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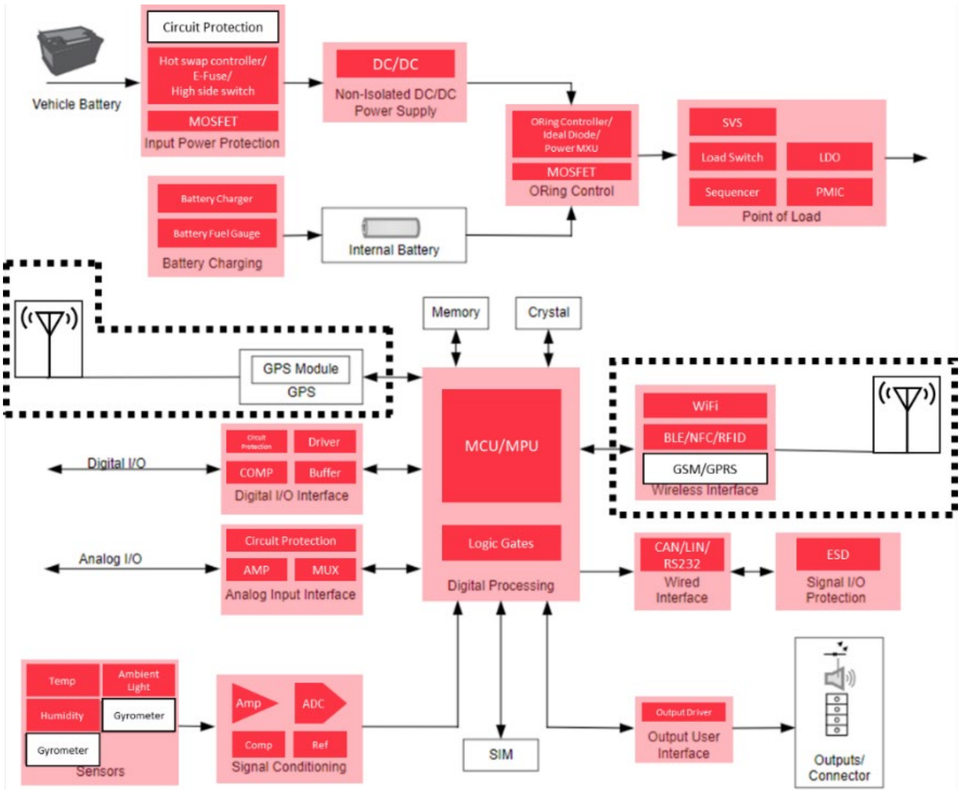
Chip vs. patch antenna on asset tracking GNSS

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™, one of our most versatile and best performing antennas. It is an antenna widely used for various IoT applications, with very good results in Asset Tracking.

Chip antennas for GNSS: top performance in a small, efficient and cost-effective package

Chip antenna technology has been proven to deliver a **top GNSS performance** in a variety of tracking devices, fleet management and wearable 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 portable devices is very large**, all of them have different sizes and requirements and the most important consideration**: they are located everywhere and not always stable and facing to the satellite reception**. Therefore, you need a small and versatile antenna to integrate into your portable device that allows this final device to receive the best GNSS signal regardless of the satellite location.

At this point, with the endless diversity of new devices requiring versatile GNSS connection, is when **chip antennas** become the perfect choice where **size, weight, portability and cost** are a priority.

TABLE OF CONTENTS

1. CHIP ANTENNAS vs. PATCH ANTENNAS for GNSS

Ceramic patch antennas, a usual choice for RF engineers when designing a GNSS application, feature a fairly *hemispherical radiation pattern*, which means they inherently deliver about 2-3 dBi more directivity than an omnidirectional antenna. This is a fact when the antenna can be conveniently mounted parallel to ground, the hemispherical pattern enables the GNSS receiver to stare at the satellite constellation without distraction from nearby devices, and when the entire antenna aperture is facing the sky with little reception from the ground.

To make this antenna somewhat compact, patch antennas need to be built on a high-permittivity ceramic material so a wavelength that is about 20 cm long can be packed in a square package about 20-30 mm with 4-7 mm thickness. Packaging an antenna into an area which is about 1/100th of a square wavelength has a *penalty in bandwidth*. The high permittivity of the ceramic in a highly resonant component, which stores significant reactive energy within the patch, is resulted in a narrow band performance and, most of the times, a *lower gain*. In smaller patches, for example 10 x 10 mm, about x 10 times smaller in surface, the *gain is dramatically reduced*, so the 2-3 dBi of gain obtained in a 30 x 30 mm patch quite often is translated into -4/-6 dBi. This becomes too much of a loss and *a low-noise amplifier (LNA)* integrated on an active package is required to enable some GNSS reception.

The use of patch antennas for GNSS reception becomes particularly **problematic when the antenna is mounted on a small and portable tracking device**, such as those for tracking goods and for fleet management applications (*IoT sensors, bikes, sport boats*, etc.). Those tracking devices usually feature a small size and, owing to its portable nature, their attitude and orientation with respect to the satellite constellation is uncertain and variable over time. For this reason, a patch antenna might eventually lose track when the receiver is rotating and changing the orientation: a user is grabbing the device on his hand or when a bike is left on the floor. Moreover, those smaller tracking devices cannot afford to fit a bulky, heavy and often expensive ceramic patch. Those applications need a **tiny, light, low-cost chip antenna** which **fits everywhere and provides an omnidirectional radiation pattern** to get satellite signals from any angle in any orientation.

Several **chip antenna** architectures such as *fractal based* and *antenna-less* technologies, currently offer **top GNSS performance** in small commercial satellite tracking platforms. Those chip components come in a **tiny SMD chip package** built on a *lightweight, durable, laminate substrate*. They feature an **omnidirectional radiation** pattern that enables **tracking satellites in any position and orientation** and since they feature a **high efficiency and gain,** they do not require an extra energy consuming amplifying LNA to make the job. Chip antennas benefit from the coupling to the electronic board of the device to optimize radiation, which means that their size can be significantly reduced without compromising on performance. Even if their polarization is not perfectly circular, their higher gain which is about 6 dB above that of a ceramic patch with a similar footprint, by far compensates the 1.5-2.5 dB of polarization mismatch. As a result, the integration of GNSS functionality into a wireless device becomes **easier, faster and more cost-effective** than that of ceramic chunk.

The present report illustrates the performance of two different types of chip antenna products, the **Geofind^{TM}** and the **RUN mXTEND^{TM}** by Ignion for GNSS applications. The performance is compared to that of a small ceramic patch that features a low gain and requires an embedded LNA to compensate for the loss of signal**. It is shown how the fully passive chip antenna**

solutions with no amplifier can deliver better results than that of the ceramic. That is the case even considering that the platform of the wireless device hosting the antenna is about 4 times smaller in the chip antenna case (70 x 30 mm) compared to that of the ceramic patch antenna (127 x 60 mm).

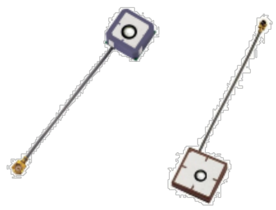
These are the products that will be used in the comparison.

CHIP ANTENNA PRODUCTS

Antenna Component: RUN mXTEND™ NN02-224
Dimensions: 12.0 mm x 3.0 mm x 2.4 mm
Frequency regions: 698 - 3800 MHz

Antenna Component: Geofind™ NN01-103
Dimensions: 10.0 mm x 10.0 mm x 0.9 mm
Frequency regions: 1561 MHz, 1575 MHz and 1598-1606 MHz

PATCH ANTENNA PRODUCTS



Antenna Component: Circular Polarized Microstrip Patch Antennas
Dimensions: 10.0 mm x 10.0 mm x 4.0 mm & 17.0 mm x 17.0 mm x 6.3 mm
Frequency regions: 1561 MHz, 1575 MHz and 1598-1606 MHz

2. PRODUCT DESCRIPTION

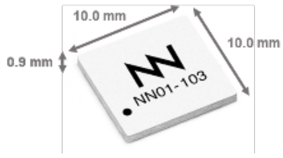
2.1. CHIP ANTENNA PRODUCTS

RUN mXTEND™ antenna booster, featuring a multipurpose versatile specification owing to its underlying antenna-less Virtual Antenna™ Technology (VAT), covers among many others, the frequency ranges used for operating at the Global Navigation Satellite Systems: GPS, Galileo, GLONASS and BeiDou. Its miniature size and the high level of flexibility of this standard component, along with the standardized feature, allows an easy implementation of the antenna booster on any GNSS wireless device. For this application note the RUN mXTEND™ antenna booster is used to demonstrate how linear polarized antennas could be implemented since the performance is competitive.

Geofind™ chip antenna is specifically engineered for low cost consumer electronics mobile GNSS devices. It uses a space-filling technology to minimize its size and cost while maintaining a high radiation efficiency value. This monopole antenna performs an omnidirectional radiation pattern, allowing it to work effectively regardless of the position of the GNSS device.

TOP

TOP



BOTTOM

BOTTOM

Material: The RUN mXTEND™ antenna booster (left) and the Geofind™ chip antenna (right) are built on glass epoxy substrate.

APPLICATIONS

- GPS/GLONASS/BeiDou modules
- Fleet Management
- Navigation Devices
- Vehicle Track systems
- Handsets and Smartphones
- Tablets
- Digital Cameras
- Smart Watches, wearables
- Metering (Gas, Electricity, Water...)
- Sensors (Parking, Speed control, Optics...)
- IoT Devices

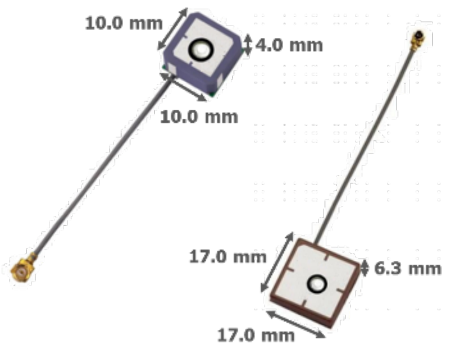
BENEFITS

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

2.2. PATCH ANTENNAS

Two small ceramic patch antennas with an embedded LNA are used in this report for comparison. They are designed to be circularly polarized which allows to maximize the received power of a circular polarized signal such as GPS.

TOP



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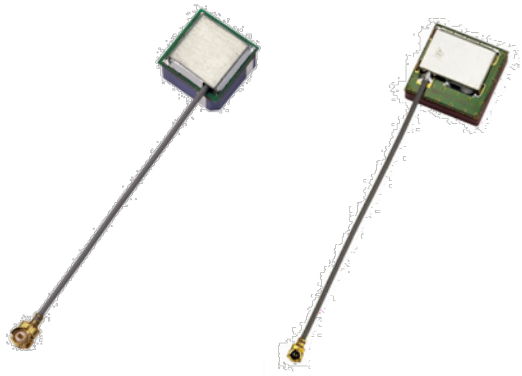


Material: Ceramic Patch Antenna.

APPLICATIONS

- GPS/GLONASS/BeiDou modules
- Fleet Management
- Navigation Devices
- Vehicle Track systems
- Handsets and Smartphones
- Tablets
- Digital Cameras
- Smart Watches, wearables
- Metering (Gas, Electricity, Water...)
- Sensors (Parking, Speed control, Optics...)
- IoT Devices

BENEFITS

- Small size
- Circular Polarization
- Maximize the received power of a circularly polarized signal
- Easy-to-use (pick and place)

3. RUN mXTEND™ EVALUATION BOARD GPS/GLONASS/BeiDou

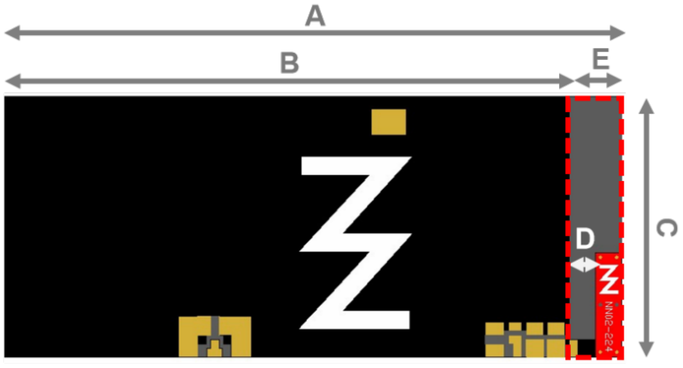
3.1. QUICK REFERENCE GUIDE

Technical Features	1561 MHz	1575 MHz	1598 – 1606 MHz
Average Efficiency	> 55.0 %	> 60.0 %	> 65.0 %
Peak Gain	1.1 dBi	1.6 dBi	2.0 dBi
VSWR	< 2:1		
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 Evaluation Board having a size of 71 mm x 30 mm. See Figure 1.

3.2. EVALUATION BOARD

The Evaluation Board integrate a UFL cable to connect the RUN mXTEND™ antenna booster with the SMA connector. The RUN mXTEND™ provides operation in three frequency regions, 1561MHz (BeiDou E1 band), 1575 MHz (GPS L1 band & Galileo (E1 band), and from 1598 MHz to 1606 MHz (GLONASS L1 band), through a single input/output port.



Measure	mm
A	71.0
B	65.0
C	30.0
D	3.0
E	6.0

Tolerance: ±0.2 mm

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

Material: The Evaluation Boards are built on FR4 substrate. Thickness is 1 mm

Clearance Area: 6.0 mm x 30 mm (ExC)

Figure 1 – EB_NN02-224-1561-1606 Evaluation Board for providing operation at BeiDou E1 band (1561 MHz), GPS L1 band (1575 MHz), Galileo E1 band (1575 MHz), and GLONASS L1 band (from 1598 MHz to 1606 MHz).

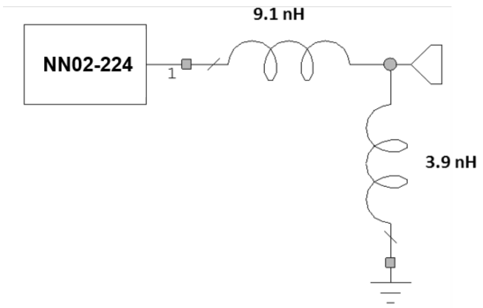
This product and/or its use is protected by at least one or more of the following patents PAT. US 9,130,259 B2; PAT. US 8,237,615 B2, and another domestic and international patents pending. Additional information about patents related to this product is available at www.ignion.io/virtual-antenna/.

3.3. MATCHING NETWORK

The specs of a Ignion standard product are measured in a reference evaluation board. In a real design, components nearby the antenna, LCD's, batteries, covers, connectors, etc. may affect the antenna performance. Accordingly, placing pads compatible with 0402 and 0603 SMD components for a matching network as close as possible to the feeding point is recommended. The matching network should be implemented in the ground plane area rather than the clearance area, this provides a degree of freedom for tuning the RUN mXTEND™ antenna booster once the design is finished and considering 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). If you need assistance to design your matching network, please contact support@ignion.io, or try our free-of-charge[1] **Antenna Intelligence Cloud** design service, you will get your chip antenna design including a custom matching network for your device in 24h[1]. Other information related to Ignion's range of R&D services is available at: https://www.ignion.io/rdservices/

1561 MHz, 1575 MHz and 1598 – 1606 MHz



Value	Part Number
9.1 nH	LQW18AN9N1G80
3.9 nH	LQW15AN3N9B80

Figure 2 – Matching Network implemented in the Evaluation Board (Figure 1).

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

3.4. VSWR AND TOTAL EFFICIENCY

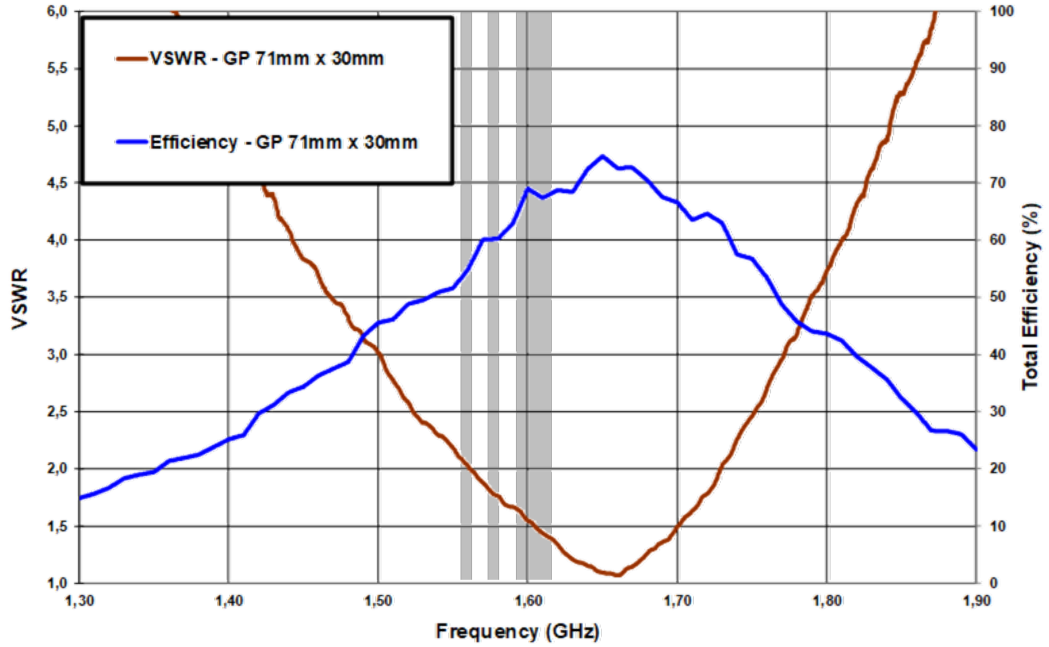


Figure 3 – VSWR and Total Efficiency for BeiDou E1 band (1561 MHz), GPS L1 band (1575 MHz) and GLONASS L1 band (1598 – 1606 MHz) (from the Evaluation Board (Figure 1).

4. GEOFIND™ EVALUATION BOARD GPS/GLONASS/BeiDou

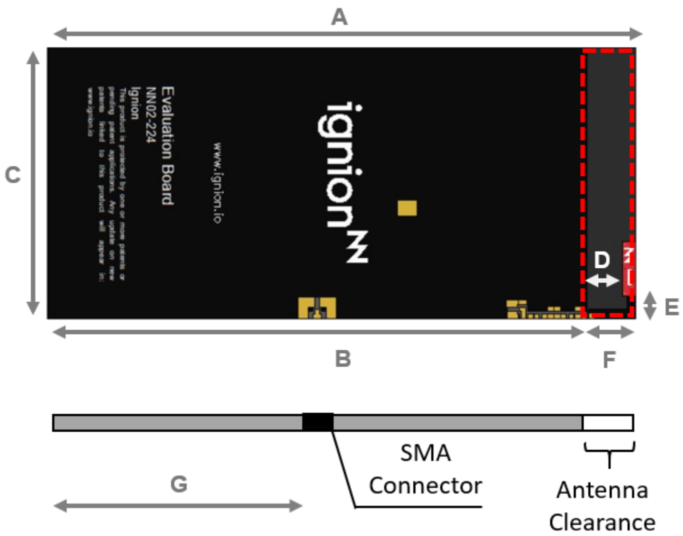
4.1. QUICK REFERENCE GUIDE

Technical Features	1561 MHz	1575 MHz	1598 – 1606 MHz
Average Efficiency	> 75.0 %	> 70.0 %	> 70.0 %
Peak Gain	1.4 dBi	1.2 dBi	1.3 dBi
VSWR	< 2:1		
Radiation Pattern	Omnidirectional		
Polarization	Linear		
Weight (approx.)	0.2 g		
Temperature	-40 to +125º C		
Impedance	50 Ω		
Dimensions (L x W x H)	10.0 mm x 10.0 mm x 0.9 mm		

Table 2 – Technical Features. Measures from the Evaluation Board. See Figure 4.

4.2. EVALUATION BOARD

The Evaluation Board for testing the Geofind™ chip antenna is displayed in Figure 4.



Measure	mm
A	60.0
B	30.0
C	71.0
D	17.0
E	35.0
F	11.0

Tolerance: ±0.2mm

Material: The Evaluation Board is built on FR4 substrate. Thickness is 1.0mm.

Clearance Area: 30 mm x 11 mm (BxF)

Figure 4 – EB_NN01-103. Evaluation Board for providing operation in BeiDou E1 band (1561 MHz), GPS L1 band (1575 MHz), Galileo E1 band (1575 MHz), and GLONASS L1 band (from 1598 MHz to 1606 MHz).

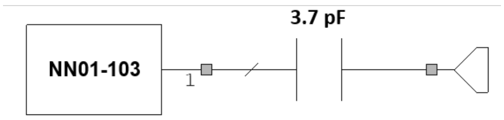
This product and its use are protected by at least one or more of the following patents PAT. US 7,148,850, US7,202,822.

4.3. 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 Geofind™ 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 Geofind™ chip antenna 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 assistance to design your matching network, please contact support@ignion.io, or try our free-of-charge[1] **Antenna Intelligence Cloud** design service, you will get your chip antenna design including a custom matching network for your device in 24h[2]. Other information related to Ignion's range of R&D services is available at: https://www.ignion.io/rdservices/

1561 MHz, 1575 MHz and 1598 – 1606 MHz



Value	Part Number
3.7 pF	GJM1555C1H3R7WB01

Figure 5 – Matching Network implemented in the Evaluation Board (Figure 4).

4.4. VSWR AND EFFICIENCY

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

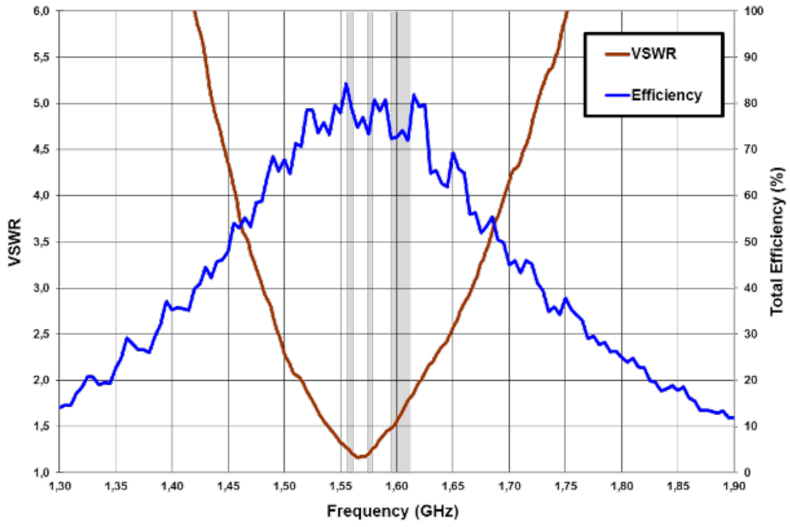


Figure 6 – VSWR and Efficiency vs. Frequency (GHz).

5. PATCH ANTENNA EVALUATION BOARD

5.1. QUICK REFERENCE GUIDE

Technical features	1575 MHz	
	Microstrip Patch 10mm x 10mm	Microstrip Patch 17mm x 17mm
Peak Gain	-5.4 dBi	-0.2 dBi
Radiation Pattern	Maximum Gain @ Zenith	
Polarization	RHCP Circular	
Weight (approx.)	2.70 g	6.5 g
Temperature	-40 to +85 ºC	
Impedance	50 Ω	
Dimensions (L x W x H)	10.0 mm x 10.0 mm x 4.0 mm	17.0 mm x 17.0 mm x 6.3 mm

Table 3 – Technical Features. Measures from the Evaluation Board. See **Figure** 7.

5.2. EVALUATION BOARD

The Evaluation Board for a commercially available microstrip patch antenna with integrated LNA is displayed in Figure 7. It includes a 3V battery to feed the low noise amplifier of the active microstrip patch antennas. Two different microstrip patch antennas of different sizes have been analyzed. The first one having a size of 17 mm x 17 mm and a second one featured by a size of 10 mm x 10 mm.

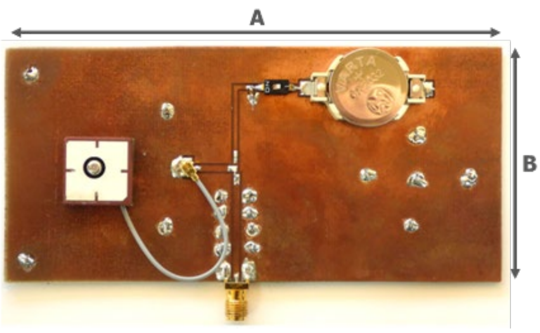


Figure 7 – Evaluation board used for the microstrip patch antennas measurement with a Ground Plane of 127 mm x 60mm.

Measure	mm
A	127.0
B	60.0

Tolerance: ±0.2mm

Material: The Evaluation Board is built on FR4 substrate. Thickness is 1.0mm.

6. FIELD-TEST MEASUREMENTS

The objective of the field-test is to analyze the performance of the evaluation boards presented above on different environments while placing them inside a moving vehicle, in this case a car.

During the test, the antenna is constantly receiving signal from any of the Global Navigation Satellites while the car is moving through different environments (urban, suburban, tunnels, countryside). The received power is measured in all the cases.

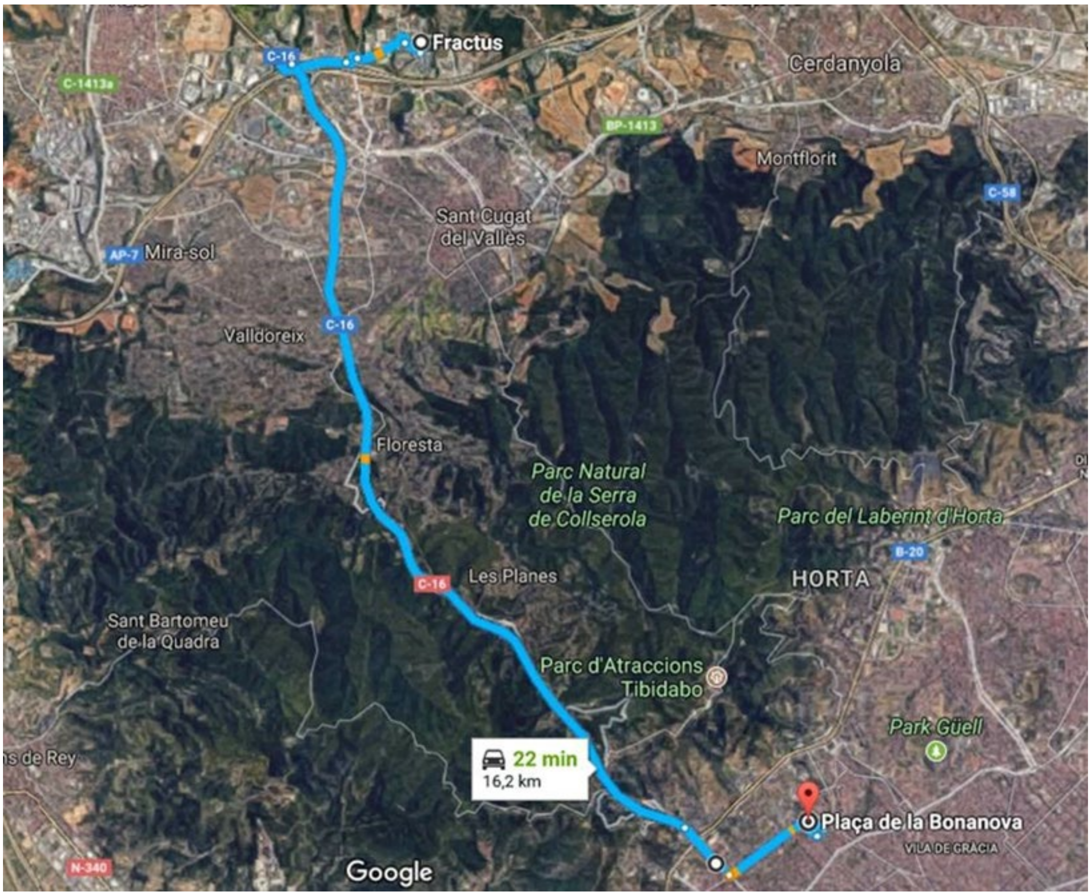


Figure 8 – Field-test route performed for this experiment (satellite vision)

6.1. SET-UP

In order to measure the received power (in dBm), each evaluation board is placed on the windscreen and connected to a portable spectrum analyzer through a coaxial line covered with ferrites to minimize its impact over the measurements.

The received power has been tracked every 30 seconds for each evaluation board to obtain the average received power (in dBm) during the route. For each case, 34 samples have been measured every 30 seconds while the car is moving from the starting point to the end point of the field test.

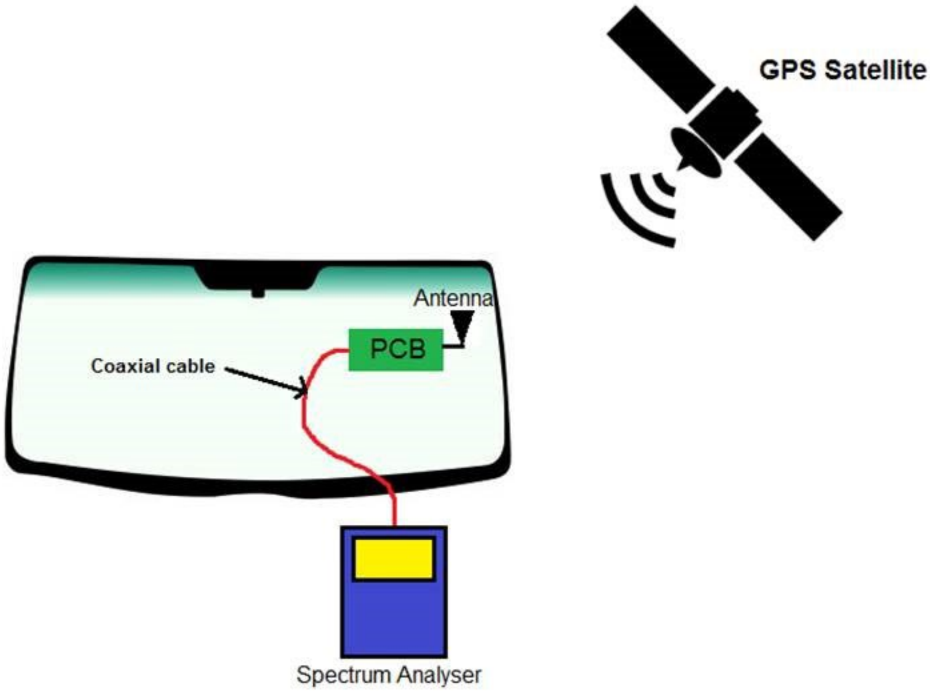


Figure 9 – Schematic of the set-up implemented for the field test measurements.

6.2. RESULTS

The results illustrate that the RUN mXTEND™ antenna booster part behaves similar than the microstrip patch antennas when considering the big evaluation board size (127 mm x 60 mm) (blue and green bars). Nevertheless, when regarding the small Evaluation Board size (pink and grey bars), both Geofind™ and RUN mXTEND™ offer a better antenna performance with the additional advantage of **its reduced form factor, price, and battery consumption**.

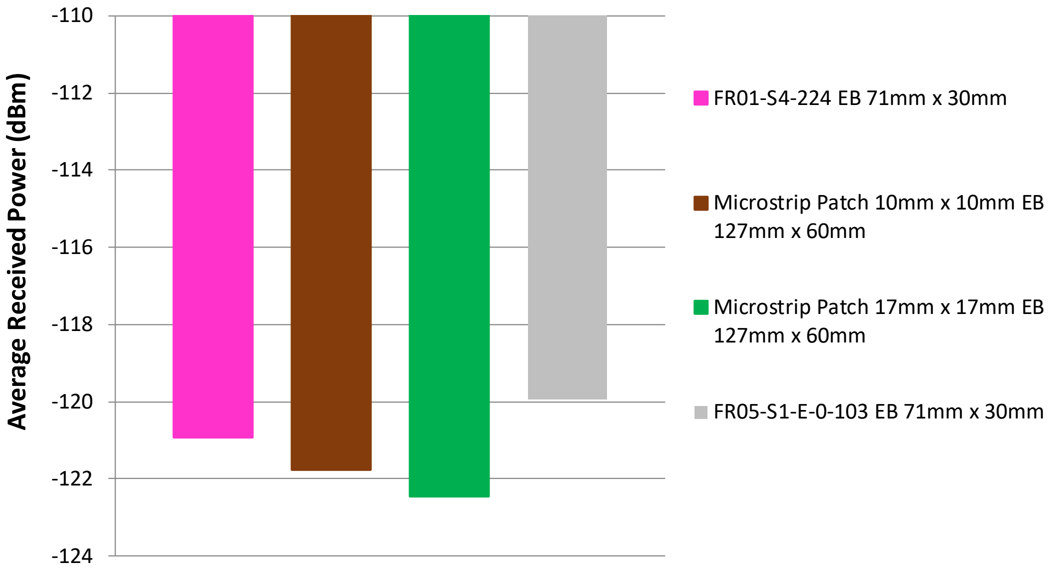


Figure 10 – Average received power (in dBm) for all the Evaluation boards tested during the field-test.

Evaluation Board	Average Received Power (dBm)
RUN mXTEND™ (EB 71 mm x 30 mm (Figure 1))	-120.9 dBm
Microstrip Patch Antenna 10mm x 10mm (Figure 7)	-121.7 dBm
Microstrip Patch Antenna 17mm x 17mm (Figure 7)	-122.4 dBm
Geofind™ Ev. Board (Figure 4)	-119.9 dBm

Table 4 – Antenna average received power measured on the Field-Test for the two RUN mXTEND™ Evaluation Boards (Figure 1), the microstrip patch antennas Evaluation Board (Figure 7) and the Geofind™ Evaluation Board (Figure 4).

The results conclude that both Geofind^{TM} and RUN mXTEND^{TM} can be successfully implemented on GNSS devices improving the microstrip patch antennas performance.

In addition, the Geofind^{TM} and RUN mXTEND^{TM} chip antennas present size and implementation advantages in comparison with the microstrip patch antennas since Geofind^{TM} and RUN mXTEND^{TM} components are both smaller and easy-to-use (pick and place) with an Off-the-Shelf implementation (no customization is required). Furthermore, they do not require active components such as the low noise amplifier to compensate the inherent losses within the small ceramic patch, thus reducing battery consumption and cost.

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