IoT DEVICES AND WI-FI 6E

Explore Wi-Fi 6E technology, its benefits for IoT devices, key antenna selection considerations and the future of Wi-Fi 7

Introduction

There are a growing number of Internet of Things (IoT) devices that need to be connected through one or more wireless technologies. Each IoT device has its own application, environment and use case. Some devices need to work in high temperature environments, such as a sensor mounted on an engine, while a smart water meter may be installed in a house basement with concrete walls. Other devices may be mounted on metal walls; for example, a smart electric meter in an electricity cabinet or asset tracking devices in metallic shipping containers. In hospitals, smart medical devices are attached to the human body to measure vitals and provide trackers, alarms and communications to nurses and doctors.

Similarly, each wireless technology has its own pros and cons. Cellular, for example, offers longer ranges and greater reliability in a wider coverage area. Other wireless technologies, such as Wi-Fi, can provide higher data rates in certain coverage areas. Therefore, it's critical to keep the application and use case in mind when selecting a wireless technology or multiple wireless technologies for an IoT device. The focus of this white paper is to study Wi-Fi 6E technology and its benefits for IoT devices.

IoT Connectivity Considerations

Three key parameters to consider for a good IoT wireless technology are bandwidth, range and power consumption. There are other factors to consider, such as reliability, cost, latency, mobility, compatibility with existing infrastructure, future proofness, scalability and installation location.

Some applications require one or more of the above-mentioned parameters and factors. Medical devices, health trackers and rescue drones demand 100% reliable connectivity, as a single failure could lead to loss of human life. Another example would be an asset tracker on a ship, which needs consistent cross-border network coverage around the world, rather than continuous real-time positioning data transmission. Many IoT devices have multiple connectivity technologies for different use cases or as fallback solutions. The following table shows a comparison of strengths and weaknesses of some of the major IoT connectivity technologies:

Technology	Bandwidth	Coverage	Power Consumption	Cost
4G/5G	High	High	High	High
LTE-M	Medium	High	Low	Low
NB-IoT	Low	High	Low	Low
LoRa	Low	High	Low	Low
Sigfox	Low	High	Low	Low
Wi-Fi	High	Low	High	Medium
Zigbee	Medium	Low	Medium	Low
Bluetooth	Medium	*Low	High	Low

TABLE 1. COMPARISON OF DIFFERENT IoT WIRELESS CONNECTIVITY TECHNOLOGIES

The Early Evolution of Wi-Fi

In 1997, Wi-Fi was made available commercially to consumers and has been evolving continuously since. With the introduction of the smartphone in 2009, Wi-Fi became one of the leading technologies for connectivity after cellular technology. Consecutive versions of the Wi-Fi standard have targeted faster speeds and better network/spectrum efficiency. To make it easier to remember improvements made in the standards, the Wi-Fi Alliance assigned generation numbers, such as Wi-Fi 4, Wi-Fi 5 or Wi-Fi 6 compared to standards body specification names, such as IEEE 802.11n, 802.11ac and 802.11ax.

IEEE 802.11b was released in 1999 and used the 2.4 GHz band. This frequency band was also used by other technologies, such as the Bluetooth standard and cordless handsets, which caused interference and limited data rates. IEEE 802.11a introduced the 5 GHz band and orthogonal frequency-division multiplexing (OFDM), which increased the theoretical maximum data rate to 54 Mbps compared to 11 Mbps delivered by IEEE 802.11b. But the acceptance of IEEE 802.11a products was limited due to high cost; lower coverage ranges because of the higher frequency; and incompatibility with IEEE 802.11b products.

In 2003, IEEE 802.11g combined the best of the previous two standards and set a stronger foundation for the acceptance of the technology. A major advancement occurred with the release of IEEE 802.11n (Wi-Fi 4) in 2009. Multiple input, multiple output (MIMO) combined with 40 MHz bandwidth channels were introduced, which increased the theoretical maximum data rates to 600 Mbps.

A Comparison of Wi-Fi 5, Wi-Fi 6 and Wi-Fi 6E

Wi-Fi 5 (IEEE 802.11ac), which was introduced in 2014, took theoretical data rates up to several gigabits per second with the help of a wider channel bandwidth of 160 MHz; up to eight MIMO spatial streams; up to four multi-user MIMO clients; and higher density modulation with 256-QAM (quadrature amplitude modulation). Beamforming was also introduced in this version, allowing for the transmission of radio signals directed at a specific device. Despite these improvements, there were still limitations. The standard only made use of the 5 GHz frequency band, which had lower coverage and backward compatibility issues with 2.4 GHz devices.

Released in 2019, Wi-Fi 6 (IEEE 802.11ax) improved the performance of the technology in dense environments, such as offices, shopping areas and buildings. Wi-Fi 6 also includes 2.4 GHz and 5 GHz frequency bands for operation. Based on IEEE 802.11ax specifications, Wi-Fi 6E was released in 2021 as an extension and opened the 6 GHz (5.925 to 7.125 GHz) frequency band. Wi-Fi 6 and Wi-Fi 6E have denser modulation schemes with 1024-QAM and orthogonal frequency-division multiple access (OFDMA) compared to Wi-Fi 5, enabling up to 9.6 Gbps, reduced subcarrier spacing (78.125 kHz), and schedule-based resource allocation. While the previous standards supported MU-MIMO for downlink connections, Wi-Fi 6 supports 8X8 connections for both uplink and downlink.

	IEEE 802.11ac (Wi-Fi 5)	IEEE 802.11ax (Wi-Fi 6/6E)
Bands	5 GHz	2.4, 5, 6 GHz
Channel Bandwidth	20, 40, 60, 160 MHz	20, 40, 60, 160 MHz
Subcarrier Spacing	312.5 KHz	78.125 KHz
Symbol Duration	3.2 us + 0.8/0.4 us	12.8 us + 0.8/1.6/3.2 us
Highest Modulation	256-QAM	1024-QAM
Max Data Rate	6933 Mbps	9607.8 Mbps

TABLE 2. BASIC PARAMETER COMPARISON OF 802.11AC AND 802.11AX

The Benefits of Wi-Fi 6E in IoT Devices

1. Frequency Bands

Wi-Fi 6E has a clear advantage with an added 6 GHz frequency band. This enables much higher data rates when a device is in close range, given the wider channel bandwidth. As Wi-Fi 6E also supports lower frequency, it is possible to have longer range when the device is far away from the transmitter. The 2.4 GHz and 5 GHz bands tend to be crowded, as many devices use these bands, while the 6 GHz band exists without interference and overlap. This equates to lower latency and faster speeds. In hospitals, for example, there are many devices and equipment that communicate with each other. As the 6 GHz band has recently opened with Wi-Fi 6E, the chance of interference from other technologies is much lower, which increases the reliability of communication in these critical environments.

2. Power Consumption and Battery Life

Most IoT devices that use Wi-Fi as their major connectivity technology are connected to a power supply. However, there are still many IoT devices and applications, which are powered through the battery for the lifetime on a single charge or with rechargeable batteries. Wi-Fi 6/6E offers a unique battery conservation benefit thanks to a new feature called Target Wake Time (TWT). IoT Devices can make use of TWT by turning off their Wi-Fi radio when not in transmission, and can also determine when their Wi-Fi needs to be active to send and receive data. This helps increase the sleeping time of the radio unit and saves battery power. Extended battery life decreases the down time (charging), which makes it possible to reuse the device for different persons working shifts in hospitals who may use the same device. It is worth noting that TWT is not available in Wi-Fi 5.

3. Data Rates

Wi-Fi 6E has a theoretical maximum data rate of 9.6 Gbps compared to 6.9 Gbps offered by Wi-Fi 5. Faster data rates shorten download times and provide faster data transfer and browsing, which reduces battery consumption. However, the real benefit of faster data rates is constant high performance when there are multiple devices connected, whereas in Wi-Fi 5, the speed drops significantly due to multiple devices sharing the same bandwidth. Patient surveillance cameras, for example, can generate heavy traffic due to high quality video demands, therefore high bandwidthreduces the risk of lost connectivity.

4. MU-MIMO and Beamforming

While MIMO can direct multiple streams to a single user, MU-MIMO can direct spatial streams to multiple users simultaneously, which can improve network efficiency. Wi-Fi 6E offers MU-MIMO 8X8—both in uplink and downlink—while Wi-Fi 5 is limited to 4X4 only in downlink. This technology significantly helps Wi-Fi 6E to perform in congested environments and show good performance in data rates, latency and packet losses. As indicated by the name, beamforming creates a stream of data in a specific direction to a device, rather than spreading it around in all directions. It is not new in Wi-Fi 6E, but due to the possibility of using eight antennas to form the beam compared to four in Wi-Fi 5, the router can have higher data rates and better signal range. In hospital environments where a lot of users simultaneously share the same Wi-Fi access point, MU-MIMO and beamforming play an important role in providing a higher quality of service.

5. Latency

Certain IoT devices and their functionality are highly dependent on latency. Wi-Fi 6E offers lower latency by using MU-MIMO, which allows multiple users to communicate in uplink or downlink concurrently. OFDMA technology lets different devices share the same channel, making communication much faster, rather than waiting for a subcarrier to become available.

6. Network Security Protocol

Wi-Fi allows multiple users and devices to be connected simultaneously to the same access point. As mentioned earlier, Wi-Fi is heavily used in public areas, such as hospitals, therefore privacy and security could become a big concern. Wi-Fi 5 supports WPA and WPA2 protocols for a secure connection. Wi-Fi 6 takes it to the next level by adding the WPA3 protocol, which improves multi-factor authentication and encryption.

The Future: Wi-Fi 7

Wi-Fi has been an evolving technology since 1999. IEEE 802.11be or Wi-Fi 7 is expected to be released in 2024. Theoretical maximum data rates will be increased 4x to 46 Gbps with help from 320 MHz wide channels in 6 GHz bands, and 4096-QAM compared to 1024-QAM in Wi-Fi 6E. Other performance-enhancing features that will be introduced in Wi-Fi 7 include multi-chassis link aggregation (MLAG) and operation; coordinated beamforming; MU-MIMO 16x16; and flexible channel utilization based on preamble puncturing to avoid channels with interference. Wi-Fi 7 promises highly improved congested network performance based on capacity, latency and coverage.

	Wi-Fi 6	Wi-Fi 7
IEEE Standard	802.11ax	802.11be
Maximum Transmission Rate	9.6 Gbps	46 Gbps
Frequency Band	2.4 GHz, 5 GHz, 6 GHz (Wi-Fi 6E)	2.4 GHz, 5 GHz, 6 GHz
Security Protocol	WPA3	WPA3
Channel Bandwidth	20 MHz, 40 MHz, 80 MHz, 160 MHz, 80+80 MHz	Up to 320 MHz
Modulation Mode	1024-QAM OFDMA	4096-QAM OFDMA
MIMO	8x8 UL/DL MU-MIMO	16x16 UL/DL MU-MIMO

TABLE 3. BASIC PARAMETER COMPARISON OF IEEE 802.11AX AND IEEE 802.11BE

Competing Technologies

IEEE 802.15.4

For IoT devices and applications that require low cost, low data rates (up to 250 Kbit/s), lower battery consumption, short range communication, high reliability and less dependency on the infrastructure, then you could look at IEEE 802.15.4. Also known as low-rate wireless personal area network (LR-WPAN), it operates on one of three unlicensed frequency bands:

1. 868.0–868.6 MHz: Used in Europe and allows one communication channel.
2. 902–928 MHz: Used in North America and originally allowed up to ten channels (2003) but has been extended to thirty (2006).
3. 2400–2483.5 MHz: Used worldwide with up to sixteen channels

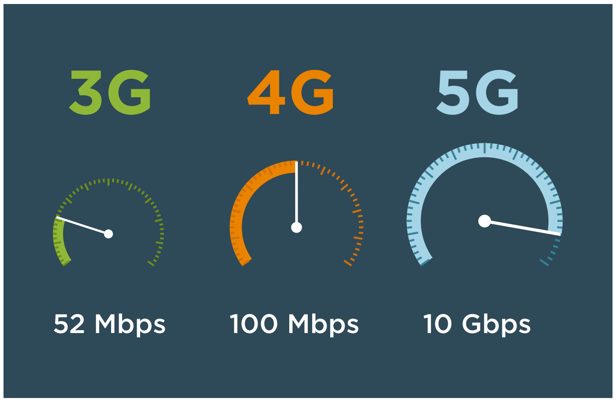
LR-WPAN uses carrier-sense multiple access with collision avoidance (CSMA/CA) for network access. There are two types of network nodes:

1. Full-function devices (FDD) may function as a common node and can serve as the coordinator of a personal area network (PAN).
2. Reduced-function devices (RFD) are extremely simple devices with very modest resource and communication requirements. RFDs can only communicate with FFDs and cannot act as coordinators. Networks can use peer to peer or star topologies. Zigbee, based on the 2.4 GHz frequency, is one of the more known and commonly used technologies based on this standard.

Cellular 4G/5G

Wi-Fi and cellular have been have been competing technologies for some time now. 4G is the first generation to use Long-Term Evolution (LTE) technology to deliver theoretical download speeds between 10 Mbps and 1 Gbps. 4G is the first IP-based mobile network to handle voice just as another service. 5G networks use a combination of existing 4G LTE and 5G New Radio (5G NR) technology.
5G enhances 4G in three main use cases:

1. Enhanced mobile broadband
2. Critical communications
3. Mobile IoT



Enhanced mobile broadband is currently targeted towards consumers that need ever-increasing bandwidth. It also enables new IoT use cases that require high data volumes, such as streaming video. Critical communications demand a much faster response and increased quality of service and security. To meet this need, 5G introduced 5G NR technology, which uses a higher radio frequency.

LTE-M and Narrowband-IoT (NB-IoT) were designed specifically for the mobile internet of things. LTE-M and NB-IoT support devices that need a long battery life and good network access in areas that are difficult to reach. These technologies do not deliver the bandwidth of 5G, but for many IoT use cases, data rates and latency are more than sufficient. Plus, lower power consumption means longer device service life. LTE-M and NB-IoT are forward compatible with 5G NR technology, which means that LTE-M and NB-IoT technology can be used throughout the complete 5G life cycle.

Antenna Design and Selection

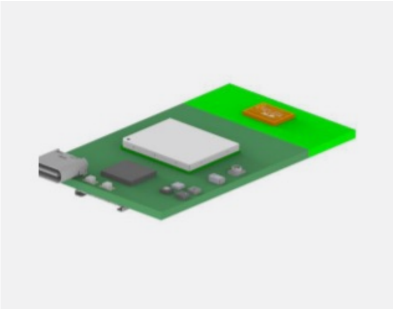
A careful selection of the antenna needs to be made by considering the device size, shape and material. Performance of PCB-based antennas are strictly dependent on the size of the PCB. The datasheet of the antenna is normally made by considering the reference size of the PCB. Reducing the size of the PCB degrades antenna performance. Evaluation boards and application notes are helpful to understand the different influences of the surrounding environment on the antenna.

Different antenna types have their pros and cons:

- Surface mount antennas need a large enough PCB and an adequate size ground free PCB area, but offer advantages, such as a low profile and small size.
- Tab mount antennas build on height but require a much smaller PCB area and smaller clearance zone.
- Cable fed or remote antennas don't need any PCB space and can be far away from the PCB, reducing influence from the PCB components. However, they do need mounting assembly and space.
- Custom-designed antennas can be developed for specific requirements and can be integrated deeper into the device with limited PCB space for traditional antennas. TE Connectivity (TE) offers all the different types of Wi-Fi 6E antennas, which can also be used for Wi-Fi 7 products as the frequency bands remain the same.

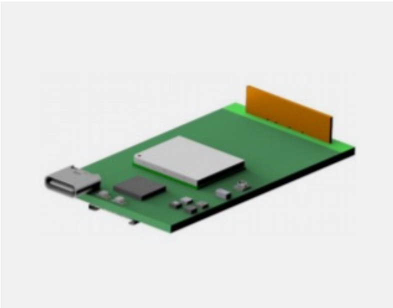
TE Antenna Mounting Types

Board Mount Antennas



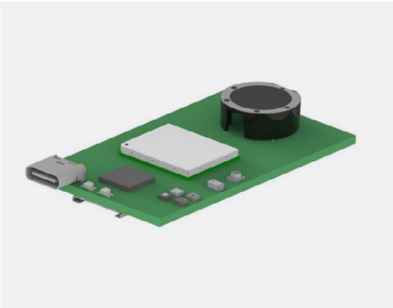
Surface Mount

- Consists of element + keep out + ground
- Small size, low profile
- Ideal for devices with a very low height requirement
- Relatively large PCB ground keep out of 10 mm to 20 mm is required



Tab Mount

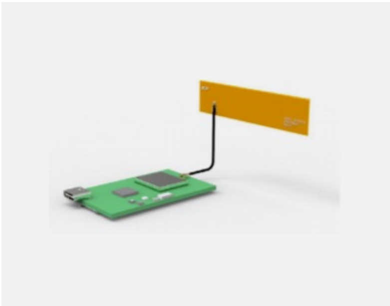
- Consists of element + keep out + ground
- Higher profile of 10 mm to 20 mm
- Smaller PCB ground keep out of 5 mm to 10 mm is required
- Can save PCB space and offer good antenna performance



Surface Mount on Ground

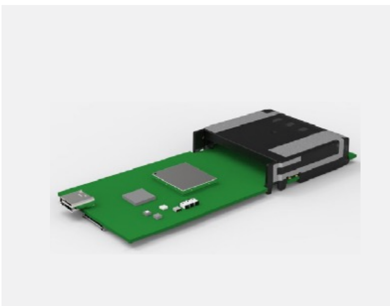
- Consists of element + ground
- Higher profile of 5 mm to 25 mm
- No PCB ground keep out is required
- Can save PCB space
- On-ground type is ideal for single/dual high band antennas

Embedded Antennas



Chassis Mount, Cable Feed

- Larger antenna
- Ground plane independent antenna
- Ground plane + components have little impact on RF
- Manual assembly



Direct Feed

- Compact antenna
- Uses existing ground plane
- Components/routing have an impact on RF
- Automatic and repeatable assembly

External and Terminal Mount Antennas

- Stand-alone antenna
- Preferred option for metal cases
- Higher gain options available
- Adapter cable
- Better manipulation with minimal RF design effort

TE Antennas for Wi-Fi 6E Solutions

Different cable lengths and connectors are available.

Embedded Wi-Fi 6E Solutions

						
Wireless applications	Bluetooth, Wi-Fi, ZigBee, ISM	Wi-Fi, Bluetooth, ZigBee, ISM	Wi-Fi, Bluetooth, ZigBee, ISM	Wi-Fi Bluetooth, ZigBee, ISM	Wi-Fi, Bluetooth, ZigBee, ISM	Wi-Fi, Bluetooth, ZigBee, ISM
Size	18.9mm x 6.2mm x 0.76mm	41.24mm x 29.mm x 0.34mm	40mm x 8mm x 1mm	40mm x 10mm x 0.12mm	15mm x 17mm x 10mm	45mm x 7mm x 0.1mm
Mounting type	SMD	Adhesive backing with MHF/MHF4 connector	Adhesive with MHF connector	Adhesive with MHF connector	Through hole	Adhesive with u.fl/ MHF4 connector
Antenna type	PCB IFA	Thin FPC Monopole	PCB Dipole	FPC Dipole	Stamped metal Monopole	FPC Dipole
Peak gain	2.3dBi @ 2.4GHz 2.8dBi @ 5GHz 2.3dBi @ 6GHz	3.0dBi @ 2.4GHz 3.1dBi @ 5GHz 3.5dBi @ 6GHz	4.3dBi @ 2.4GHz 4.3dBi @ 5GHz 5.0dBi @ 6GHz	4.9dBi @ 2.4GHz 3.5dBi @ 5GHz 4.5dBi @ 6GHz	3.5dBi @ 2.4GHz 3.8dBi @ 5GHz 3.8dBi @ 6GHz	4.8dBi @ 2.4GHz 6.3dBi @ 5GHz 7.4dBi @ 6GHz
VSWR	<2.0:1 @ 2.4GHz <2.5:1 @ 5GHz <2.5:1 @ 6GHz	<1.4:1 @ 2.4GHz <1.6:1 @ 5GHz <1.9:1 @ 6GHz	<1.9:1 @ 2.4GHz <1.8:1 @ 5GHz <2.2:1 @ 6GHz	<2.1:1 @ 2.4GHz <2.1:1 @ 5GHz <1.7:1 @ 6GHz	<2.9:1 @ 2.4GHz <1.9:1 @ 5GHz <3.2:1 @ 6GHz	<1.5:1 @ 2.4GHz <1.6:1 @ 5GHz <1.5:1 @ 6GHz
Part number	2118908-1/2	2118907-1/2/3/4/5/6/7/8/9	2118909-1/2/3/4/5/6/7/8	2108792-1/2/3/4/5/6/7/8/9	ANT-W63-MSA-TH1	ANT-W63-FPC-LV

External Wi-Fi 6E Solutions

					
Wireless applications	Bluetooth, Wi-Fi, ZigBee, ISM	Wi-Fi, Bluetooth, ZigBee, ISM	Wi-Fi, Bluetooth, ZigBee, ISM	Wi-Fi, Bluetooth, ZigBee, ISM	Wi-Fi, Bluetooth, ZigBee, ISM
Size	19.91mm x 135.80 mm (Unfolded) 19.91mm x 115.00 mm (Folded)	71.1 mm x 9.3 mm	85.5 mm to 179.6 mm (straight) - 65.0 mm to 156.0 mm (bent 90 degrees)	178.0 mm x 25.0 mm	132.0 mm x 24.0 mm
Mounting type	90-degree hinge type SMA/ RP-SMA	Compact swivel whip with SMA/RP-SMA plug	Hinged design with detents for straight, 45-degree and 90-degree positioning with SMA And RP-SMA plug	Outdoor (IP67) whip with N-plug	Outdoor (IP67) whip with N-plug
Antenna type	External dipole	Monopole	Dipole	Dipole Stubby	Dipole Stubby
Peak gain	2.3dBi @ 2.4GHz 3.2dBi @ 5GHz 2. 5dBi @ 6GHz	3.2dBi @ 2.4GHz 4.2dBi @ 5GHz 3.4dBi @ 6GHz	1.2-2.3dBi @ 2.4GHz 1.5-1.8dBi @ 5GHz 1.5-3.5dBi @ 6GHz	3.2dBi @ 2.4GHz 8.7dBi @ 5GHz 5.5dBi @ 6GHz	7.0dBi @ 2.4GHz 5.0dBi @ 5GHz 5.6dBi @ 6GHz
VSWR	<1.6:1 @ 2.4GHz <1.8:1 @ 5GHz <1.9:1 @ 6GHz	<2.4:1 @ 2.4GHz <2.3:1 @ 5GHz <2.0:1 @ 6GHz	<1.2-2.3 @ 2.4GHz <1.5-1.8 @ 5GHz <1.5-3.5 @ 6GHz	<4.1:1 @ 2.4GHz <2:1 @ 5GHz <2.3:1 @ 6GHz	<2.5:1 @ 2.4GHz <1.7:1 @ 5GHz <2.8:1 @ 6GHz
Part number	2108923-1/2/3/4	ANT-W63-MON-ccc	ANT-W63WSx Series	ANT-W63-IPW1-NP	ANT-W63-IPW2-NP

How TE's Expertise Helps to Optimize Antenna Performance

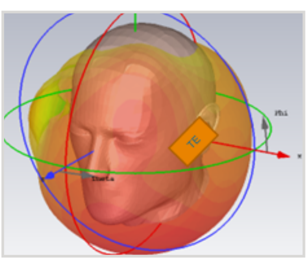
With decades of antenna development and manufacturing experience, TE offers a wide range of antennas to accelerate the success of our customers' products. Often, customers face several common challenges in finding the right antennas for seamless connectivity. That's why having a trusted RF technology partner early in the design phase is critical.

Common Challenges and Solutions

Challenge	Solution
Challenge 1 Integrate multiple technologies in a desired design, while ensuring adequate performance to cost tradeoffs	**Solution 1** Leverage a supplier with extensive experience in delivering multi-band antennas
Challenge 2 Severe industrial design product constraints	**Solution 2** Benefit from varied manufacturing capabilities, including 3D antennas, for greater flexibility
Challenge 3 Complex radiation environments	**Solution 3** Utilize MIMO/diversity, radiation pattern optimization and polarization schemes
Challenge 4 Quick time to market (TTM) requirements	**Solution 4** Partner early and utilize platform products where applicable
Challenge 5 Unfamiliar with RF requirements or expectations	**Solution 5** Consult an expert early to choose appropriate technologies

End-to-end Capabilities to Get it Right the First Time, at Scale.

Design



- Antenna solution architect to help define requirements
- Robust simulation in CST/HFSS

Prototype

- 3D print, CNC, prototyping
- Same facility prototyping and production

Build

- 20+ years of experience
- All processes under one roof
- 1 Billion+ antennas delivered to the market

Test

- Satimo SG24 Multi-Probe System
- Frequency: 600 MHz – 10 GHz

Learn more about TE's IoT products and expertise at te.com/IoT

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