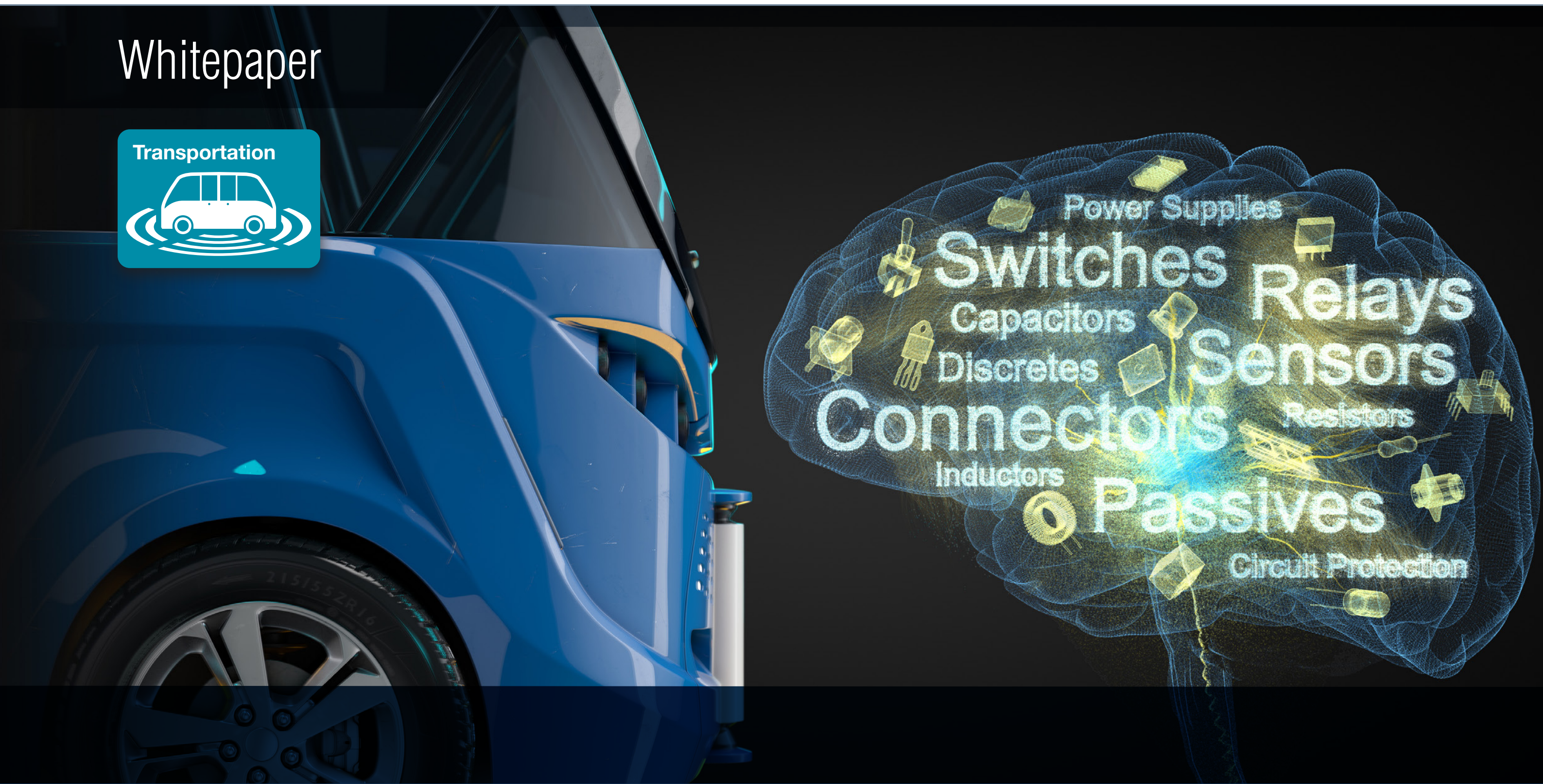
Whitepaper



Selecting antennas for ADAS and telematic applications

By Edoardo Genovese, Technical Development Manager RF Europe

In our connected society, establishing and maintaining an optimal and reliable wireless link is of paramount importance. For communication over more than a few metres, a suitably matched antenna helps maintain a resilient link. It ensures the transmitter operates in an efficient manner using only the power consumption needed. Selecting an antenna is a complex matter that requires a complete understanding of the use cases an end-product needs to operate within and the technical specifications of the antenna too.

This white paper investigates the critical characteristics of antennas for various driver assistance and telematics applications, from 5G-based V2X to high precision GNSS, how to choose a suitable antenna, and how to ensure it is probably matched to the transmitter.

Driver assistance systems; not just for cars

When you think of advanced driver assistance systems (ADAS), the mind automatically thinks of those we might be familiar with in our cars. Travelling by car has undoubtedly become safer, and the past years have seen a dramatic increase in the number of ADAS functions available. Initially sold as optional extras, many are now becoming standard across all vehicle variants. The list of ADAS capabilities continues to grow, but the most popular include adaptive cruise control (ACC), lane assist, blind-spot vehicle detection, emergency braking, and traffic sign detection.

New ADAS functions based around vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2X) are still in their infancy. Once fully deployed, they will open up a host of safety innovations as a vehicle becomes connected to other road users and traffic management infrastructure. Semi- and fully autonomous vehicles are reliant on ADAS and other sophisticated technologies to operate safely.

However, there are many applications for driver assistance systems in other vehicle types. In addition to conventional ADAS functions, commercial vehicles like trucks and vans also use online tracking, route planning, and driver performance applications. Driverless industrial forklifts use precise indoor location services to navigate a warehouse, and driver-based forklifts use data terminals to receive work orders. Agriculture vehicles also increasingly use ADAS and other telematics functions to maximise crop yields and precision fertiliser application.

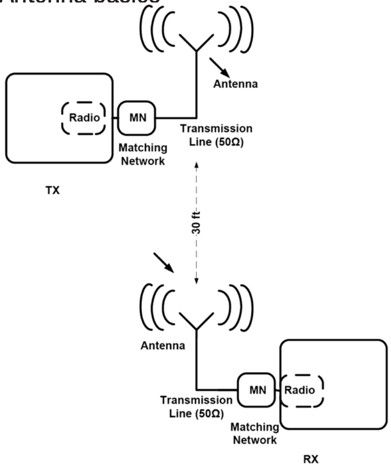
A recent innovation by John Deere, an agriculture machinery manufacturer, connects a combine harvester and the collecting tractor and trailer. With Machine Sync, the trailer tractor maintains the same speed as the harvester and the correct distance apart. With this approach, crop wastage is eliminated, machine damage is avoided, and higher harvesting speeds achieved [1].

ADAS functions keep the driver informed of potential traffic delays and other hazards for public service vehicles used in urban transportation. Telematics informs service operators of dynamically changing passenger numbers so that operations staff can quickly add extra services to boost capacity during busy periods.

Ensuring that ADAS and telematics functions operate as planned requires reliable and robust wireless communication, of which the antenna plays a critical role.

Key antenna parameters and principles

Antenna basics



Achieving an optimal RF transceiver and antenna design are essential elements in creating an energy-efficient and reliable communication link over any distance. Ensuring that the maximum possible amount of power leaves the final stage of the RF amplifier, is transferred along a transmission line, and is radiated from the antenna is crucial. Likewise, any received signal needs an equally efficient and low loss path from the antenna to the receiver front-end. See Figure 1.

Figure 1 - An example short-range wireless (source Cypress)

[1] https://www.deere.co.uk/en/agricultural-management-solutions/guidance-automation/machine-sync/

An antenna is essentially a wire in free space. There is a direct correlation between the wire's length and the frequency or wavelength, it is most efficient radiating at. The wavelength of a wire, or conductor, sets the point of resonance, and typically antennas only operate efficiently over a relatively narrow range of frequencies. The simplest antenna is a dipole, and these are usually described as a fractional part of the operating wavelength – for example, a half-wave dipole, a quarter-wave dipole.

Wavelength is measured in metres and describes how far a radiated radio frequency signal will travel in one cycle. To put wavelength into context, most short-range to medium-range applications (typically up to 5 km) operate in the very high frequency (VHF) and the ultra-high frequency (UHF) spectrum ranging from 150 MHz up to 2,400 MHz. V2X and V2V applications may utilise 5G cellular technologies that go as high as 6 GHz.

The higher the frequency, the more a signal becomes attenuated by walls, buildings, and vegetation, so antenna efficiency is vital. A ground plane serves as an essential aspect of the antenna's performance and radiation characteristics with any antenna.

A frequency of 300 MHz equates to a full wavelength of 1 metre. A half-wave antenna length would be 50 cm and a quarter-wave 25 cm. At 6 GHz, the wavelength is 50 mm.

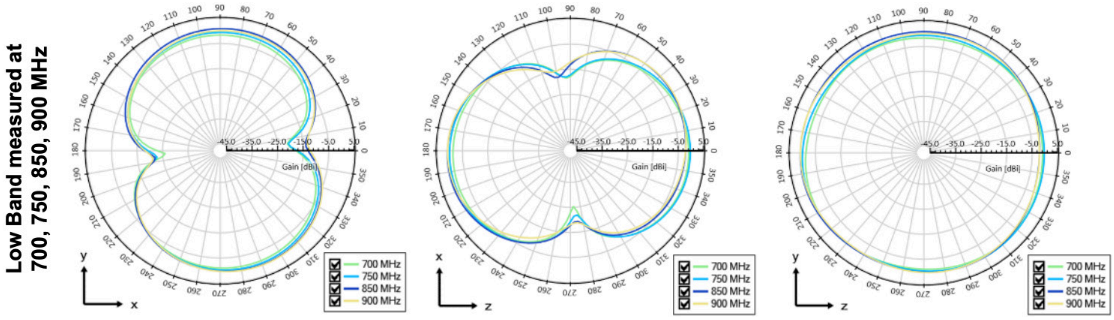
GNSS signals operate around 1.2 GHz - 1.6 GHz (20 cm wavelength). Stationed 20 km above the Earth's surface, they have the furthest to travel and experience significant attenuation before they reach an antenna mounted on your vehicle's roof.

When selecting an antenna, here are some explanations of the technical terms you will encounter and why they are essential.

Bandwidth and impedance matching: Most antennas and transmission lines have a 50-Ohm impedance. Maintaining an efficient transfer of the RF energy leaving the transmitter or received by the antenna is critical. The impedance of an antenna varies with frequency, so make sure you know the frequencies your application will use. Matching components, typically comprising inductors and capacitors, can change the antenna's impedance to the transmitter. The bandwidth characteristic of an antenna highlights how well the antenna is matched to the 50-Ohm transmission line (coax or feeder) across the active frequency range. The antenna will exhibit its lowest impedance at its resonant frequency, and this is usually the quoted centre frequency. Below this frequency, the antenna has a more capacitive impedance and above the antenna becomes more inductive.

Antenna gain and radiation pattern: The nature of antenna construction makes them more effective at radiating power in a particular direction. An omnidirectional antenna is preferred for most purposes, radiating and receiving signals equally in all directions in a fixed plane. For fixed point-to-point wireless links, antennas that exhibit directional characteristics can be used to increase the transmitter's energy in a given direction. Antenna gain is measured in dB against a standard model antenna. An antenna datasheet will highlight its gain and directional characteristics by frequency and X, Y, and Z axes. Figure 2 highlights the plots of an AVX Ethertronics 1004795 / 1004796 Universal Broadband Embedded LTE antenna.

Figure 2 - Antenna gain and radiation chart examples (source AVX/Ethertronics)



Return loss and VSWR: Return loss expresses how well an antenna is matched to the 50-Ohm impedance of the transmitter and the transmission line. Together with voltage standing wave ratio (VSWR), return loss indicates how much of the RF power is reflected back to the transmitter and how much is radiated. Return loss is measured in dB, and the higher the number, the less reflected power. An infinite return loss means that the antenna is perfectly matched to the transmitter's impedance so that 100% of the transmitter's energy is delivered to the antenna. VSWR expresses the performance as a ratio between the power transmitted and the power reflected. A VSWR of 1:1 indicates a perfect match.

A VSWR of 3:1 highlights 75 % of the transmitter's energy is delivered to the antenna, and 25 % is reflected. This VSWR equates to a 6 dB return loss, which for all practical purposes, represents the worst-case VSWR and return loss characteristics to be avoided. For most practical purposes, a return loss of 10 dB (VSWR 2) or better should become the benchmark to achieve. Attempts to improve the return loss further than this metric can become an expensive and time-consuming task with little gain.

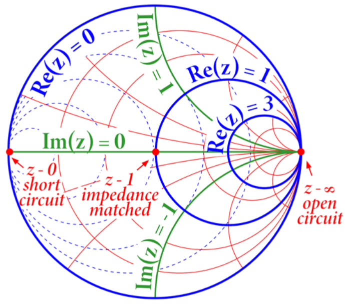


Figure 3 - A Smith chart source Abracon

Antenna impedance measurement: A vector network analyser (VNA) is used to plot the impedance of an antenna across a given frequency range. The plots are termed Smith charts and are used to visualize the 1-port S11 scattering parameter. A VNA function is typically integrated into bench-mounted RF spectrum analysers, but small portable units are also available for less than $100 and can give adequate results.

Types of antenna suitable for ADAS and similar functions

Antennas for ADAS applications fall into broadly two categories. For applications like GNSS, where signal strength is low, and for cellular voice and data communication, where link reliability and range are paramount, externally mounted antennas provide the best performance. Some externally mounted antennas include pre-amplifiers and signal conditioning circuits and are termed active antennas. Applications within the vehicle, such as in-vehicle Wi-Fi and short-range ADAS connectivity, such as blind-spot detection sensors to the relevant ECU, internally mounted embedded antennas are simpler and cheaper to install.

External antenna types and their placement

External antennas are typically mounted on the rear roof of the vehicle. They are exposed to the elements, so protection against moisture and dust ingress is essential. Externally mounted antennas need to have an IP rating. GNSS, cellular and V2X/V2C antennas are often incorporated into a single streamlined package along with pre-amplifiers and matching components. An example is TE Connectivity's HIRSCHMANN 955-181-004 7-band antenna, see Figure 4.

Figure 4 – TE's HIRSCHMANN 955-181-004 is an external 7-band integrated antenna (source HIRSCHMANN/TE Connectivity)

Another outdoor antenna example is the Abracon ‘dome’ style AECR1808X4 - see Figure 5.

Figure 5 - The Abracon AECR1808X4 is IP67-rated and have a 4 x 5G MIMO antennas inside, covering the 600-6000 MHz frequency range (source Abracon)

External antennas are supplied as a complete assembly with separate coaxial transmission lines for each application. No additional matching components are typically required, although it is prudent for the application engineer to validate its return loss and impedance characteristics when used with the intended application.

Internal and embedded antenna types

PCB antennas are created by a trace directly from the wireless transceiver. Several different types describe the layout of the 2D trace. They can be a straight trace like a wire dipole, an inverted F-type, a meandering inverted F antenna (MIFA), curves, and other shapes. Typically, a PC antenna requires sufficient free space on the PCB to give good performance and be located where the PCB is close to an external surface. Despite demanding a larger PCB area, this type of antenna is easy to manufacture and gives an acceptable range, especially for single band applications like BLE.

Where space is limited, or for multiband applications like cellular, chip antennas are an alternative option. Typically packaged in a ceramic housing, they can be surface-mounted, further simplifying production and saving valuable PCB space. See Figure 6.

Figure 6 - An example of a ceramic chip antenna from Pulse Larsen, the W3089, is a two-port omnidirectional antenna covering all bands used for GNSS. (Source Pulse Larsen)

Stamped metal antennas are also a popular option, many taking the format of a MIFA mounted on the PCB. See Figure 7.

Figure 7 - An omnidirectional stamped metal MIFA from AVX 1002298. This antenna provides a dual-band 2.4 GHz and 5 GHz capability for Wi-Fi and Bluetooth. (source AVX)

Another PCB mounted antenna is a patch style - see Figure 8.

Figure 8 - A circular polarised directional patch antenna from AVX - model 9001118 - The antenna is designed for V2X and 5G applications operating at 5.9 GHz. (Source AVX)

The placement of an internal antenna does need consideration when designing the PCB enclosure.
Attenuation of UHF signals due to enclosure materials and shielding can significantly impact range, even over short distances within a car. Signal reflections also impact overall signal-to-noise conditions and the robustness of a link.

Another consideration is that the surrounding PCB and enclosure can change the antenna's resonant frequency and impedance. In-situ testing using a VNA should always be conducted to confirm that the ADAS function is operating as expected. Ground-plane influences resulting from metallic surfaces also impact antenna performance.

Additional matching components may be required for each of the examples highlighted previously highlighted. The antenna's datasheet should provide details on the antenna's resonant frequency and impedance. A simple PCB matching network can be implemented depending on how the transceiver links to the antenna, either by a suitable printed circuit transmission line or coaxial cable.

The most common matching network topologies are L-matching, π-matching and 4 components matching, see Figure 9.

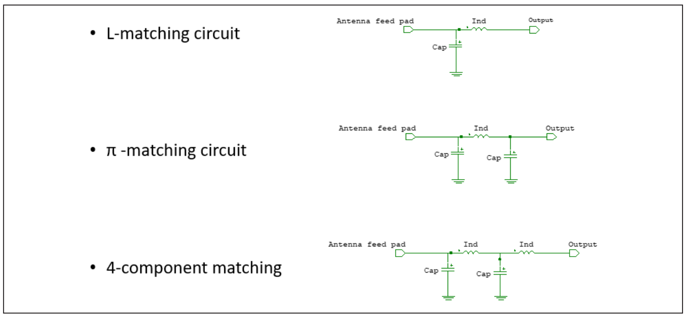


Figure 9 – Typical matching networks

Internal cabled FPC antennas are also available. These antennas can be glued inside the plastic cover and are a good option if the radio PCB becomes too crowded or too small to fit an embedded antenna. Several options are available: single antennas, MIMO antennas or multiband antennas with two or more cables. Cable length and connector type can typically be customized. Figure 10 shows an example.

Figure 10 – Molex LTE/GPS Combo Flexible Antenna, covering 5G and GNSS frequencies – Part Number 213353-0100

Getting connected

Advanced driver assistance systems and vehicle telematics rely on reliable and resilient wireless connectivity to operate safely. The critical component of any wireless link is the antenna. Responsible for radiating the transmitter's energy in the most efficient way relies on matching the impedance of the transmitter to the antenna at the desired frequency of operation.

In this white paper, we've highlighted some of the key antenna criteria that design engineers need to consider when selecting a suitable antenna. With this insight and a simple VNA, engineers can rest assured their selected antenna will perform efficiently.

[1] https://www.deere.co.uk/en/agricultural-management-solutions/guidance-automation/machine-sync/

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