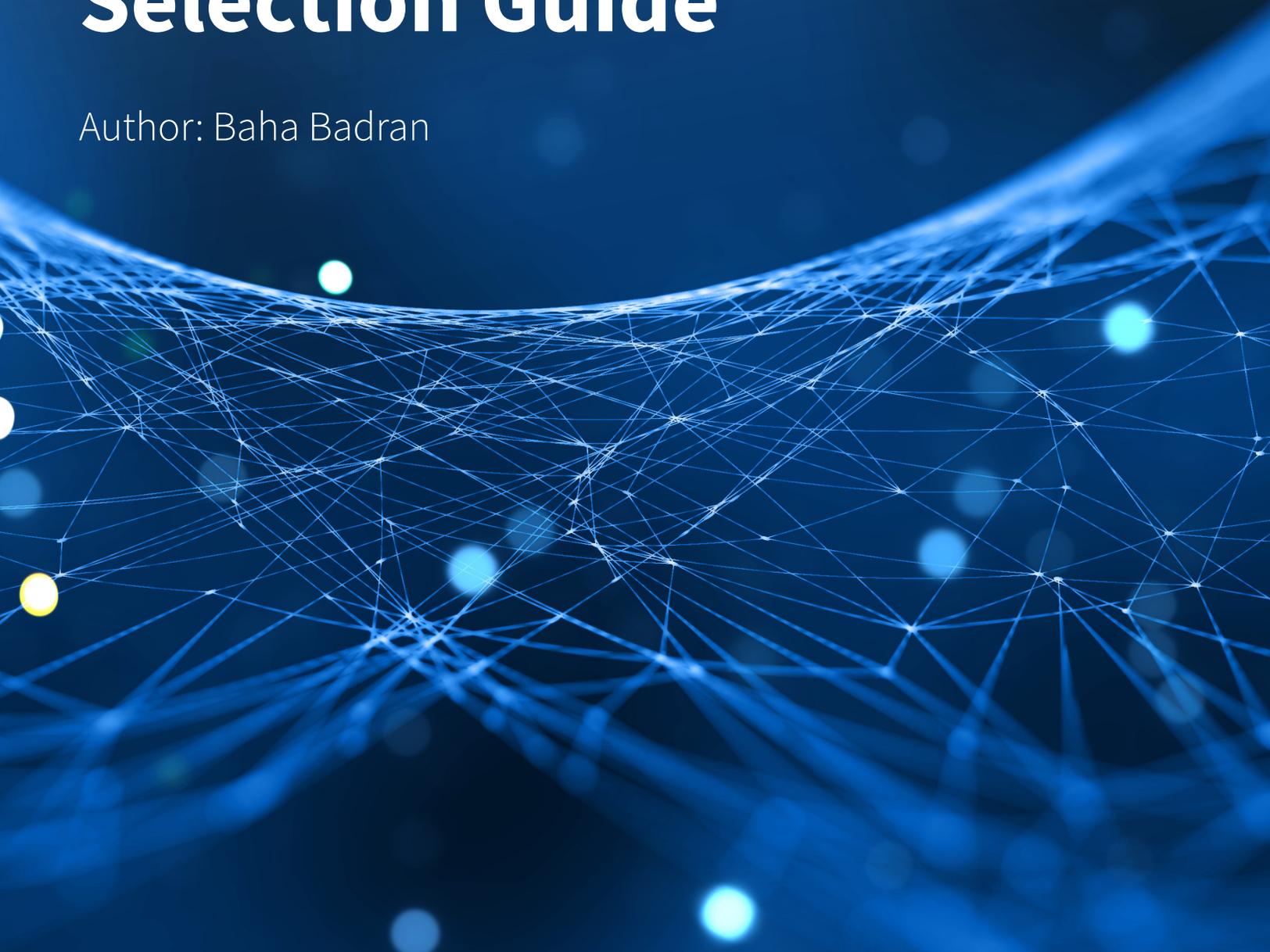


GNSS Antenna Selection Guide

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As GNSS technology continues to advance, a new reality is emerging. Our world increasingly relies on location-based services for daily activities, and this trend is set to continue. According to research by MarketsandMarkets, the global GNSS chip market is projected to grow to \$4.9 billion by 2026, representing a remarkable 48% growth over the next five years. The rise of autonomous vehicles, advanced robotic applications, precision agriculture, and many other use cases is spurring this demand. As a result, we are witnessing GNSS technology become a more integral part of our daily lives, cities, and industries.

In recent years, there has been a trend towards combined technologies (sensor fusion, PPP, RTK etc.) in GNSS systems, resulting in productivity gains and devices that are increasingly accurate and versatile. However, this adds further complexities and challenges for antenna design. Selecting the correct GNSS antenna performance is crucial to deliver a high level of accuracy and to justify the GNSS receiver's cost. GNSS signals are extremely weak; with that, you need a high-performing antenna and receiver, but most importantly, the optimal integration for the antenna, which many underestimate. Poor antenna integration will result in poor system performance, low accuracy, delays in device development, and commercial costs, ultimately leading to unhappy customers. So always consider which antenna best suits your application and the required receiver, and ensure you integrate them properly inside your device. Choosing the most suitable GNSS antenna for your device can be daunting, especially with many available options. In this article, we will determine the necessary considerations for selecting your device's GNSS antenna.

Multi-Constellations GNSS Systems

While GPS-based positioning served us well in the past for applications such as navigation and logistics, today's use cases demand higher precision. In particular, mission-critical applications such as emergency services and autonomous driving require cm-level accuracy. New technologies such as Real-Time Kinematic (RTK), which uses a reference ground station to provide real-time corrections to GNSS signals, can correct errors in GNSS signals and other positioning systems. Additionally, a multi-constellation, multi band approach helps to minimize the influence of obstructions caused by cityscapes or foliage and enables more precise location information. These receivers can improve accuracy and reliability by combining signals from multiple systems, such as GPS, GLONASS, and Galileo. Consumer chipset manufacturers have recognized the benefits of multi-constellation, with more than 30% of all chipsets supporting four constellations.

GNSS Frequency Bands

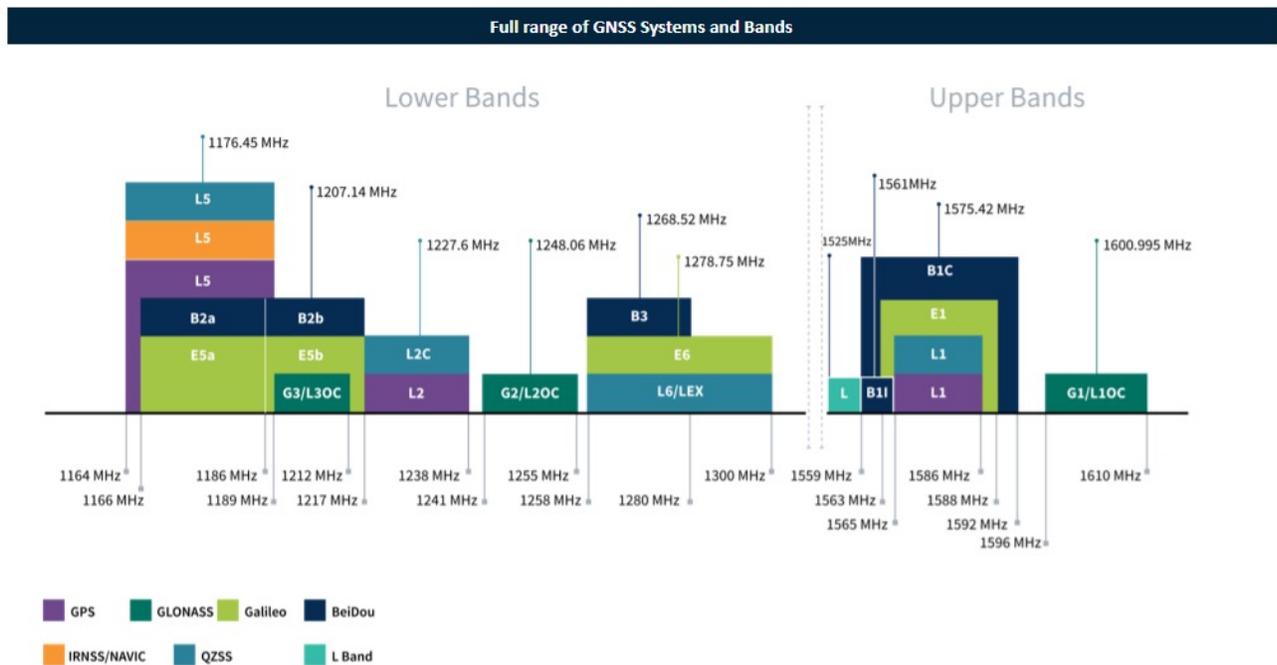


Figure 1: GNSS Constellation Types and Spectrum Bands

Figure 1 shows the bands that each constellation uses. The most common band used for GNSS is the L1 band, as it's been available for several years. But in the last few years, bands L2, L5 and L6 were made available to the public sector, and they are allowing greater access to many more satellites. The introduction of the L2 band, the increasing availability and utilization of L1+L5, and the development of dual-band receivers have all contributed to improved positional accuracy and reduced impact from ionospheric errors and interference in GNSS systems.

Multiband GNSS Receivers

When it comes to multiband GNSS receivers, selecting the correct radio module plays a crucial role in boosting the precision and reliability of your device, as it determines the constellations and bands accessible to you. To maximize the capabilities of your GNSS receiver, choose a device that offers access to a wide range of constellations and bands. By doing so, you ensure that your receiver can tap into the signals transmitted by multiple satellite systems, enabling you to benefit from a larger pool of measurements, achieve enhanced accuracy in your positioning calculations and open a world of capabilities for improved performance in positioning.

The accuracy of a GNSS receiver is also heavily dependent on the quality of its antenna. A poor-performing antenna can introduce errors in the positioning data, leading to reduced accuracy and sub-par performance. To simplify selecting the appropriate antenna, Taoglas provides [reference guides](#) for leading module providers including u-blox, Nordic, and Sierra Wireless, making it easier to filter and choose the most suitable antenna for the module. By selecting the right radio module and antenna combination, device manufacturers can optimize their products' performance and improve the user experience.

GNSS Antenna Form Factors and Environment

GNSS antennas come in many different sizes and form factors from chip, flexible PCB, and patch to dipole and helical. Figure 2 summarizes the major types and characteristics.



Figure 2: GNSS Antenna Types, Characteristics and Form Factors

The type of antenna you choose for your device will depend on the commercial application of the device. Key considerations include (but aren't limited to) the device's application/use case, the type of enclosure you need, how much space is available, what kind of directionality is required, if the device is static or mobile and how you will connect the antenna.

Motorsport Telemetry solutions can help us understand some of the challenges and considerations when choosing an antenna. In Motorsport, accuracy is everything. The margins are impossibly slim, and the difference between winning and losing can come down to a few thousandths of a second. The harsh environment of racing vehicles also presents unique challenges, such as heat and vibration, so when developing a telemetry solution, you're straddling the boundaries of what is both technically and physically possible. Every gram counts - the antenna needs to be highly compact and lightweight, so it doesn't affect the vehicle's overall weight. In addition, it needs to work across several frequencies seamlessly. Lastly, it is essential that the antenna solution can withstand harsh conditions for long periods without its performance being affected.

In this case, choosing a high-performing, multi-band GNSS antenna such as Taoglas' ADFGP.60A is an example of considering these challenges. It is made from Terrablast, a material used instead of traditional ceramic antennas when impact resistance and weight are key considerations for the device's use case. Terrablast antennas are 30% lighter than ceramic antennas and highly durable, making them the perfect solution for a mobile environment. Additionally, it performs well on all worldwide GNSS bands, including the L-bands.

GNSS Antenna Performance

The typical parameters you need to consider for your GNSS antenna's performance are the Antenna Gain, Axial Ratio, Phase Centre Offset (PCO), Phase Centre Variation (PCV) and Group Delay. Figure 2 further demonstrates these characteristics in detail.

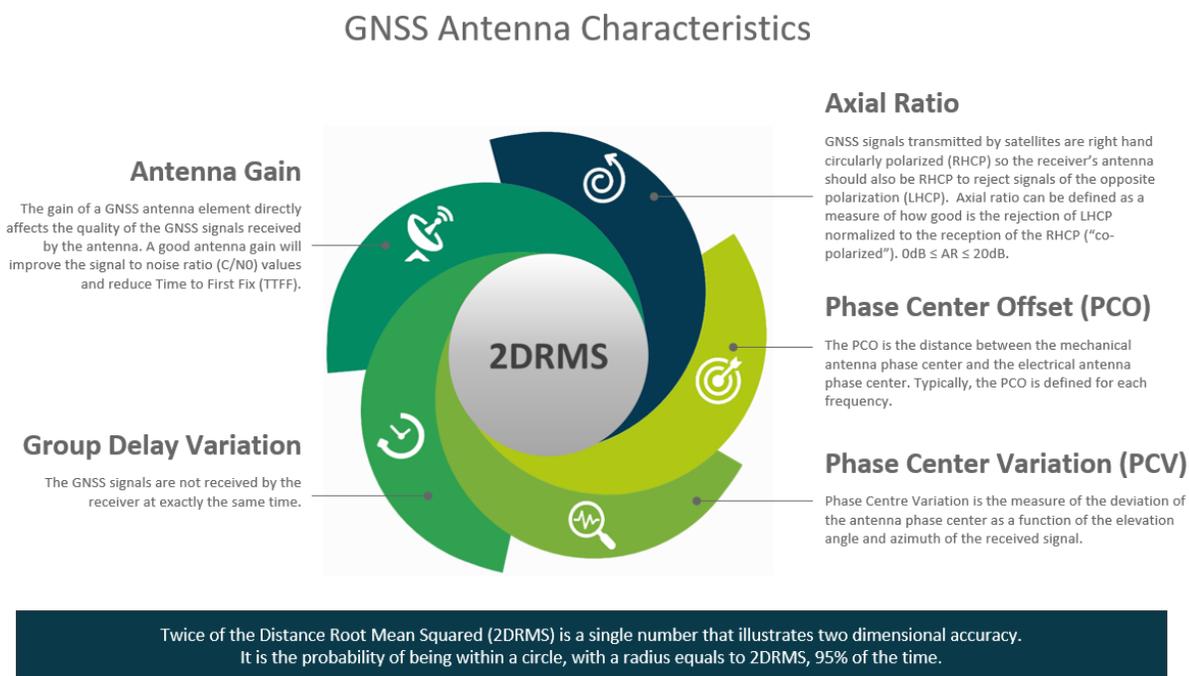


Figure 3: GNSS Antenna Characteristics

GNSS System

From the perspective of RF Engineers, when analyzing the GNSS system or subsystem within a product or device, we perceive it as comprising multiple distinct parts rather than a single subsystem. Additionally, we recognize that the GNSS system cannot be considered in isolation; it is essential to assess the entire product and understand that external factors may impact device performance or introduce issues. Figure 4 illustrates a comprehensive GNSS system encompassing the receiver, RF front end (which integrates the antenna and receiver module within the subsystem), and the antenna.

It is crucial to recognize that the GNSS system cannot be evaluated independently, as other factors can potentially cause problems. These include other radios and potential sources of noise and interference, even if they operate outside the GNSS system bands. Failure to account for these factors may result in jamming and interference with the GNSS system. While 3G GPRS radios posed challenges a decade ago, the concern today is typically LTE, and we anticipate 5G to present future issues.



Figure 4: GNSS System

GNSS Antenna Location and PCB Size

Ceramic Patch Antennas

Ceramic patch antennas are typically the primary form factor considered for a standard GNSS antenna. It is essential to determine the optimal placement of the patch antenna, whether on a PCB or a ground plane.

We recommend using a PCB with dimensions of ideally 70x70mm; however, that does not mean you cannot make this area larger or smaller. Increasing the size results in higher gain and a more directive antenna. Conversely, reducing the size of the ground plane leads to decreased gain and efficiency. Figure 5 demonstrates examples of GNSS ceramic antenna placement, illustrating that moving it towards the corner will necessitate tuning. Additionally, bandwidth and gain may also be affected. For applications requiring high precision, it is advisable to position the antenna in the middle. If you need to fine-tune the antenna you should reach out to an RF Engineer for assistance.

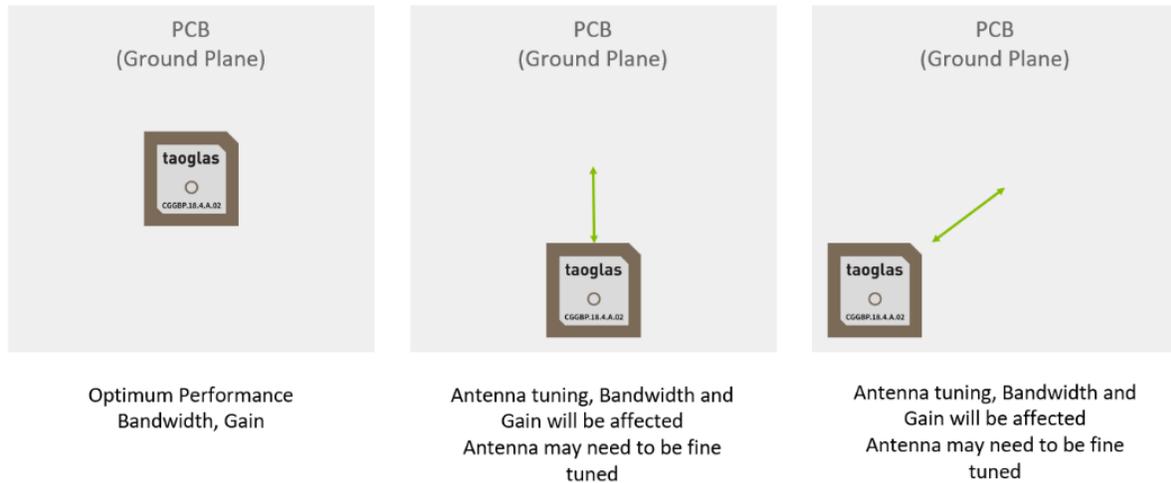


Figure 5: Examples of GNSS Ceramic Antenna Placement

Flex Antennas

Flex antennas offer an ideal solution for device designs where flexibility and space limitations are important considerations. These antennas can be easily mounted on nonmetal surfaces like plastic, glass, and screens using a simple “peel and stick” method, eliminating the need for drilling holes. When integrating the antenna, keeping it at least 1cm away from metal is essential to ensure optimal performance.

Chip Antennas

Chip antennas are tiny and compact. They can be tightly integrated into assemblies and PCBs. When working with chip antennas, it is important to consider a few key factors. Like most surface mount antennas, the visible portion of the chip antenna utilizes the PCB’s ground plane as an integral component of the antenna. Consequently, both the PCB’s size and the antenna’s placement on the PCB can significantly impact its performance.

The width of the PCB, especially when it reaches 80mm, becomes a critical dimension that must be maintained. If this area is reduced, it will noticeably degrade the antenna’s performance. However, the length of the PCB has a different level of criticality. When placing the chip antenna, we recommend mounting it in the centre of the longest edge of the PCB. Remember that during the device development process, you may need to modify the values of the matching circuit to optimize the antenna’s performance. Adjustments to these values are to be expected at some stage in the development of your device.

- Exceptionally small
- Mind the PCB size and tuning components – may need adjustment
- PCB Width: larger is better
- PCB Length: not critical, but larger is helpful
- Place the antenna roughly in the middle

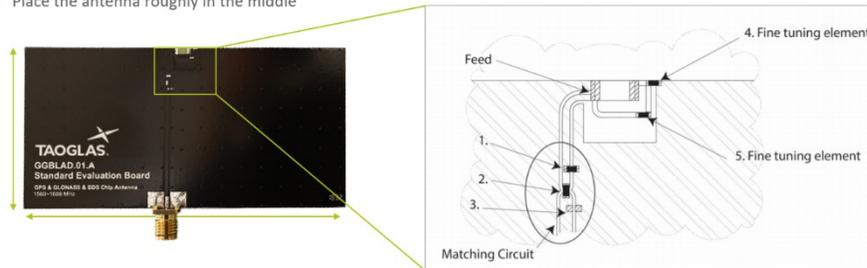


Figure 6: Example of internal chip antenna placement

External Antennas

External antennas are often considered plug-and-play. However, a key consideration includes a good sky view. Additionally, the ground plane can often be helpful (for example, the vehicle roof) as some antennas expect the ground plane to be there and having a ground plane in place can help negate the multipath.

Commercial Considerations

The most accurate and sensitive antennas and receivers tend to cost more. Therefore, weighing the cost against the benefits is essential to determine whether your application requires the investment. Additionally, consider whether an augmented service from Wi-Fi or cellular could be a viable alternative. The decision depends on your commercial application and what you hope to achieve with your device. By choosing a module and antenna that can support multiple constellations and has a higher performance, a device could give its product a competitive edge, futureproofing the design and gaining added value for your customers.

Seek Expert Advice on Integration

If you are still deciding which GNSS antenna to choose, consult expert advice from an antenna manufacturer, such as Taoglas, who can provide guidance and recommendations based on your specific application. Device OEMs often need more in-house RF resources to integrate the correct module and antenna into their design to ensure reliable performance. Choosing an antenna manufacturer that can help design and optimize RF and antenna performance can significantly benefit device OEMs time to market. Such vendors can offer design support that allows customers to achieve even greater positional accuracy (down to the cm level) by testing their high-precision GNSS antennas in an open sky view environment to simulate the expected values that an end-user may expect in a field test, in addition to utilizing anechoic chambers. These engineering services can significantly improve product performance and reduce the likelihood of design flaws.