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Wireless connectivity and electromagnetic compatibility in IIoT

The challenges of wireless connectivity and electromagnetic compatibility in IIoT

INTRODUCTION

Many manufacturing environments are seeing an end to efficient returns on their traditional quality improvement programs. With hundreds or more incremental improvements implemented, there is often little more fine tuning that can be done – only serious investment remains, requiring major changes to equipment. These improvements involve integration of Industrial Internet of Things (IIoT) technology to deliver the insights required that feed the decisions that make the next efficiency improvements possible.

While industrial systems offer a wide range of wired networking technologies that variedly fill all points along the performance versus price axis, there are many applications for which a tethered solution is of no use. The logistics industry, moving shipping containers across continents, or warehouse robots, necessarily demand the use of wireless technology. Some new applications that today do not exist will only be possible thanks to wireless services coupled with long-life, low-power electronics.

Many engineers still consider radio frequency, or RF, technology and electromagnetic compatibility (EMC) to belong to the black arts. But semiconductor vendors and other suppliers increasingly raise the attractivity of RF technology and its ease of use by offering modules that seem to resolve a large portion of the risk. Here we review some of the remaining challenges around using wireless technology and EMC and what to consider when developing an IIoT application.

WHAT ARE SOME OF THE KEY ISSUES AROUND WIRELESS AND EMC?

Perhaps the best advice that can be shared around the challenges of wireless technology and EMC is to assume, from the beginning of the project, that there will be challenges. Simply ignoring the issue until the product fails during certification will result in unnecessary delay, frustration and costs. Most issues that are discovered during the certification process could have been avoided through correct circuit board layout, appropriate testing, and an appreciation for RF issues. And, perhaps just as importantly, they are rarely easily solved with the simple addition of ferrite beads and some shielding.

After this, the next consideration is of the desired antenna performance in the context of the environment it is to be used. This may be on a container crossing the Atlantic, fixed to a streetlamp, or integrated on to an automated guided vehicle in the relative comfort of a warehouse. The antenna could be **fixed to the outside of the equipment** or integrated onto the circuit board of the control system. If the antenna is embedded, a cross-functional review of all engineering disciplines is needed to review what impact paint or housing materials may have on RF performance. In the case of embedded antennas, it should also be remembered that the entire system must be considered part of the antenna. It is never a bad idea to start with the antenna and then design around it.

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WHAT WIRELESS CONNECTIVITY DOES IIOT USE?

The range of wireless connectivity options in use is as varied as the applications themselves, with often more than one wireless technology being integrated into a single application in some cases. This often occurs where **Global Navigation Satellite Systems (GNSS)** are used to provide location services and accurate timing along with **mobile networks (2G to 4G and, in future, 5G)** for data exchange. Such solutions require a suitable power source to ensure the system can operate reliably over long periods.

For applications that need to be lower power but communicate over a long range, solutions such as LoRa® or Sigfox may be suitable. These low-power, sub-gigahertz technologies allow large areas, such as an entire cities or countries, to be covered by their services. This incredible range has to be traded-off against a combination of data throughput, power consumption, and latency. For LoRa®, data rates can lie between 50kbps and 250bps, whereas Sigfox is optimized for tiny 8 to 12-byte payloads.

Shorter range technologies (sub 100m) are provided in the form of Bluetooth and Wi-Fi that again offer trade-offs between range, power consumption and throughput. Wi-Fi is well understood, provides high bandwidth, and integrates easily with Internet Protocol (IP) networks. However, it requires a wired power supply to support its energy consumption needs. Bluetooth covers a wide range of throughputs and power consumption needs and was originally designed for battery operation within the mobile phone. The Bluetooth Low Energy technology also offers indoor positioning capability from battery-powered beacons that can run for several months to more than a year.

HOW WILL 5G IMPACT IIOT IMPLEMENTATIONS?

Perhaps the first thing to note is that 5G is not just another `G'. Since the roll-out of the initial analog mobile networks of the 1980s the focus has primarily been on improving throughput and speed to the end consumer. While 5G does offer lower latencies and higher data rates than 4G, it is the connection density and therefore the ability to support more subscribers per base station that is the key added value. If considered beneficial, operators of large manufacturing complexes can even operate their own 5G networks. And, thanks to the use of **Multiple-Input Multiple-Output (MIMO)** Active Antenna Systems (AAS), the era of omnidirectional broadcasting is ending in favor of directional communication.

However, as highlighted in the Ericsson Mobility Report (July 2019)1 the impact of this technology will take time to reach users and their potential applications, with only around 20% of subscribers worldwide on 5G networks by 2024. Regional roll-out and coverage will depend highly on the infrastructure plans of network providers, meaning that IIoT implementations will likely have to plan with existing technology in the near term.

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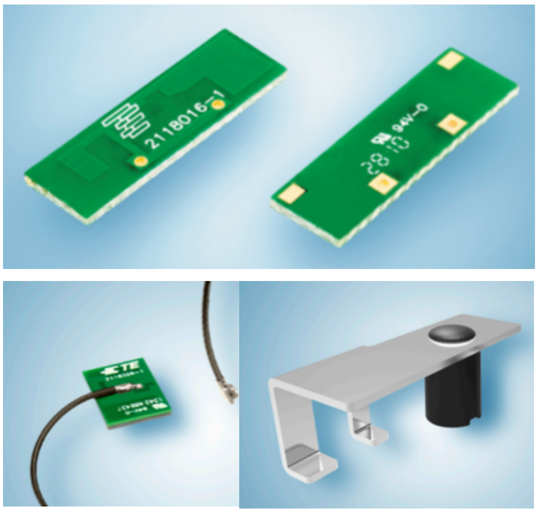
HOW DO I HANDLE WIRELESS IIOT IN CHALLENGING ENVIRONMENTS?

Seemingly regardless of size, construction or materials used, its feels like radio technology can be integrated into anything. Long gone are cell phones with extendable antennas or stubby aerials. Technological advances mean that an antenna can be implemented as a surface mount printed circuit board (PCB), a stamped metal solution, or even a 3D plastic molded part. But before the imagination runs off thinking the antenna issue is solved, it is worth remembering the antenna axiom: an antenna can be small, efficient and have the desired bandwidth, but you can only pick two of those options.

If possible, antenna design should remain in the realm of the two-dimensional. A PCB antenna is a simple solution that is easy to mount and requires minimal or sometimes no matching circuitry. Some solutions offer dual band support, such as **2.4 GHz and 5 GHz for Wi-Fi applications**. An example omni-directional antenna, measuring just 18.9 x 6.2 x 0.79 mm, requires location along an edge of the PCB. An example antenna that covers all the cellular bands is the MetaSpan multi-band LTE/cellular antenna. Bandwidth and performance are dependent on ground plane size, which should be located on the top layer, and maintaining the minimum antenna feed length. Early in the design phase it should also be considered that a keep-out area of between 4 and 10 mm is also required around the entire antenna. This may constrain the placement of other application elements, such as displays, switches, batteries, cables and connectors (Figure 1). (#2118016)

Should ease of manufacture be a concern, 2.5D pick and place surface-mount options are available. These stamped metal antennas can stand around 5 mm proud of the surface of the PCB. Like PCB antennas, their performance is dependent on the ground plane size and antenna feed length and the keep-out zone must be respected. (#2118316). However, if space on the PCB is at a premium, a wired PCB antenna featuring a **miniature U.FL connector** may be a better option. Again, mounting needs to be considered early on in the design. A 5 GHz antenna targeting IEEE 802.11 a/g/n/ac applications recommends a 5 mm keep-out zone across all of its planes and mounting on a plastic surface. (#2118326).

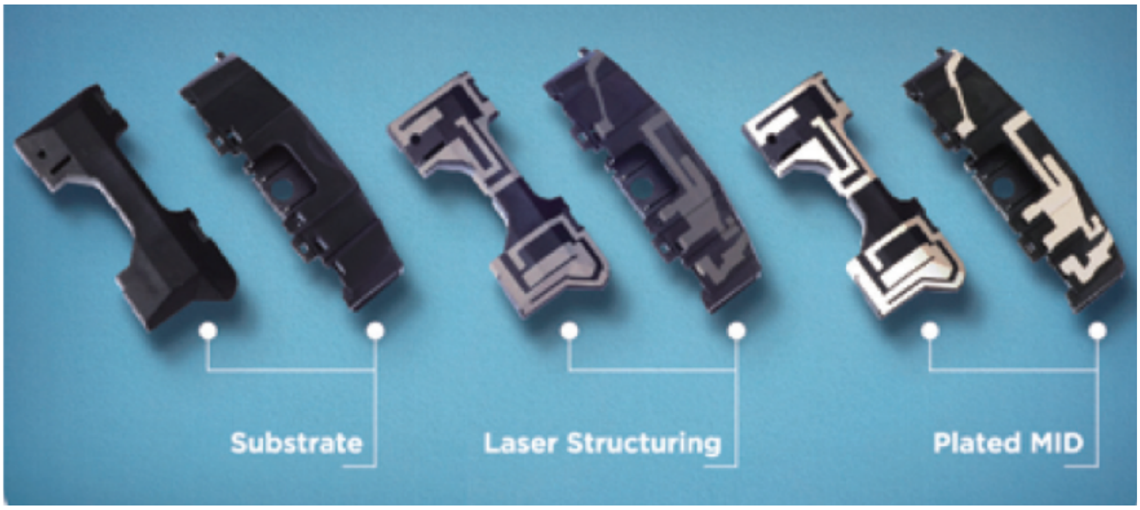


▲ **Figure 1:** A PCB, wired PCB and stamped antenna, providing various compromizes on space, fixture and volume as well as radiation characteristic. (Left to right #2118016, #2118316, #2118326)

Once the application starts to become exceptionally compact, other custom antenna options can be considered that are applied to three-dimensional surfaces. Molded Interconnect Devices, or MID, technology enables an antenna to be integrated onto the surface of a plastic molded housing (Figure 2). Two Shot MID uses an injection molding process of two distinct thermoplastic polymers and an electroless plating process to selectively plate the antenna to the plastic part. The metalizing occurs initially in copper, followed by nickel and an optional gold plating. Laser Direct Structuring, or LDS, requires that the housing is molded in an LDS resin. In the next step a 3D laser is used to structure the antenna pattern onto the molded part. A plating step then creates the required conductive pattern on the section activated by the laser.

HOW DO I DEFINE A CUSTOM WIRELESS ANTENNA?

Both 3D antenna approaches are better suited to volume production in applications where alternative antenna implementations would result in a poorer bandwidth performance in the given volume. The approach also requires that there is a ground plane or motherboard available for the antenna to radiate and is fed by a strip or microstrip line connected via an SMD spring finger.



▲ **Figure 2:** Both the MID and LDS technologies allow antennas that offer optimal efficiency and bandwidth within a given volume.

It is imperative that collaboration with the chosen supplier occurs as early as possible during the design. Thus, the requirements, both of the antenna and of the available space/volume, can be discussed and reviewed, allowing limitations to be accommodated. It is critical that the frequency bands and any need for multiband support are defined, along with bandwidth, efficiency and link budget. If the application is to be sold into different geographic zones, this may also impact the frequency bands that need supporting.

The environment where the unit will be used, any cosmetic concerns, and the need for ruggedization should also be determined early on. Fulfilment of these requirements can be assessed in the prototyping phase, a critical point for evaluating the system, but there are a number of further steps between this point and achieving an industrialized solution that can be constructed with repeatability.

HOW DO I TACKLE ELECTROMAGNETIC COMPATIBILITY ISSUES?

Without doubt it should be considered that EMC will be an issue from the beginning of the project and, should there not be an expert on the team, help should be hired as early as possible. A thorough understanding of the standards relevant to the application space and markets of sale is an essential first step. Tackling EMC starts with all switching signals in the circuit to ensure that fast rising edges do not cause issues and avoiding the creation of current loops that can act as antenna and radiate.

Board Level Shielding (BLS) is an option that can be implemented to bring a design within the levels defined by the CISPR, FCC and other standards. However, it is essential that BLS is seen as an intrinsic part of the design and not as a method to pass EMC testing should the application fail due to poor inherent design. Simply applying BLS to a design has shown to reduce antenna efficiency by 3 dB, effectively reducing range by half.

BLS solutions are available as a single piece formed shield, or a two-piece shield (frame and cover) that enables the underlying circuitry to be accessed if required (Figure 3). They are offered in standard square or rectangular dimensions ranging from around 12 mm (shortest) up to around 50 mm (longest) on a side, up to 9 mm in height, and can be supplied on reels for pick and place. Materials used include cold rolled steel (CRS) or aluminium. Should the shield also be part of the heat-sinking strategy aluminium is the preferred material which conducts up to five times better than CRS, as well as being one third its density for weight sensitive applications. Both materials offer similar suppression capability.

▲ **Figure 3:** One and two-piece shields are available in standard sizes

Should the standard offering not suit the application, a custom design can be defined. These can typically be a rectangle, pentagon (usually a rectangle with one corner removed) or L-shape (Figure 4). In conjunction with the supplier the end result can be single or two-piece, and even deep drawn to provide varying height over the area of the BLS.

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▲ **Figure 4**: Custom BLS solutions can be provided in both one and two-piece designs in three typical shapes.

SUMMARY

Achieving a high-quality wireless design for IIoT applications that fulfils all EMC standards requires careful and continuous consideration for the associated challenges from the outset of a project. Wireless modules, standardized BLS options, and off-the-shelf antenna may seem to imply that it is all plug-and-play, but the laws of physics still apply. Working with a competent partner from the outset, especially when custom parts are planned for use, is indispensable, saving considerable amounts of time and money along the way.

We can provide support and advice in selecting the optimal TE Connectivity wireless solution that best meets your application challenge. Speak to one of our experts.

References

1. https://www.ericsson.com/en/mobility-report

Featured products from TE Connectivity

Multi-band cellular antennas

TE Connectivity's multi-band LTE/cellular standard antennas are suitable for 698-960, 1710-2170 & 2300-2700 MHz frequency ranges based on a 140mm ground plane size. They have a small and lightweight design with an operating temperature of -40° - +85°C.

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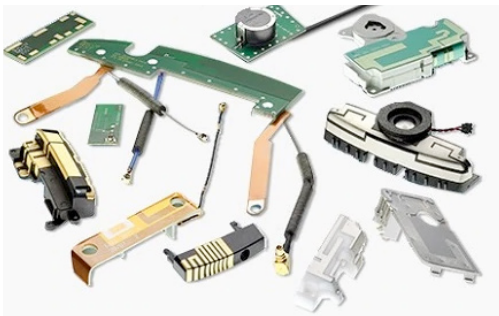
GNSS antenna

TE's new standard portfolio of GNSS antennas make positioning wireless connections more reliable by using a range of multi-band antennas for individual device configuration. With the upcoming 5G roll out, quality of service is becoming more and more critical for a non-interrupted wireless experience.



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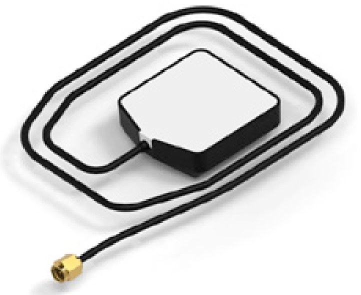
TE's new standard portfolio of external antennas makes wireless connections more reliable by using a range of multi-band antennas for individual device configurations. Useful for 4G and 5G applications, these antennas can enable applications where embedded antennas can't be used.



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RF and Coax connectors

This type of device is engineered to carry analog signals while minimizing RF signal losses. TE Connectivity (TE) RF and coax connectors feature impedance-matched designs and microminiature interfaces, with the ruggedness to help withstand high-use in harsh environments.

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Board level shielding

TE's new standard portfolio of board level shields (BLS) is available on-demand so you can quickly get the parts you need to minimize crosstalk and reduce EMI susceptibility in your application. In addition to standard cold rolled steel (CRS) material, our portfolio includes aluminum options which are 1/3 the weight.

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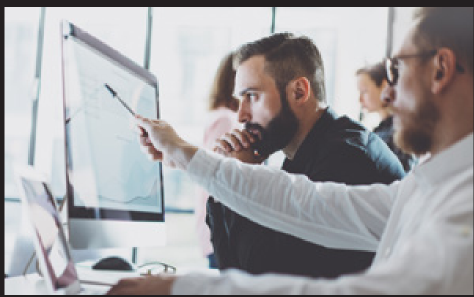
Engineering Services

Have an Industrial IoT question?

Our IIoT specialists are on hand to give you advice on your design.



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