the device's design has to be in an early stage.
Furthermore, when tracking assets globally or through different types of networks and frequency bands, Virtual Antenna® technology will enable for a single antenna to be used, making the overall tracking device smaller, slimmer, and simpler.

In summary, when designing an Asset Tracking Device, you should consider, at an early stage, the best performance and size antenna needed for your device. This will ensure its optimal clearance area as well as placement within the PCB, along with the avoidance of any potential future connectivity, efficiency, de-tuning and/or interferences issues. By choosing Virtual Antenna® technology as your antenna solution, thanks to its high RF efficiency and adaptability, you will ensure best performance in your Asset Tracking 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 performance and different metrics of the RUN mXTEND™ on various ground planes and clearance lengths.

RUN mXTEND™ – Clearance Length and Ground Plane Length Experiments on 824-960 MHz and 1710-2690MHz

Ignion specializes in enabling effective mobile communications. Using Ignion technology, we design and manufacture optimized antennas to make your wireless devices more competitive. Our mission is to help our clients develop innovative products and accelerate their time to market through our expertise in antenna design, testing and manufacturing.

RUN mXTEND™ antenna booster
NN02-224

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

ISO 9001: 2015

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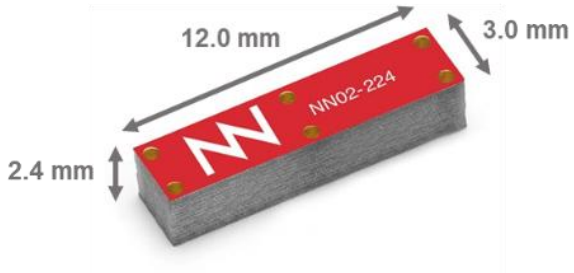
1. PRODUCT DESCRIPTION NN02-224

The RUN mXTEND™ antenna booster (NN02-224) has been specifically designed for providing multiband performance in wireless devices, enabling worldwide coverage by allowing operation in the communication standards 2G, 3G, 4G, ISM, Zigbee, RFID, GPS, GLONASS, Bluetooth, Wi-Fi, and WLAN.

TOP



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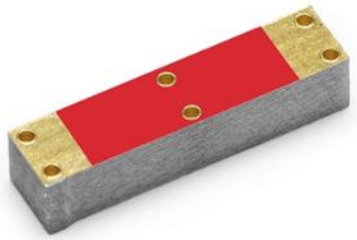


Material: The RUN mXTEND™ antenna booster is built on glass epoxy substrate.

APPLICATIONS

- Handsets and Smartphones
- Tablets and PCs
- Modules
- Routers
- Headsets
- USB Dongles
- Navigators
- Digital Cameras and Smart Watches
- Metering (Gas, Electricity, Water…)
- RFID
- Sensors (Parking, Speed Control, Optics…)

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)

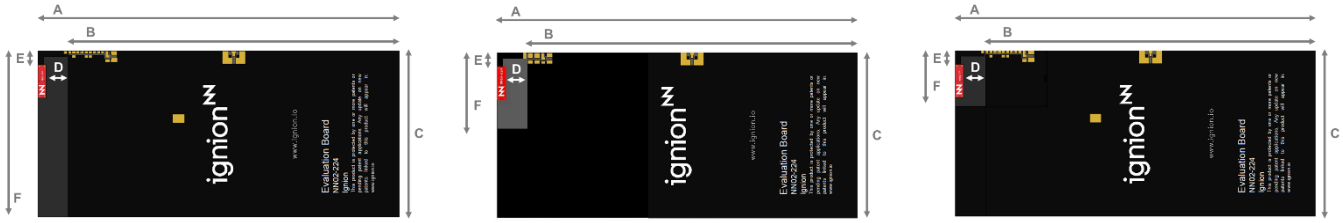
The RUN mXTEND™ antenna booster belongs to a new generation of antenna solutions based on the Virtual Antenna® technology developed by Ignion. The technology is mainly focused on replacing conventional antenna solutions by miniature and standard components.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement Nº 674491

2. CLEARANCE LENGTH EXPERIMENTS

2.1. EVALUATION BOARD

This Evaluation Board EB_NN02-224-1B-2RJ-1P integrates a UFL cable to connect the RUN mXTEND™ antenna booster with the SMA connector. The experiment consists of reducing the clearance length, going from 60mm (original case) to 20mm.



Clearance Length: 60 mm | Clearance Length: 30 mm | Clearance Length: 20 mm

Measure	mm
A	131
B	120
C	60
D	8
E	5
F	60-20

Tolerance: ±0.2 mm

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

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

Figure 1 – Evaluation boards with different clearance lengths that provide operation from 824 MHz to 960 MHz and from 1710 MHz to 2690 MHz.

2.2. VSWR AND EFFICIENCY

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

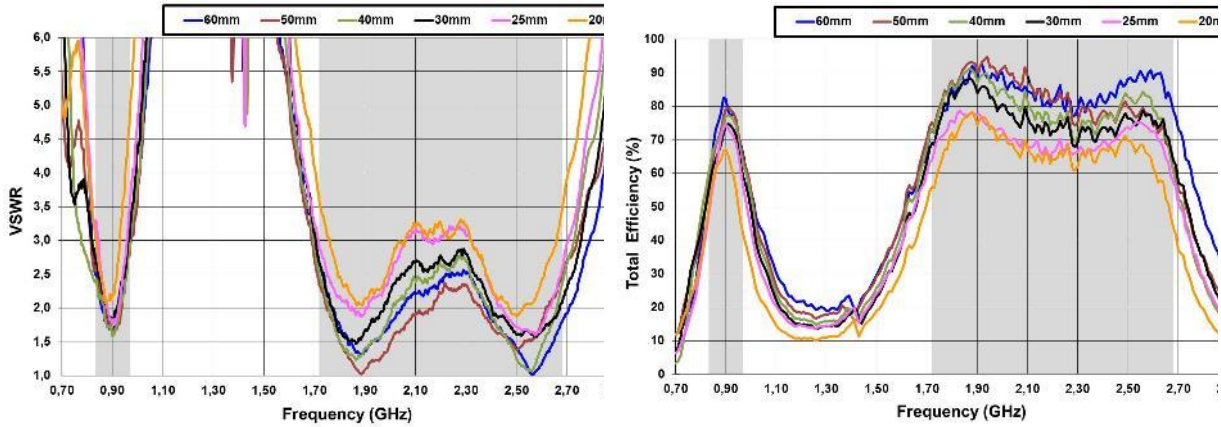


Figure 2 – VSWR and Total Efficiency for the 824 – 960 MHz frequency range and for the 1710 – 2690 MHz frequency range from the evaluation board (Figure 1).

	LFR (824 – 960 MHz)					HFR (1710 – 2690 MHz)				
F	**$\eta_{a\ 824MHz}$**	**$\eta_{a\ 960MHz}$**	**Min**	**Max**	**Av. η_a**	**$\eta_{a\ 1710MHz}$**	**$\eta_{a\ 2690MHz}$**	**Min**	**Max**	**Av. η_a**
60mm	54.3	68.2	54.3	84.6	73.5	74.5	74.7	71.1	94.7	84.5
50mm	54.7	66.5	54.7	80.3	71.8	76.6	57.6	57.6	95.7	82.0
40mm	58.8	64.5	58.8	78.2	71.1	74.3	53.7	53.7	92.1	79.6
30mm	53.6	60.9	53.6	75.5	67.6	69.9	59.9	59.9	89.1	76.3
25mm	46.3	55.6	46.3	74.6	64.5	64.6	47.5	47.5	79.4	70.8
20mm	47.7	43.5	43.5	68.2	58.7	56.7	39.1	39.1	78.6	66.4

Table 1 – Antenna efficiency (%) comparison considering the different clearance lengths.

2.3. MATCHING NETWORK

The specs of a Ignion standard product are measured in their evaluation board, which is an ideal case. In a real design, components nearby the antenna, LCD's, batteries, covers, connectors, etc. affect the antenna performance. This is the reason why 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. 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 and taking into account all elements of the system (batteries, displays, covers, etc.).

Please notice 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). Please, if you need assistance contact support@ignion.io for more information related to the antenna booster matching service.

824 – 960 MHz and 1710 – 2690 MHz

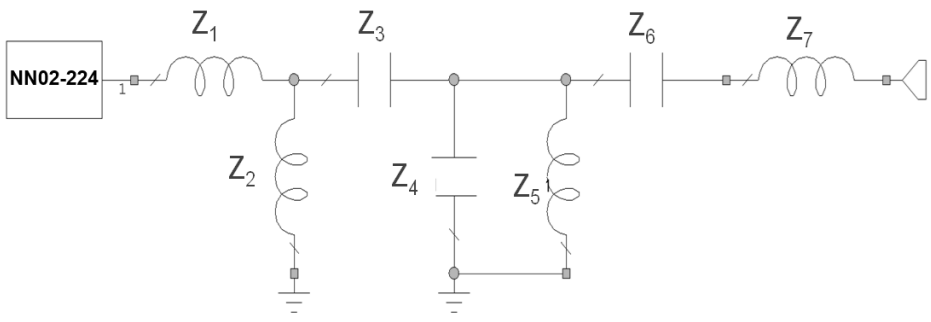


Figure 3 – Topology of matching network mounted at the different solutions.

F	Z_1	Z_2	Z_3	Z_4	Z_5	Z_6	Z_7
60mm	4.3 nH	18 nH	0.9 pF	1.0 pF	13 nH	2.0 pF	4.5 nH
50mm	6.5 nH	18 nH	0.8 pF	1.0 pF	11 nH	1.8 pF	4.5 nH
40mm	6.5 nH	18 nH	0.7 pF	1.0 pF	10 nH	1.6 pF	5.1 nH
30mm	6.5 nH	18 nH	0.7 pF	0.9 pF	11 nH	1.6 pF	4.9 nH
25mm	6.1 nH	17 nH	0.8 pF	1.0 pF	11 nH	2.0 pF	4.5 nH
20mm	4.9 nH	18 nH	0.8 pF	1.0 pF	11 nH	1.8 pF	4.5 nH

Table 2 – Values of the components for each clearance length.

Value		Part Number
Z1	4.3 nH	LQW15AN4N3B80
	6.5 nH	LQW15AN6N5G80D
	6.1 nH	LQW15AN6N1B80D
	4.9 nH	LQW15AN4N9B80
Z2	18 nH	LQW18AN18NG10
	17 nH	LQW18AN17NG80D
Z3	0.9 pF	GJM1555C1HR90WB01
	0.8 pF	GJM1555C1HR80WB01D
	0.7 pF	GJM1555C1HR70WB01D
Z4	1.0 pF	GJM1555C1H1R0WB01
	0.9 pF	GJM1555C1HR90WB01
Z5	13 nH	LQW15AN13NG00
	11 nH	LQW15AN11NG80
	10 nH	LQW15AN10NG80D
Z6	2.0 pF	GJM1555C1H2R0WB01
	1.8 pF	GJM1555C1H1R8WB01
	1.6 pF	GJM1555C1H1R6WB01
Z7	4.5 nH	LQW15AN4N5B80
	5.1 nH	LQW15AN5N1B80D
	4.9 nH	LQW15AN4N9B80

Table 3 – Values and part numbers of the components used for the matching networks for the cases with clearance length equal to 60 mm, 50 mm, 40 mm, 30 mm, 25 mm and 20 mm.

For additional information, please visit www.ignion.io or contact info@ignion.io.

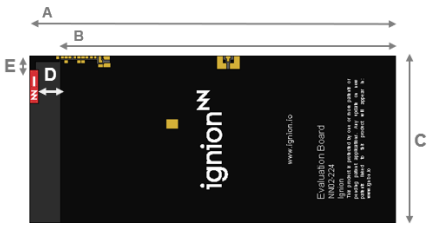
If you are designing a different device size or frequency band, run your configuration through Oxion™ at https://oxion.ai, Ignion's free-of-charge[1] AI-powered antenna integration platform, and get a complete design report with a custom matching network for your device in 24h. Ignion's engineering services: https://ignion.io/design-center/engineering-support/

3. GROUND PLANE LENGTH EXPERIMENTS

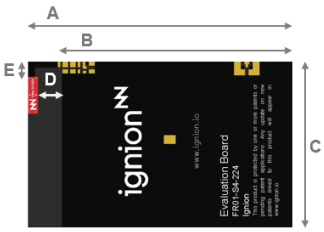
1 See terms and conditions for the free-of-charge Oxion™ service at: https://oxion.ai

3.1. EVALUATION BOARD

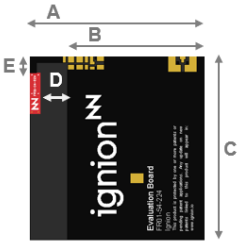
This Evaluation Board EB_N002-224-1B-2RJ-1P integrates a UFL cable to connect the RUN mXTEND™ antenna booster with the SMA connector. The experiment consists of reducing the ground plane length, going from 120mm (original case) to 40mm.



Ground plane Length: 120 mm



Ground plane Length: 80 mm



Ground plane Length: 40 mm

Measure	mm
A	131 – 51
B	120 – 40
C	60
D	8
E	5

Tolerance: ±0.2 mm

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

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

Figure 4 – Evaluation boards with different ground plane lengths that provide operation from 824 MHz to 960 MHz and from 1710 MHz to 2690 MHz.

3.2. VSWR AND EFFICIENCY

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

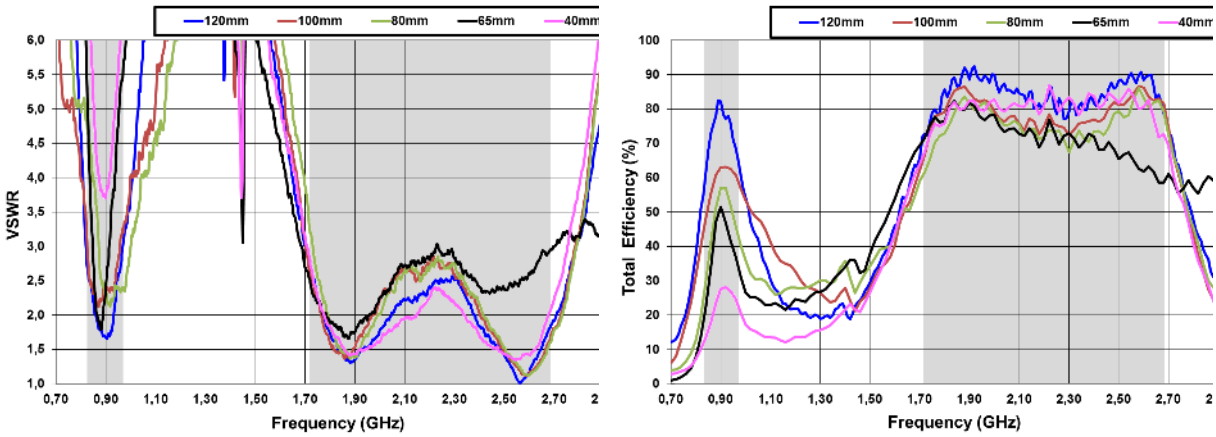


Figure 5 – VSWR and Total Efficiency for the 824 – 960 MHz frequency range and for the 1710 – 2690 MHz frequency range from the evaluation board (Figure 4).

	LFR (824 – 960MHz)	HFR (1710 – 2690MHz)

B	$\eta_{a\ 824MHz}$	$\eta_{a\ 960MHz}$	Min	Max	Av. η_a	$\eta_{a\ 1710MHz}$	$\eta_{a\ 2690MHz}$	Min	Max	Av. η_a
120mm	54.3	68.2	54.3	84.6	73.5	74.5	74.7	71.1	94.7	84.5
100mm	45.9	59.3	45.9	63.4	59.5	66.7	74.5	66.7	88.4	79.1
80mm	25.7	43.0	25.7	58.8	48.2	61.6	72.3	61.6	87.0	76.0
65mm	18.9	34.4	18.9	53.0	40.5	71.5	61.2	57.1	83.9	71.9
40mm	12.2	22.8	12.2	28.7	23.4	67.5	68.9	67.5	89.2	80.4

Table 4 – Antenna efficiency comparison considering the different ground plane lengths.

3.3. MATCHING NETWORK

The specs of a Ignion standard product are measured in their evaluation board, which is an ideal case. In a real design, components nearby the antenna, LCD's, batteries, covers, connectors, etc. affect the antenna performance. This is the reason why 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. 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 and taking into account all elements of the system (batteries, displays, covers, etc.).

Please notice 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). Please, if you need assistance contact support@ignion.io for more information related to the antenna booster matching service.

824 – 960 MHz and 1710 – 2690 MHz

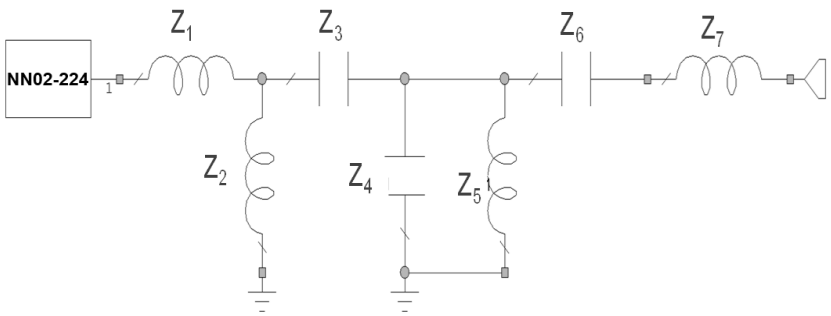


Figure 6 – Topology of matching network mounted at the different solutions.

B	Z_1	Z_2	Z_3	Z_4	Z_5	Z_6	Z_7
120mm	4.3 nH	18 nH	0.9 pF	1.0 pF	13 nH	2.0 pF	4.5 nH
100mm	5.1 nH	18 nH	0.8 pF	1.0 pF	10 nH	2.0 pF	4.7 nH
80mm	4.5 nH	18 nH	0.8 pF	0.9 pF	14 nH	2.0 pF	4.9 nH
65mm	3.6 nH	18 nH	0.6 pF	0.4 pF	-	-	3.3 nH
40mm	4.3 nH	18 nH	0.9 pF	1.0 pF	13 nH	2.0 pF	4.5 nH

Table 5 – Values of the components for each ground plane length.

Value		Part Number
Z1	4.3 nH	LQW15AN4N3B80
	5.1 nH	LQW15AN5N1B80D
	4.5 nH	LQW15AN4N5B80D
	3.6 nH	LQW15AN3N6B80D
Z2	18 nH	LQW18AN18NG10
Z3	0.9 pF	GJM1555C1HR90WB01
	0.8 pF	GJM1555C1HR80WB01
	0.6 pF	GJM1555C1HR60WB01
Z4	1.0 pF	GJM1555C1H1R0WB01
	0.9 pF	GJM1555C1HR90WB01
	0.4 pF	GJM1555C1HR40WB01
Z5	13 nH	LQW15AN13NG00
	10 nH	LQW15AN10NG00
	14 nH	LQW15AN14NG00
Z6	2.0 pF	GJM1555C1H2R0WB01
Z7	3.3 nH	LQW15AN3N3B80D
	4.5 nH	LQW15AN4N5B80
	4.7 nH	LQW15AN4N7B80
	4.9 nH	LQW15AN4N9B80

Table 6 – Values and part numbers of the components used for the matching networks for the cases with ground plane length equal to 120 mm, 100 mm, 80 mm, 65 mm and 40 mm.

For additional information, please visit www.ignion.io or contact info@ignion.io.

If you are designing a different device size or frequency band, run your configuration through Oxion™ at https://oxion.ai, Ignion's free-of-charge[2] AI-powered antenna integration platform, and get a complete design report with a custom matching network for your device in 24h. Ignion's engineering services: https://ignion.io/design-center/engineering-support/

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