



**SMART IOT APPLICATIONS AND ENVIRONMENTS:
KEY ANTENNA CONSIDERATIONS IN DESIGNING
YOUR SMART ECOSYSTEM**

Key Antenna Considerations in Designing Your Smart Ecosystem

In a world of uncertainties, technology is the one constant that continues to move us forward. On one hand, it is the tissue that connects people around the globe; on the other, it is the science behind solving some of our planet's most pressing concerns in the mission to create a safer, sustainable, more productive and connected future.

Nowhere is this more evident than with the emergence of the Internet of Things (IoT), the system of uniquely identified interconnected devices that are enabled to transmit and share data over wireless networks. Bridging the gap between the physical and virtual worlds, the IoT is helping to create smart environments by linking these devices to everyday settings and tasks that help individuals, businesses and potentially whole societies, live in a smarter and more comfortable way. And it's growing fast.

Machine to machine (M2M) communications utilizing low-powered networks such as UWB, WLAN, Zigbee or Bluetooth to transmit data, have helped to drive IoT adoption. Even more so, it is the advent of LPWAN's like NB-IoT, LTE Cat-M and 5G high efficiency transmission that has fueled IoT growth. While 3G and 4G networks facilitated wireless communications among people, 5G allows for the greater connection among "things" causing a paradigm shift that has directed a focus on developing sophisticated IoT solutions for a range of industrial and environmental concerns.

This has set the stage for a wide-range of applications where meaningful change and efficiencies can be affected. IoT smart environments now can be as diverse as a farm that better manages its irrigation system and equipment maintenance, to a major city seeking to create more effective utility metering, street lighting, energy and other resource management, and predictive maintenance of its facilities and operations.

IoT Growth Forecast

Cellular and noncellular IoT connections will triple worldwide between 2018 and 2025 to reach 25 billion. (1)

Global IoT revenue will increase at an average annual rate of 23% to reach \$1.1 trillion by 2023, a fourfold increase on 2018. (1)

IDC expects global IoT spending will return to double-digit growth rates in 2021 and achieve a compound annual growth rate (CAGR) of 11.3% over the 2020-2024 forecast period

IoT performance rests on other technologies: Enter the Antenna

As IoT growth has been fueled by technology, it also has been facilitated by the strength of other technological advancements. Fiber optic cable has paved the way by offering greater bandwidth that allows for multiple wireless channels to run data over high-speed 5G networks and ensure uninterrupted transmission. Cloud-based technologies are also impacting connectivity dynamics as greater utilization of cloud-like concepts are applied to both radio access and core networks. For example, C-RAN, the fast-growing global cloud radio access network, is focused on BBU pooling and the adoption of cloud technologies.

While these are two different technologies, they share a common dominator: they both demand high-speed, high-data, high-density, and reliable and rugged connectivity solutions to support IoT ecosystems.

Enter the antenna. Antennas are critical to transmitting and receiving radio frequencies (RF) and along with filter and power amplifiers, must work adeptly with fiber optic and cloud-based technologies. They must also enable near limitless wireless connectivity between devices and databases, while at the same handle high-power signals and operate within stringent thermal conditions. These are functionalities all critical to the development of an IoT application and performance of a smart environment.

Antennas are integral to the IoT application

At TE Connectivity (TE), we recognize that antennas play a complex role in the dynamics of the IoT. As IoT ecosystems move to support high-density, low latency networks and continue to incorporate various new features into radios and overall system layouts, there is an even greater premium put on antenna system design. As a result, rather than view antennas as passive products - whether they are external or embedded - our engineers treat them as integral solutions in the creation of IoT applications.

There are already examples in the market of how multiple antennas are being used to work with 5G networks and support IoT applications. Active Antenna Systems (AAS) are commonly adopted to increase the capacity and coverage of radio streams. They also feature a tighter integration of radio frequency (RF) electronics with a massive-element antenna to enable miniaturization and boost efficiency.

Advanced Antenna Systems (another AAS) are also gaining popularity. These systems comprise an array of antennas closely integrated with hardware and software components to handle increased system complexities. This includes greater steerability for adapting antenna radiation patterns to rapidly time-varying traffic and multi-path radio transmission conditions. Simply put, more antennas translate into faster data transfer - the lifeblood of the IoT.

Choosing the right antennas and customizing solutions are key

The complexities of antenna system design and the availability of more frequency bands afforded by 5G, have made choosing an antenna for a smart device that much more challenging. System designs cannot rely on “plug and play” options but instead require more sophisticated planning and a holistic assessment of all connectivity requirements. In a variety of IoT applications, it is not unlikely that an antenna solution will need to be customized and include two to 12 antenna products inside a device often the size of a mobile phone. These antennas must manage different redundancies and services while working clearly and independently from one another – a physical trick of isolating antennas within a system design.

There is another critical issue to consider in designing an antenna system for a business, industrial or real world IoT application: they must be designed to operate on secure networks. While there are a range of antennas that can be used for Wi-Fi, Bluetooth and GPS applications, there is increasing reliance on cellular antennas that offer the critical features needed for IoT success. For example, with the exponential growth of wireless traffic causing more and more interference, spectral efficiency is key. As a result, antennas must also be able to handle this bandwidth issue. Cellular antennas effectively meet this requirement.

Types of Antennas

- Cellular LTE/5G/ NB-IoT/ CAT-M
- GNSS
- Wi-Fi/Bluetooth/Zigbee
- ISM
- LPWAN and RF accessories

IoT Antenna Requirements

- High efficiency for clean transmission and optimized battery life
- High quality transmission: signal interruption against interference/noise
- Harsh environment durability: robust design in dry and moisture prone areas
- Compact design (miniaturization)
- Multiple frequencies operations: need for more bandwidth and compatibility with global cellular networks
- Shorter development cycles: reduce cost

Cellular antennas also address critical certification and regulatory standards required in the marketplace. This includes meeting the specifications of various cellular carriers operating around the world and the standards set by the GSM Association (GSMA) and the 3rd Generation Partnership Project (3GPP). It also means passing multiple rounds of testing to obtain regulatory approval from authorities such as the Federal Communications Commission (FCC) in the U.S., or the European Telecommunications Standards Institute (ETSI) and Radio Equipment Directive (RED) in the EU.

Together, these various technical and marketplace demands make clear that innovative and secure antenna systems are needed for IoT applications. The engineers who design these systems must also fully understand how antennas operate in a wide variety of technical and governing circumstances. Regardless of the situation, however, the time for “bad” antennas is over.

For smart IoT environments, smart antenna system designs are essential

As discussed, the rapid growth of the IoT is allowing for the creation of smart environments. At TE, we are committed to identifying real world situations where the ability to effectively collect data and gather knowledge can lead to developing sustainable IoT solutions. To demonstrate how our engineers are focused on smart antenna system designs, it makes sense to look at two major trends in IoT applications: **Smart Tracking** and **Smart Buildings**.

In both these cases, TE engineers examine the market issues, challenges and requirements that clients face to develop the optimal solution. Regardless of the application, there are clear standards that must be met in focusing on data management and protection, as well as backup-battery performance requirements. Other pertinent standards focus on installation practices, firmware upgrades, communications, device diagnostics, and climate-resistance measures, as the environment in which an antenna operates will impact its function.



Trend 1: Smart Tracking

Smart tracking is a growing trend presenting significant market opportunity for companies looking to enter the space. It is increasingly being developed for use in telematics and on-board diagnostics (OBD) – two major areas within the global vehicular and transport industries that are experiencing significant growth. Smart tracking is also used for the asset tracking of physical assets, again used in transport, as well as with global distribution and logistics players. Another area of growth, the IoT-supported asset tracking market is expected to account for 93% of all enterprise and industrial IoT solutions in the current environment. (3)

In building a smart tracking application, a customer has to consider a number of technological challenges and requirements to ensure the right antenna system.

Global commercial telematics market is expected to grow by \$23.15 billion from 2020-2024; the U.S., Germany, China and Canada are its largest markets, with Asia-Pacific expected to witness significant growth (2)

Global asset tracking market will reach \$32.0 billion by 2024, growing at 14.9% CAGR (3)

Global asset tracking market for AI in embedded devices will grow at 28.2% through 2024 (3)

Challenges		Solutions	
Controlling the orientation of the antenna, as well as its radiation pattern performance		Operate with multiple frequencies and provide omni-directional performance	
Harsh environmental conditions		Offer robust design in dry and moisture prone areas	
Uninterrupted cellular signal for diagnostics performance		Deliver high efficiency	
Battery power saving		Ensure high efficiency to prolong battery life	
Global tracking		Provide services across the globe, ensuring multiple frequency bands	

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Situation: An IoT start-up business focused on global tracking was using a variety of antennas that made their devices, bigger, heavier and more expensive to produce. They were also using a chip antenna that did not allow for the granular tracking data needed, nor did they understand complex radio frequency requirements. These two issues were dramatically impacting performance.

A newly formulated antenna design system required:

- Custom-designed, embedded antennas for 5G connectivity that enabled the customer to build a reusable, smart system – more as a mobile phone than an IoT device – for real-time parcel tracking
- Reducing the weight of the antennas to both lower the cost and size of the board, as well as improve performance
- Implementing on board surface mount device antennas to make the entire device part of the antenna solution; this also created the most efficient and repeatable manufacturing process
- Reviewing designs to improve battery life, and reconfiguring the board layout to properly place radio frequency (RF) components and maximize the ground plane, which enables radios to work and avoid interference

Antennas and RF components tend to be the most underestimated parts of a design. Engineers with antenna and RF expertise can help bring the specifications of an IoT product to life.

Antenna Products

- **GNSS: 2118900-1**
- **4G Cellular / Non-cellular / LPWAN Embedded Antenna: 2367286-1, 2108994-1**
- **4G, 5G Cellular Antenna: 2195729-2NB-IoT/Cat-M: 2108994-1**






Trend 2: Smart Buildings

Smart buildings have become one of the fastest-growing technologies in what is known as the “proptech” industry – the application of information technology and platform economics to real estate. While the primary market driver behind the development of smart buildings is the growing concern over energy utilization, there are other focus areas as well: security, building management and eco-friendly living measures.

In constructing a smart building, there are a variety of technological challenges to address in designing the right antenna system and choosing the optimal antenna options.

Market size of the IoT in Buildings (BIoT) is expected to be more than \$85 billion in 2020 (a rise from \$22.9 billion in 2014) (4)

Worldwide revenue from wireless control systems for smart buildings is expected to grow to \$434 million by 2023 (a rise from \$97 million in 2014) (5)

Challenges		Solutions
Physical construction material (metal/concrete can impede antenna signal)		Deliver highly efficient antennas, where signal performance is not significantly affected by a building's construction material
Interference congestion: Competition between wireless services creates interference and signal noise can block service, causing access points to compete for service		Ensure clean, free-of-interference transmission
Very little high frequency background (RF)		Implement the right antenna
Inability of 5G to penetrate windows and walls from the outside		Include micro cells and small cells to enable 5G performance inside buildings
Resilience and security requiring licensed frequency band certification		Provide engineering support and expertise to deliver successful IoT design and certification support

Situation: A real estate developer constructed a smart building in a major metropolitan area to enhance building management and provide tenant amenities. The building was designed to feature significant security and surveillance protocols, real-time energy reporting to lower costs and increase efficiency, and predictive maintenance models to avert problems and save costs. Floor plans included smart lighting, air quality monitoring and intelligent parking capabilities. Cybersecurity was also addressed as a paramount issue, since smart buildings are more exposed to the potential for cyber attacks.

Antenna systems designed for various IoT applications in the building included:

- MIMO antenna assemblies enabling high quality wireless servers to deliver uninterrupted extended range and seamless multi-user experiences, as well as bring cellular network service from outdoors to indoors
- Embedded antennas to support smart indoor cameras and cloud-based automated access control systems, including customizable credential options such as a mobile app, personalized key cards, key fobs, and links sent to a mobile phone
- 3D antenna assemblies to facilitate the real-time monitoring of electric, water and gas meters to lower energy costs, increase energy efficiency and secure energy supply, all while reducing carbon emissions
- LPWAN antennas to allow for real-time cloud visualization to monitor and maintain a building from miles away, including real-time alerts and visuals
- Robust onboard and 3D antennas to facilitate the bundling of various smart energy-saving technologies into hubs and group control functions for lighting, temperature, humidity, and other factors, with data sent to the cloud
- Secure coding standards and penetration testing practices in cellular antennas to ensure they remain strong, and release software security updates to patch newly discovered vulnerabilities

Smart buildings require a comprehensive approach to overall connectivity needs, including multiple antenna design systems to address the smooth function of various IoT applications while minimizing the threat of a cyber attack.

Antenna Products

- **4X4 MIMO (Wi-Fi With Cellular)**
- **NB-IoT / CAT-M Antenna:2108784-1**
- **Wi-Fi 6E Antenna: 2108792-1**
- **GNSS / WLAN Combination Antenna: 2195760-1**

Partner with Us

As IoT usage continues to grow and creates opportunities to reshape the world in which we live and work, a range of smart applications for smart environments will be developed. A common thread across all these opportunities, and regardless of the industry in which they will be used, is the need for antenna system designs and high-quality antennas to enable seamless, unlimited wireless communications. TE Connectivity stands ready to help.

At TE Connectivity, our engineers are not only committed to developing radio frequency solutions that meet expectations but changing them.

Leveraging more than 15 years of experience in designing complex antenna systems for smartphones and portable wireless devices, TE Connectivity engineers have a level of knowledge and understanding of how to integrate multiple antennas into small mobile wireless devices that is second to none. Our engineers repeatedly demonstrate they are prepared to meet any demanding challenge, for any client in any industry.

As a return result, through deep engineering capabilities and a commitment to testing, TE Connectivity products are reliably and dependably delivered to meet antenna system design requirements and obtain required certifications. Clients benefit from the combination of our technology leadership, commitment to superior service and global footprint.

Technical Proficiencies	Superior Service and Manufacturing
High reliability and performance in even the harshest environments	Quick turnaround of designs and prototypes
High efficiency with optimized throughput and minimal losses	In-house testing and validation of product designs
Broad wireless protocol offerings	Implementation services
Ability to handle a broad range of frequency bands for operation on any network in both regional and global markets	State-of-the-art antenna laboratories located across our global footprint

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Last, it is the spirit of partnership that defines TE Connectivity, whether a client is a start-up or a well-established company. Our engineers work closely with a client's IoT design engineers to help them navigate through antenna system design, as they typically have less wireless experience and need help navigating through antenna system design. It is this commitment to delivering an extraordinary customer experience that is fundamental to our approach and the relationships we form.

TE Connectivity

TE Connectivity (TE) is a global technology leader offering complete product portfolios across a wide-range of industry applications. TE remains committed to meeting the needs of our customers, delivering quality products and identifying opportunities for more efficiencies, cost-savings and innovations in design. Finding ways to help solve customer problems and increase the reliability and performance of their products and new designs are just some of the ways TE lives up to its purpose of creating a safer, sustainable, productive and connected future – the very essence of the IoT.

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