

Wi-Fi HaLow white paper

How Wi-Fi HaLow brings together low power, long range, strong penetration and high security to power a new generation of IoT devices



Table of contents

— Introduction	3
— Extended range and power efficiency	4
— Connectivity and integration	6
— Optimized performance across distances	7
— Uptake and use cases	8
— Conclusion	11
— APPENDIX I: How Quectel helps	12

Introduction

Wi-Fi HaLow refers to the designation for products incorporating IEEE 802.11ah technology, which is a wireless networking protocol published by the IEEE in 2017.

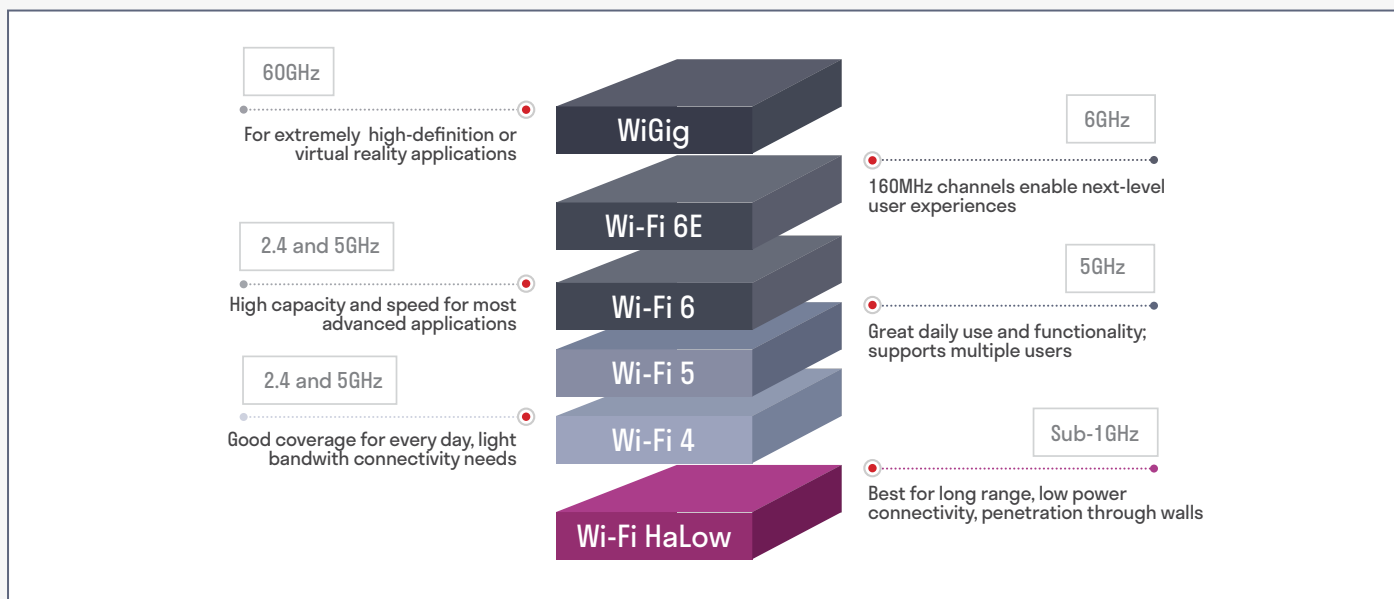
The technology was certified by the Wi-Fi Alliance in 2021 and HaLow-enabled devices are now in the early stage of deployment. HaLow operates in frequency bands below 1GHz (typically around the 900MHz band), as opposed to the 2.4GHz and 5GHz or 6GHz bands used by the more common Wi-Fi standards like 802.11n (Wi-Fi 4) and 802.11ac (Wi-Fi 5) or the latest high-capacity ones like 802.11ax (Wi-Fi 6/6E) and 802.11be (Wi-Fi 7). This strategic choice of frequency band not only enhances range and penetration but also fortifies security and power efficiency, making Wi-Fi HaLow a cornerstone technology for internet of things (IoT) use cases.

As the IoT continues to expand, analyst firm Frost & Sullivan has forecast there will be 41.76 billion active IoT-connected devices globally in 2023¹,

the demand for a versatile wireless communication standard that can meet the diverse needs of the IoT market is paramount. Wi-Fi HaLow delivers the familiar benefits of the Wi-Fi standard, such as easy integration, native IP support, the latest Wi-Fi security measures such as WPA3 and extensive ecosystem support. In addition, there is no need for proprietary hubs and gateways, since Wi-Fi HaLow is a standard. The choice of lower frequencies offers a compelling mix of extended range and robust penetration through physical obstacles. In addition, the low-power aspect of the technology enables Wi-Fi HaLow devices to be powered by coin-sized cell batteries for months and, in some cases, years.

¹ <https://www.frost.com/frost-perspectives/the-top-growth-opportunities-for-iiot-in-2023/>

FIGURE 1:



Source: Wi-Fi Alliance

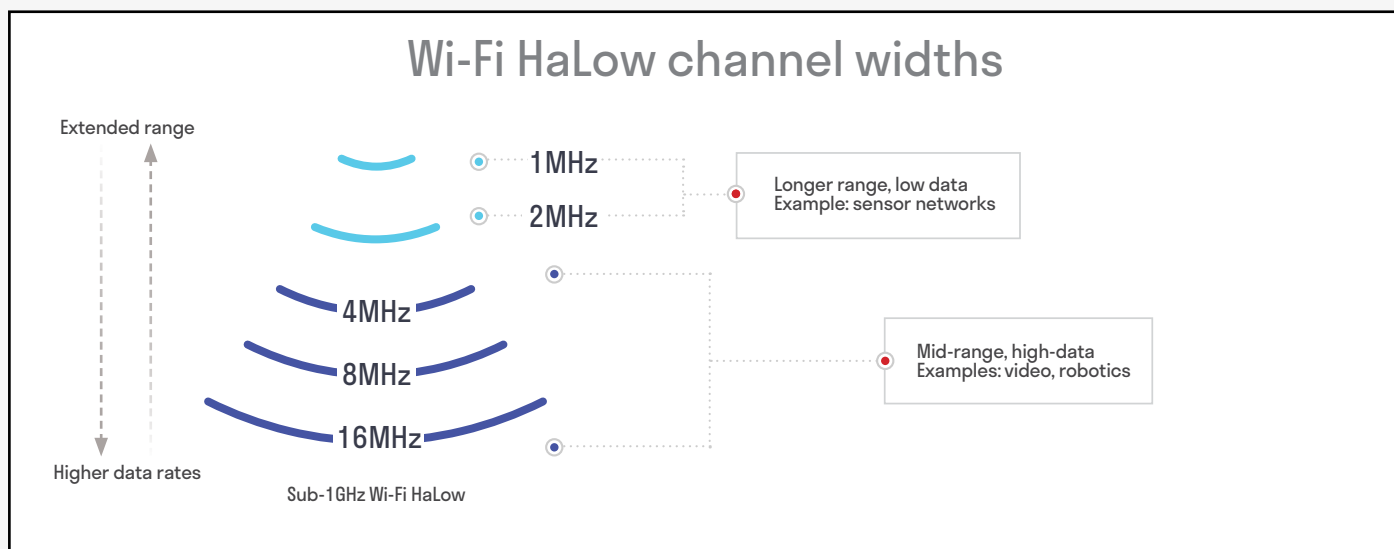
Extended range and power efficiency

One of the standout features of Wi-Fi HaLow is its range. Capable of reaching up to 1km, HaLow outperforms conventional Wi-Fi in coverage, making it ideal for sprawling industrial sites, agricultural fields, smart cities, buildings and offices. This extended range doesn't just mean fewer access points need to be deployed — it translates into reduced infrastructure costs and complexity.

Lower-frequency signals have a greater ability to penetrate walls and other obstructions.

This characteristic combined with HaLow's narrow channels make the technology particularly suitable for providing reliable indoor coverage, which is essential for smart home applications, such as security systems, thermostats and smart appliances. However, for outdoor environments, cameras for example, can be supported by HaLow as it provides better range and penetration over trees, concrete and other obstacles. This capability could be used to monitor a wide range of sensors on a farm or to help manage multi-dwelling units, including underground car parking structures.

FIGURE 2:



Power consumption is a critical consideration in the IoT market, where devices often operate on battery power exclusively. Wi-Fi HaLow addresses this by introducing mechanisms for improved power-saving, such as Target Wake Time and Restricted Access Window so the devices can conserve energy and sleep, while not responding to irrelevant network traffic. This efficiency is a game-changer for devices that require long-term deployment with minimal maintenance. An IMEC comparison study published by Wi-Fi Alliance has uncovered that battery life for Wi-Fi HaLow devices using 500mAh batteries at ten-minute transmission intervals can be 3.15 years, far exceeding the lifespans of other low-power wide-area network (LPWAN) technologies.

Queensland University of Technology² has conducted a study which compared battery life between LoRaWAN and Wi-Fi HaLow, and the result is a complicated one. Both technologies can be sufficiently low-power to enable battery-powered devices to operate in the field for years but additional considerations need to be taken into account. At first glance, LoRaWAN appears to have lower power consumption when sending and receiving data, but, due to the faster speed of Wi-Fi HaLow, the time transmitting or receiving data is more than 400 times quicker than LoRaWAN, thus giving some Wi-Fi HaLow applications the edge when it comes to reduced power consumption. The Wi-Fi HaLow device would complete transmission and go to sleep while the LoRaWAN device would still be transmitting.

² https://www.researchgate.net/publication/373415591_An_Experimental_Field_Comparison_of_Wi-Fi_HaLow_and_LoRa_for_the_Smart_Grid



Connectivity and integration

Wi-Fi HaLow is designed to accommodate a vast number of devices, up to 8,191 devices for a single access point within a network, and therefore addresses the device density challenge posed by the ever-growing IoT ecosystem. By supporting thousands of connections under a single access point, HaLow stands ready to underpin the large-scale sensor networks that define IoT landscapes in smart campuses, buildings and cities. For stakeholders who are familiar with Wi-Fi's infrastructure, the transition to HaLow is simple. HaLow devices are designed to coexist and integrate with existing Wi-Fi networks, providing a complementary

solution that expands the reach of wireless connectivity.

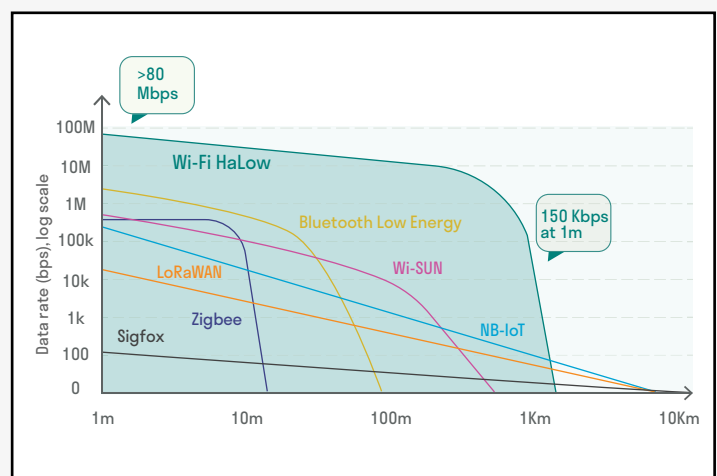
Operating in the sub-1GHz unlicensed bands, Wi-Fi HaLow is subject to regulatory considerations that vary by region. Stakeholders must be aware of the power and frequency limitations imposed by local regulations to ensure compliance and optimal deployment strategies. For example, in the EU the most recent directive imposes specific limitations as seen in the table below where the US legislation is presented for comparison:

	CE Certified	FCC Certified
Transmit power	Around 14 dBm	21dBm and above
Data rate (physical layer)	167Kbps (MCS7)	32.25Mbps (MCS7)
Band width	1MHz	1/2/4/8MHz
Duty cycle	2.8% for STA, 10% for AP	100

Note: 16MHz is valid but not available in the current market to support this channel bandwidth

According to real-life measurements in both outdoor and indoor environments performed at Nantes Université, it can be observed that we can achieve MCS 7 rate up to a distance of about 400m in clear view and about 200m in obstructed view when TX power equals 23dBm. This distance decreases to 150m for a power of 14dBm and to a hundred meters for a power of 0dBm. At these distances, the MCS 7 provides the best data rate.

FIGURE 3: Wi-Fi HaLow data rate vs distance in comparison to other low-power technologies



Source: Wi-Fi Alliance

Optimized performance across distances

Wi-Fi HaLow has a performance sweet spot, theoretically offering up to 86.67Mbps capacity over short distances with 150Kbps achievable at up to 1km.

This makes it a real alternative or complementary technology to LoRaWAN, Zigbee, Bluetooth Low Energy and even narrowband-IoT (NB-IoT). Importantly, the data rate is sufficient for streaming video, sending images or performing firmware upgrades over the network, setting HaLow apart from LoRa, Sigfox and NB-IoT.

Quectel has found in its own testing in an open area that performance of 540Kbps at a distance of 2km with 4MHz bandwidth is possible. At 1km distance under the same conditions a data rate of around 2.65Mbps can be achieved.

Wi-Fi HaLow represents a strategic evolution of the Wi-Fi standard, addressing the unique demands of the IoT market. It balances range, power efficiency, and connectivity density — all within the familiar realm of Wi-Fi technology. As the IoT market continues to grow, HaLow stands poised to offer a robust, flexible solution for a connected world where virtually ‘everything’ communicates. Wi-Fi HaLow offers greater range compared to traditional Wi-Fi and fills the gap between LPWAN (cellular, LoRa) and WPAN technologies (Bluetooth, Zigbee and others), offering the advantage of long-range transmissions, multiple data rates and energy optimization.

³ Practical evaluation of Wi-Fi HaLow performance - Sébastien Maudet, Guillaume Andrieux, Romain Chevillon, Jean-François Diouris, Nantes Université, CNRS, IETR, UMR 6164, F-85000, La Roche-sur-Yon, France



QUECTEL HAS FOUND IN ITS OWN TESTING IN AN OPEN AREA THAT PERFORMANCE OF 540KBPS AT A DISTANCE OF 2KM WITH 4MHZ BANDWIDTH IS POSSIBLE

Uptake and use cases

Although the technology has been published since 2017, it was only certified by the Wi-Fi Alliance in 2021 as IoT industry insiders recognized the technology's applicability to commercial IoT use cases. Development in the last two years has therefore been rapid and the vendor community has moved quickly to bring products to market, as Phil Solis, a research director at IDC has commented:

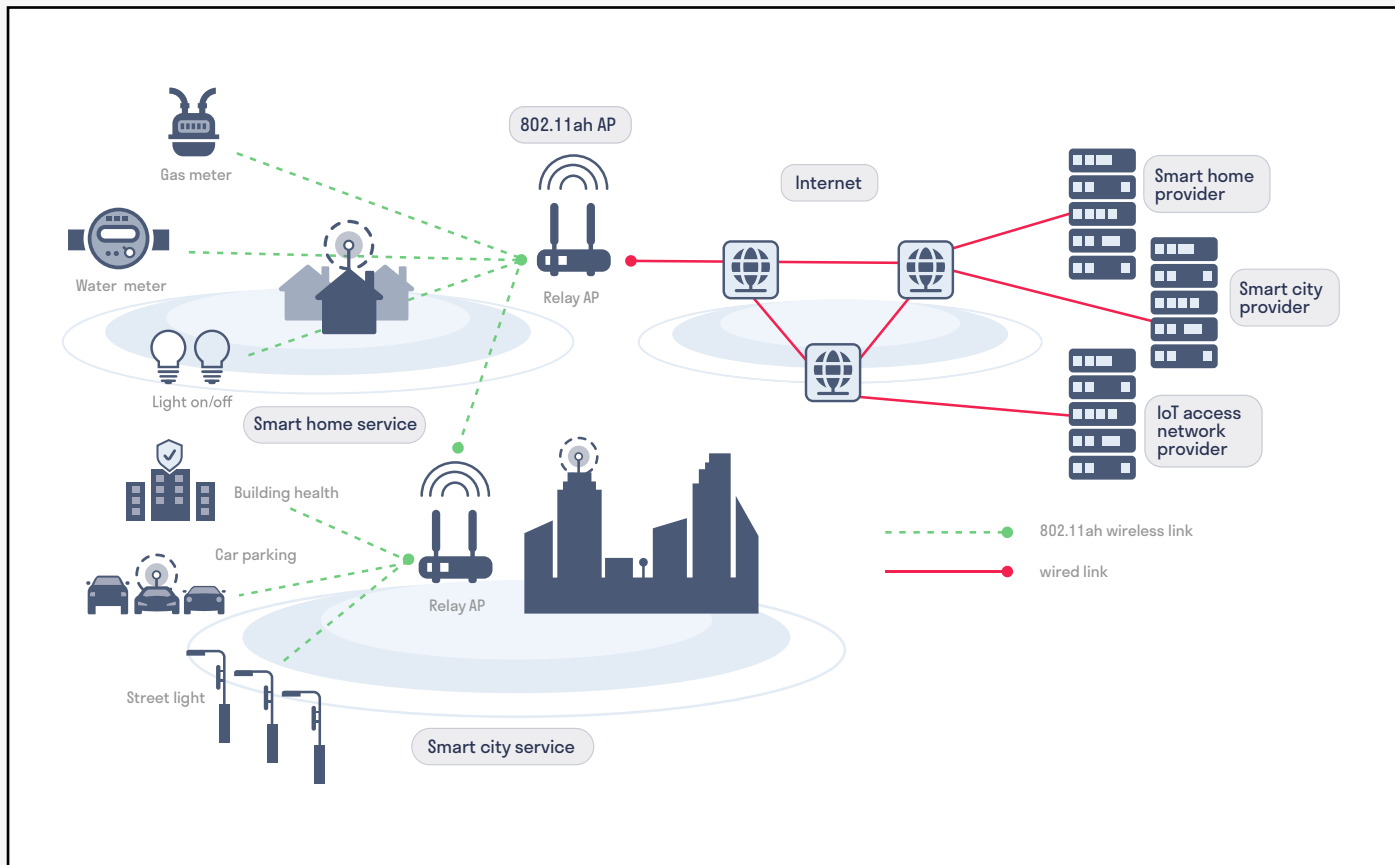
"Wi-Fi HaLow devices such as security cameras and tablets are being used in industrial environments today, and we expect devices to soon make their way to smart home environments allowing consumers to take advantage of its longer range and lower power for applications such as battery powered cameras, video baby monitors, and other smart home products," he said. "Companies have been working on Wi-Fi HaLow chipsets for years, with adoption expanding from industrial to include smart home, smart city, and retail markets."

Research firm Maravedis has also reported that, while the Wi-Fi Alliance only certified the Wi-Fi HaLow standard in October of 2021, the technology had been in development for six years. The firm says HaLow looks better placed for indoor, smart home use cases and perhaps for campus coverage where the other flavours of Wi-Fi are already well entrenched. It remains to be seen if it can challenge other LPWAN protocols for outdoor applications that require only low bit rates, such as smart metering and environmental monitoring, the firm says.



There will be multiple use cases for HaLow both as a connectivity technology for connecting sensors directly and as a backhaul method for sensor networks. Wi-Fi HaLow is particularly well-suited for connecting sensor networks because of the combination of the range, throughput and the number of connections it can support.

FIGURE 4: HaLow’s role supporting sensor networks



Kim, Kiwook & Han, Youn-Hee & Min, Sung-Gi. (2017). An Authentication and Key Management Mechanism for Resource Constrained Devices in IEEE 802.11-based IoT Access Networks. Sensors. 17. 2170. 10.3390/s17102170.
https://www.researchgate.net/publication/319972543_An_Authentication_and_Key_Management_Mechanism_for_Resource_Constrained_Devices_in_IEEE_80211-based_IoT_Access_Networks

Figure 4 illustrates how sensors directly connect to HaLow access points and relay access points. In this setup, the sensor comprises a HaLow interface so it can connect to the access points and connect a sensor network. The main purpose of HaLow in this type of deployment scenario is to create sensor networks.



FIGURE 5: HaLow enabling backbone connections

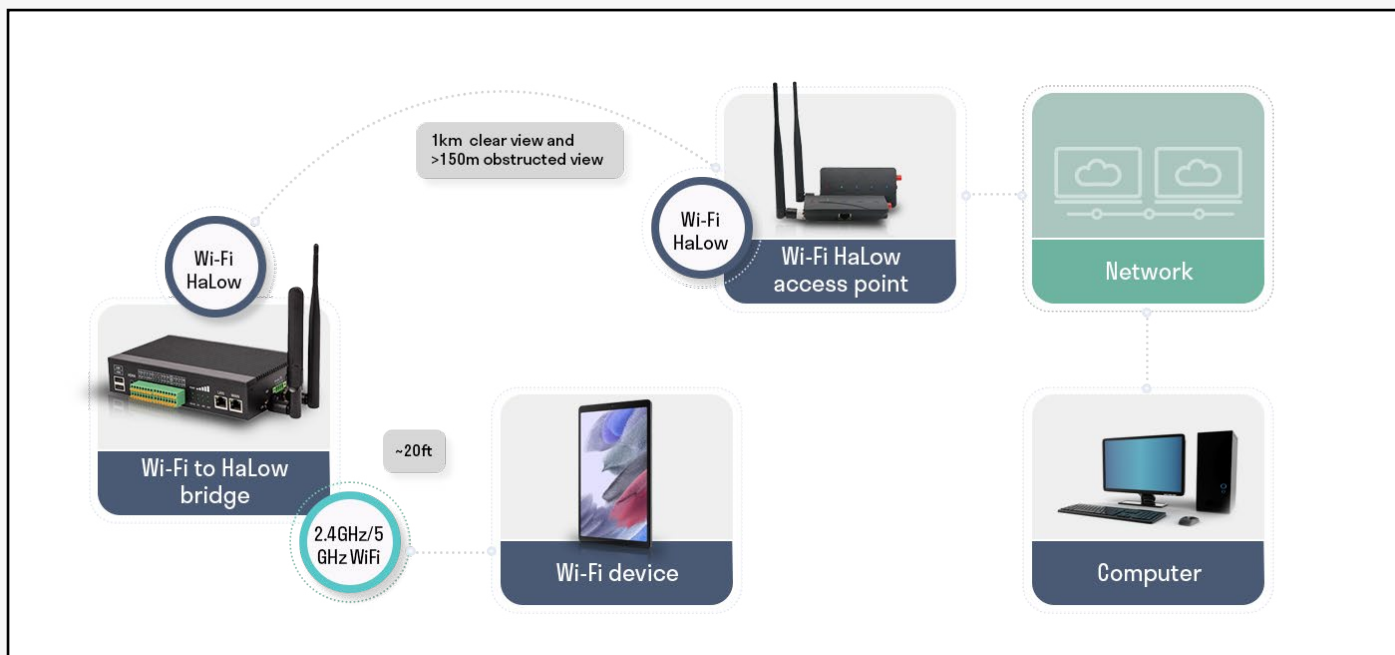


Figure 5 details an architecture in which devices or sensors are connected via a non-HaLow Wi-Fi like Wi-Fi 4, 5 or 6. Here HaLow is used for the backbone and it materializes the connection between the bridge and the access points. The reason for selecting HaLow here is to increase the penetration and the distance in both indoor and outdoor environments. For scenarios, in which significantly fewer access points and repeaters are required, HaLow facilitates the network logistics and expansion but it is not the prime connection protocol for the sensors. This approach takes advantage of the fact that most IoT devices have legacy Wi-Fi on board and therefore a HaLow interface isn't necessary for each sensor or device.



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Conclusion

Wi-Fi HaLow is not just another option in the crowded field of wireless communication technologies; it fills a critical gap in the IoT landscape. Bridging the divide between traditional LPWAN technologies like cellular and LoRa and WPAN technologies like Bluetooth and Zigbee, HaLow brings the best of both worlds: the long-range capabilities of LPWAN with the higher data rate options of WPAN. This blend makes it particularly well-suited for environments where both range and data throughput are essential.

The real-world impact of Wi-Fi HaLow is already being felt across various sectors. From smart homes and commercial buildings to expansive industrial IoT applications, HaLow is proving its worth. It's not just about connecting sensors; HaLow is enabling comprehensive bi-directional communication solutions, supporting everything from basic sensor networks to complex wireless HD video systems. This capability opens new avenues for IoT deployment, particularly in large-area applications where both range and throughput are crucial.



APPENDIX I: How Quectel helps

Quectel’s FGH100M Wi-Fi HaLow module meets the unique requirements of the Internet of Things (IoT) with its sub-1GHz signal coverage, allowing users to control IoT devices up to one kilometer radius.

It provides ten times the range of traditional Wi-Fi, making it suited for both indoor and outdoor IoT scenarios such as home and industrial automation, smart agriculture, smart cities, smart buildings, warehouses, retail stores, campuses and more.

Based on Morse Micro’s MM6108 Wi-Fi HaLow SoC, the FGH100M is compliant with the IEEE 802.11ah Wi-Fi standard and operates in 850–950MHz bands with 1/2/4/8MHz channel width. It features 21dBm maximum output power and 32.5Mbps maximum phy transmission rate. The FGH100M Wi-Fi HaLow module enables lower-power connectivity than previous Wi-Fi technologies and is able to support coin cell battery devices operating for months or years, which is critical for use cases such as smart sensors and condition monitor.

Unlike similar IoT technologies, Wi-Fi HaLow supports native IP and does not require proprietary gateways, controllers, or hubs, which greatly streamlines the installation and reduces operating costs.

With its ultra-compact size of 13.0mm × 13.0mm × 2.2mm, the FGH100M effectively optimizes end-product size and design cost, and fully meets the demands of size-sensitive applications.

The FGH100M satisfies the latest Wi-Fi requirements for authentication and encryption including WPA3 and AES for over-the-air (OTA) traffic. It also supports SHA-256, SHA-384, SHA-512 encryption algorithms to better protect transmission data.



> Antennas

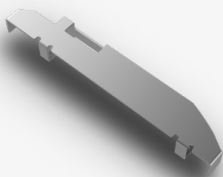
Quectel also offers a comprehensive range of antennas that can support Wi-Fi HaLow connections.

These include the [YECT002AA](#) terminal mount IoT antenna which works with various ground plane sizes and features a durable ABS plastic housing. The antenna has an SMA (male) connector and can be used straight or hinged 90 degrees. This omnidirectional antenna is ideally suited for access points, terminals, industrial products and routers.



Quectel also offers the [YPCS002AA](#) embedded surface-mount design (SMD) FR4 Antenna which operates in the 791-960MHz range. This antenna ensures a smooth and stable connection with high-efficiency data transmission even under the influence of the device's internal structure.

[YMCP003AA](#) NB-IoT Shrapnel Antenna



Ground plane dependent, the antenna is designed to be mounted directly to the device host PCB using a conventional PCB reflow process.

Supplied with tape and reel for high-volume pick-and-place assembly, this SMD antenna can be tuned specifically for the final device environment with a simple PI matching circuit.

A further option is the [YMCP003AA](#) shrapnel antenna. This operates in the 700-960MHz frequency range and has an antenna size of 40.99mm x 6.68mm x 3.99mm. This high-efficiency antenna which is mounted to the device host PCB using conventional metal shrapnel antenna reflow process, is RoHS compliant.

Completing the [Quectel antenna range](#) for HaLow use cases is

Quectel [YCIS003AA](#) ceramic chip SMD antenna. Operating in the 863-870MHz frequency band and with dimensions of 10mm x 3.2mm x 0.5mm, this antenna is ideal for situations in which antennas are mounted inside the device in order to minimize interference.




For more information, visit [Quectel.com](https://www.quectel.com)



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