# White Paper

## Wi-Fi HaLow Radio Technology with Trimble SX12 & EM130

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# Introduction

The Trimble® SX12 scanning total station comes in two different models: one with Long Range Radio, and a new version with Wi-Fi HaLow™ radio technology. Each model also includes standard 2.4 GHz Wi-Fi™ as a secondary communication method.

Traditionally, wireless communication methods are a tradeoff between range and how much data can be sent and how quickly (throughput). The Long Range Radio model of the SX12 can achieve impressive range, but is limited in throughput. Conversely, when using standard 2.4 GHz WiFi on the SX12, the throughput allows you to easily transfer scans or panoramas, though the range is limited.

The new SX12 with Wi-Fi HaLow model provides the best of both technologies -- you can perform all of the high-throughput functions you require, the connection is extremely robust, and you can work at the range that you want with a robotic total station, all without having to switch or think about communication methods.

This white paper describes Wi-Fi HaLow technology, how it compares to other radio technologies, and how it works with a Trimble SX12 scanning total station and a Trimble controller equipped with an EM130 module.

***Note - Due to government regulation of communication frequencies, the Trimble SX12 with Wi-Fi HaLow model and EM130 are only available in the United States of America, Canada, Australia and New Zealand.***

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# What is Wi-Fi HaLow?

Wi-Fi is one of the most popular standard wireless communication technologies used in our connected world today, along with other wireless communication technologies such as cellular and Bluetooth®. The Wi-Fi Alliance is the organization that oversees the evolution of various Wi-Fi technologies which are developed and maintained under the umbrella of IEEE 802.11 standards.

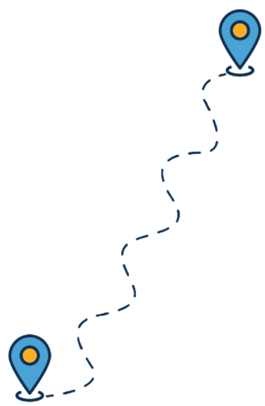
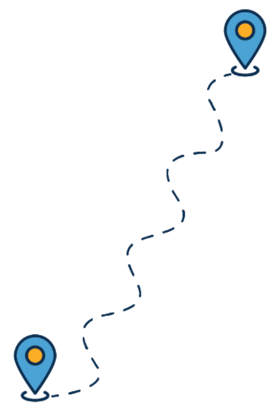
Wi-Fi HaLow is developed and maintained under the IEEE 802.11ah standard. Put simply, Wi-Fi HaLow is an offshoot of traditional Wi-Fi standards, but the operating frequency band is changed from 2.4 GHz to a sub-1GHz.

Most home internet routers have two Wi-Fi frequencies: 2.4 GHz and 5GHz. Using 2.4 GHz you can stay connected when farther from the router, but at lower throughput. Conversely, using 5 GHz you have to stay closer to the router, but you get higher throughput. The relationship between Wi-Fi HaLow and 2.4 GHz Wi-Fi is similar to the relationship between 2.4 and 5 GHz Wi-Fi. In general, changing the operating frequency band allows Wi-Fi HaLow to provide longer range compared to standard Wi-Fi but with a lower throughput.

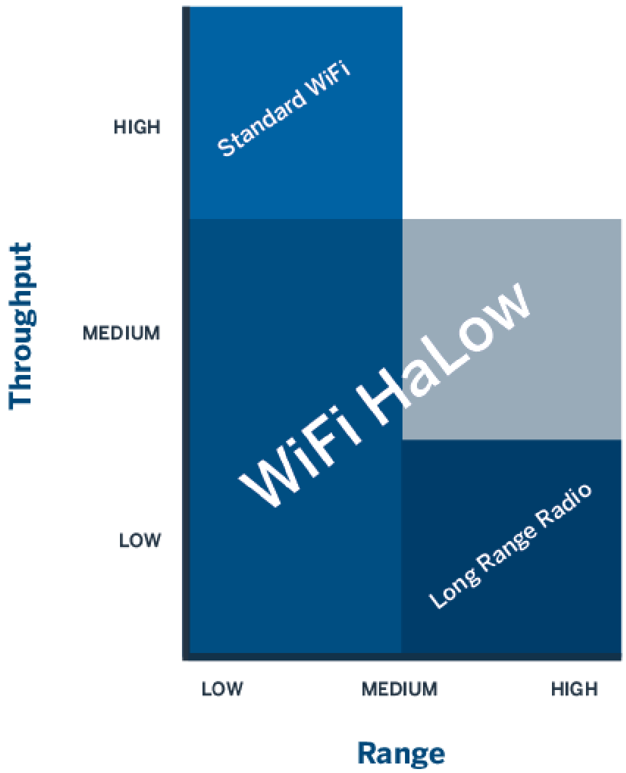
Throughout the remainder of this white paper, we will refer to 2.4 GHz Wi-Fi as “standard Wi-Fi.”

The term “radio” is generically used to encompass all wireless communications, including Wi-Fi HaLow, Trimble Long Range Radios, as well as home Wi-Fi networks, cellular communications, and so on.

# Comparison of Wi-Fi HaLow, Standard Wi-Fi, and Long Range Radio

| | Wi-Fi HaLow | Standard Wi-Fi | Long Range Radio |
|---|---|---|---|
| **Best Use** | Any action with Trimble SX12<br>Video streaming, aiming, scanning, panoramas, etc. | Any action with Trimble SX12<br>Video streaming, aiming, scanning, panoramas, etc. | Measurements that Require Minimal Data Transfer/Video<br>For example, turn-to and measure backsights, or topographic surveys with Autolock® tracking |
| **Working Range between Controller and SX12** |  |  |  |
| **Throughput** |  |  |  |
| **Frequency** | 0.9 GHz ISM band<br>902 - 928 MHz in USA and Canada<br>915 - 928 MHz in Australia and New Zealand | 2.4 GHz ISM band | 2.4 GHz ISM band<br>Frequency Hopping Spread Spectrum (FHSS) |
| **Trimble Controller Compatibility** | TSC5, T7, TSC7, or T100 controllers<br>With Trimble EM130 | TSC5, T7, TSC7, or T100 controllers<br>No EMPOWER module is needed, this utilizes the controller's internal 2.4 GHz Wi-Fi | TSC5, T7, TSC7, or T100 controllers<br>With Trimble EM120 |

The following image is a simplified visual to illustrate how Wi-Fi HaLow technology compares with standard Wi-Fi, and Trimble Long Range Radio.




## Wi-Fi HaLow compared to Standard Wi-Fi

Both Wi-Fi HaLow and standard Wi-Fi radios are based on the IEEE 802.11 standard and operate in license-free ISM frequency bands. The frequency of operation for Trimble SX12 standard Wi-Fi radio is within 2.4 GHz band whereas Wi-Fi HaLow radio uses sub-1GHz frequency band.

In the field, Wi-Fi HaLow provides a more robust radio link at a further range compared to standard Wi-Fi based on the following two factors:

1. 900 MHz radio waves (Wi-Fi HaLow) have longer range and better penetration through objects because they don't reflect off of dense objects as much as 2.4 GHz radio waves (standard Wi-Fi).
2. In populated areas, the standard Wi-Fi spectrum is often congested by consumer devices such as home Wi-Fi networks and Bluetooth devices.

## Wi-Fi HaLow vs. Long Range Radio (LRR)

Trimble Long Range Radio is a proprietary radio that operates in 2.4 GHz ISM band while using Frequency Hopping Spread Spectrum (FHSS) technology for communication. As a result, it can achieve a longer range than standard Wi-Fi radios.

In absence of external sources of interference, both Wi-Fi HaLow Radio and Long Range Radio can be expected to significantly surpass the connection range of standard Wi-Fi.

However, Wi-Fi HaLow is significantly better than Long Range Radio in terms of wireless link throughput. “Wireless link throughput” refers to how much data can be transmitted over a period of time. Wi-Fi HaLow has a wireless link throughput between 8 and 14 times higher than LRR. The higher throughput means the communication link can seamlessly transfer large amounts of data, such as point clouds or streaming video.

### Single-Link Communication Solution for Trimble SX12 & EM130

To connect to an SX12 using Wi-Fi Halow, Trimble Access™ must be running on a Trimble controller that has an EMPOWER EM130 Wi-Fi HaLow module.

Wi-Fi HaLow allows you to work at both short and long ranges with no need to switch communication methods. Moreover, Wi-Fi HaLow provides a fast, robust, and responsive way for the instrument and controller to communicate. Previously the Trimble SX12 (and SX10) used both standard Wi-Fi and Long Range Radio (LRR) to optimize how you work at different ranges. Wi-Fi HaLow removes the need to switch between communication methods, and is instead built to be a single-link communication solution for the Trimble SX12 and its controller.

In short or medium ranges, Wi-Fi HaLow performs similarly to standard Wi-Fi in terms of video quality and scan data transfer time. But at longer ranges where standard Wi-Fi cannot reach, Wi-Fi HaLow provides a more robust link with better video quality than LRR.

Considering these advantages, Wi-Fi HaLow is the perfect solution for users who prefer a single link to complete their job without requiring to switch back and forth between standard Wi-Fi and LRR.

It’s worth noting that the Trimble SX12 with Wi-Fi HaLow model also has standard Wi-Fi included. For the majority of situations, Wi-Fi HaLow is the only communication link that is needed, however we included standard Wi-Fi as a backup method in case of interference on the Wi-Fi HaLow frequencies.

## Factors that Impact Video Quality, Data Transfer, and Range

Video quality, the data transfer rate (throughput), and communication range is highly dependent on many factors including: localized interference, line of sight, multipath, Fresnel zone, antenna, the video or image resolution, and frequency being used. This section dives into the most notable factors to consider during a survey.

### Effect of Localized Sources of Radio Interference

When multiple radios are operating on similar frequencies, they can interfere with one another. For the user that could mean decreased range, decreased video quality, or video lag. This is true for all radio types, including long range radio, standard Wi-Fi, and Wi-Fi HaLow.

Since Wi-Fi HaLow uses the license-free sub-1GHz ISM frequency band, it shares the spectrum with other radio devices that use the same band such as other Wi-Fi HaLow devices, mesh networks deployed in mining or construction sites, high-power 900MHz UHF radios, miscellaneous ISM equipment, amateur radios, and smart utility meters.

Other high-power transmitting radios such as cellular communication towers operating in adjacent bands could potentially impact the performance of the Wi-Fi HaLow radio.

In addition, power conversion devices or electrical motor drivers could potentially generate strong broadband electromagnetic waves (EMI) which could also impact the performance of the radio.

Because it is not always simple to identify a source of radio interference, you can run the Auto-Select Channel tool in the Trimble Access software to scan the available channels looking for the best channel. To learn more about the Auto-Select Channel tool, please see the Troubleshooting section below.

## Effect of Environmental Elements: Line of Sight

Generally in outdoor environments, the best user experience is achieved when there is line of sight between the transmitter and the receiver. That is, when the SX12 and EM130 module antennas have an unobstructed view of each other.

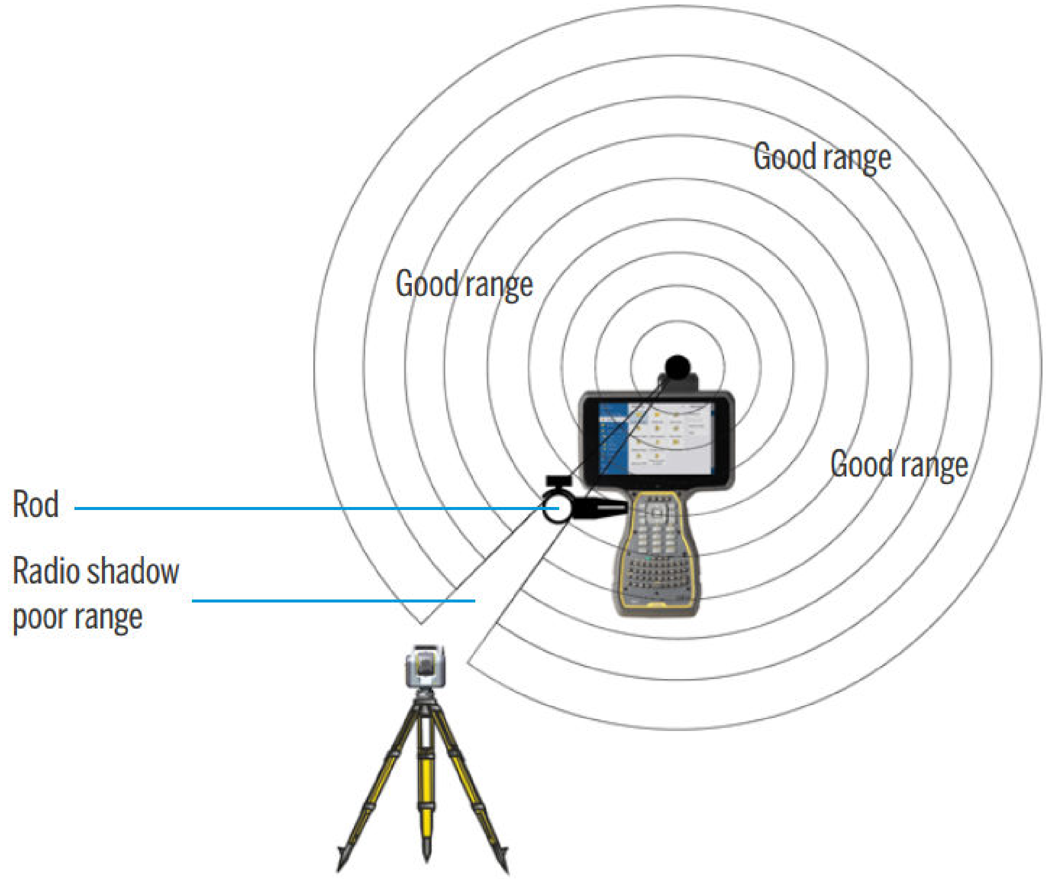
In practice, in outdoor environments Wi-Fi HaLow radio is more robust than standard Wi-Fi and Long Range Radio in situations without a clear line of sight. When using Wi-Fi HaLow, one should expect fewer link connect/disconnect issues in busy urban environments with significant traffic, or when there are obstructions within line of sight such as dumpsters or trucks, or when the signal is going around a building corner or through tree line. This is especially helpful when performing a full dome scan, where you don't want to be included in the scan, so you can position yourself behind a building or object without losing connectivity.

### Line of Sight: Body-Blocking Effect

For optimal performance during radio operation, avoid "body-blocking" the antenna. That is to say, as much as possible, the user should try to position themselves so they are *not* between the EM130 antenna and instrument antenna.

### Line of Sight: Effect of the Survey Rod (Range Pole)

If the survey rod is in the line of sight between the Trimble EM130 antenna and the SX12 antenna, it's possible that the user could experience issues with the radio performance. Whether using the fiber carbon or aluminum rods, if the EM130 antenna is too close to the rod (less than about 2 inches), the rod can partially block the radio signal.




If the data collector has more than one Empower module bay, Trimble recommends mounting the EM130 module on the bay ***farthest*** from the rod to help mitigate this effect. Moreover, if you experience radio issues, try rotating the rod to allow for a clear line of sight.

## Effect of Environmental Elements: Multipath

Reflection of radio waves off of various objects, such as heavy machinery, could result in radio signals arriving at the receiver via two or more routes, known as multipath. When this occurs it results in laggy video quality.

When this is the case, if possible, move the Data Collector fitted with the EM130 module 1–2 meters in any direction to improve the performance.

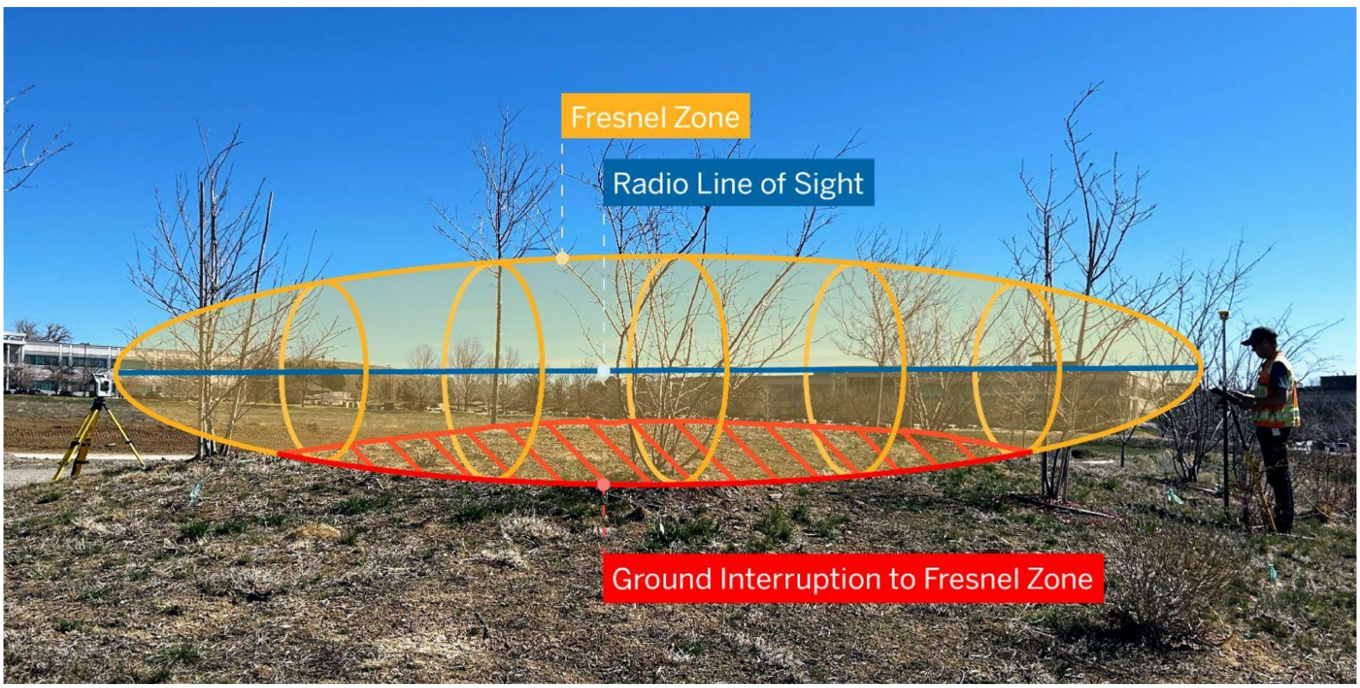
In indoor environments, multipath can actually help reduce the need for line of sight. Though multipath can affect the video quality, it can also ensure the signal bounces around obstructions where you otherwise would not be able to receive a signal.

## Effect of Environmental Elements: Fresnel Zone

When a radio signal travels between two points, it doesn't stay in a perfect line. The area it occupies is called the Fresnel Zone. When the Fresnel zone is free from obstructions, the signal strength is improved.

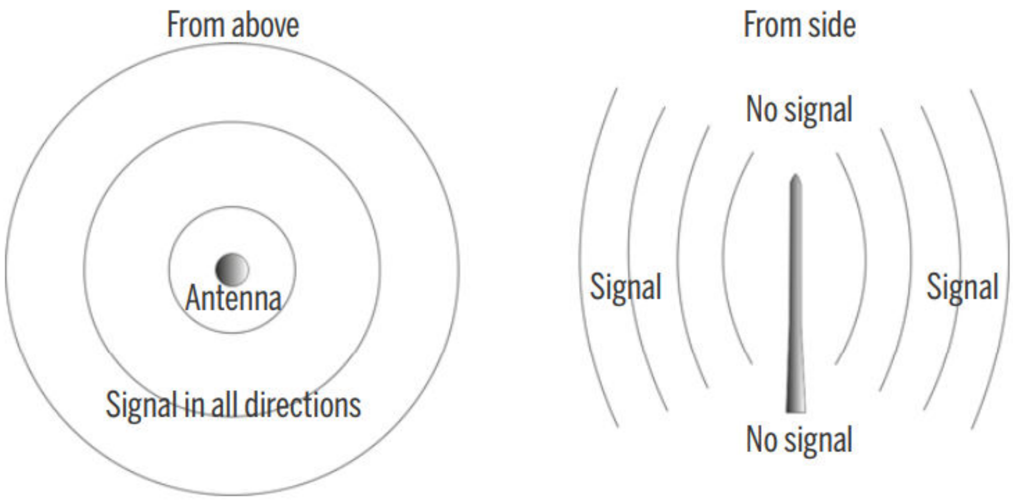
Generally, the higher the transmitter and the receiver antennas are placed above the ground, the longer the range that can be achieved. In the case of the Trimble SX12 and EM130 module, it's not always possible or practical to have the two antennas high in the air. It's generally expected that the antenna height on the total station would be about 1.8 m, and antenna height for EM130 module would be about 1.5 m.

In the below example, the hill impedes the fresnel zone. At such a short distance, the impact on performance is not noticeable, but if the surveyor wanted to walk a long distance to the right and further downhill, they would eventually notice degraded performance or reduced range. When possible, try to plan instrument setups so that the total station is at a higher elevation, like the top of a small hill to help achieve the furthest possible range and best performance.

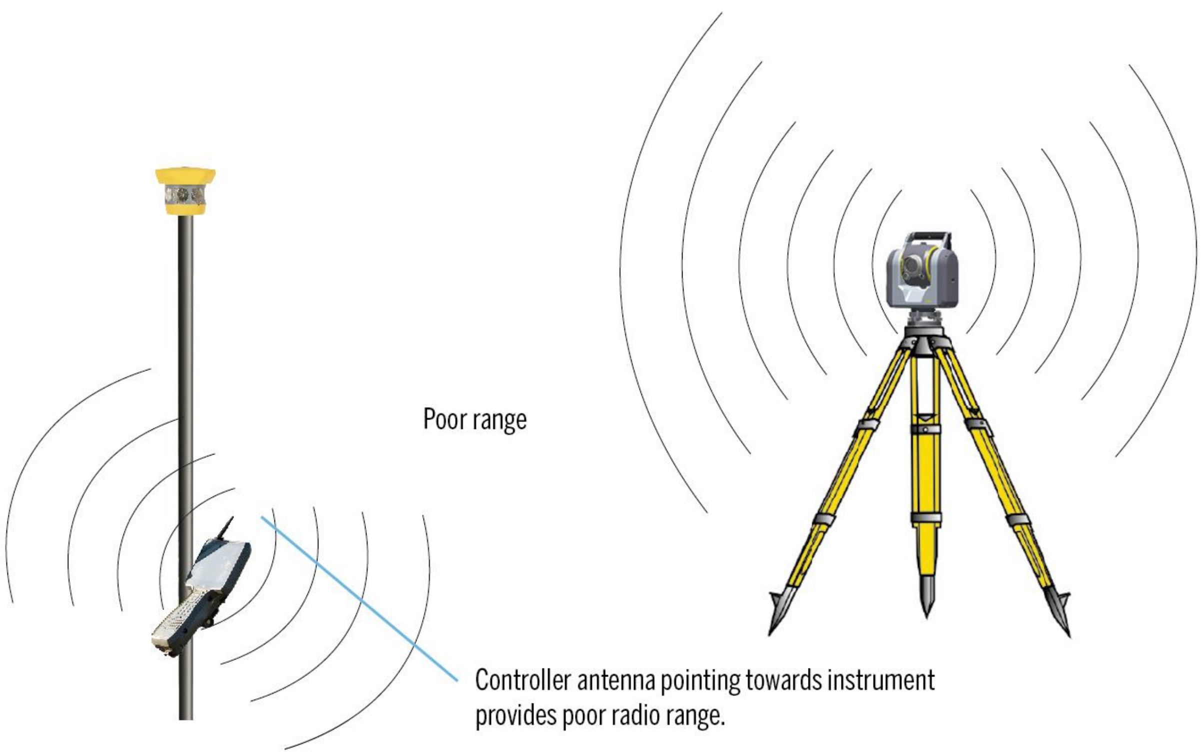


## Effect of Antenna Angle

The antenna radiates the signal in all directions except from the top and bottom:




To get good radio range it is therefore important that both the Trimble EM130 and SX12 antennas are oriented in the same direction. As the Trimble SX12 antenna is fixed in a vertical position, make sure to position the tiltable antenna on the EM130 in the same vertical position to help achieve maximum range.



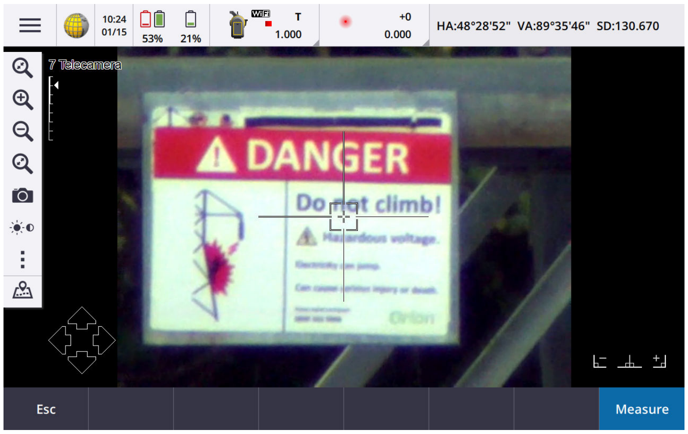

## Effect of Range on Throughput

Over long distances, it typically takes longer to transfer panorama photos or scans because throughput decreases over range. This decrease in throughput will also affect scan transfer/video performance (smoothness etc.).

### Video Zoom Level

Using a Trimble SX12, most of the time you will be streaming video so you can aim the total station. The reason performance can be affected is there are three forward-facing cameras within the instrument, and they generate different image file sizes. Because throughput is decreased at longer range, it takes longer to transfer the larger image files; this could result in lag in the video.

The Overview camera is used in zoom levels 1 and 2. The Primary camera is used in zoom levels 3 and 4. The Telecamera is used for zoom levels 5 through 8.

Lower zoom levels require lower throughput so they don't put as much strain on the radio link. Zoom levels 5-8 have the highest data traffic and put the highest strain on the radio link. It is expected and understandable that the user would have to use higher zoom levels to visually find the target and lock to it when they are at a long range from the instrument. However, if the video is laggy and the user suspects that the radio link might be experiencing performance issues, zooming out or turning off the video should improve the situation by reducing the data traffic.

#### Movement within a Video

The amount of movement within the video can affect the size of each image frame in the video, and thereby affect performance.

The Trimble SX12 firmware includes some clever video compression algorithms; when parts of an image are really uniform, for example a bright blue sky, the instrument is able to compress the image that's being transferred without losing any of the details or quality within the original image. This is also true when using video and pointing at a still scene; because very little is changing within the video from frame-to-frame, the instrument is able to compress the video more.

Conversely, when the instrument video is streaming a dynamic scene with lots of movement, for example a forest where every leaf is blowing in the wind, the video frames are larger, and so streaming that type of large video to a controller can have a negative effect on performance: either shorter range, or some lag in the video stream.

### Effect of High Bandwidth vs Low Bandwidth Channels

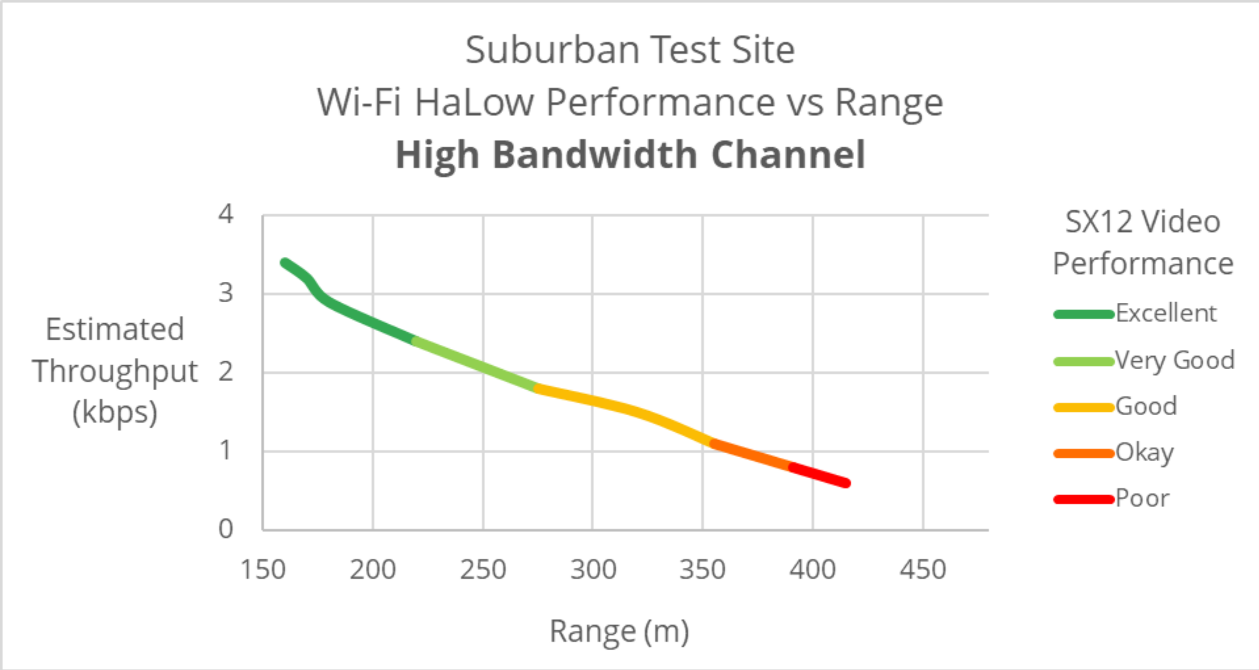
The terms "bandwidth" and "throughput" are often used interchangeably to mean the amount of data that can be transmitted over a period of time. There is a small difference between the two terms: "bandwidth" refers to the portion of frequency band that is utilized for data transfer and it directly correlates with the theoretical capacity of the radio link for data transfer, whereas "throughput" or "data rate" refers to the empirical amount of data transferred per unit of time. The Trimble SX12 and EM130 have two operating modes to choose from within Trimble Access: High Bandwidth, and Low Bandwidth. In practice, this is synonymous with "High throughput" and "Low throughput."

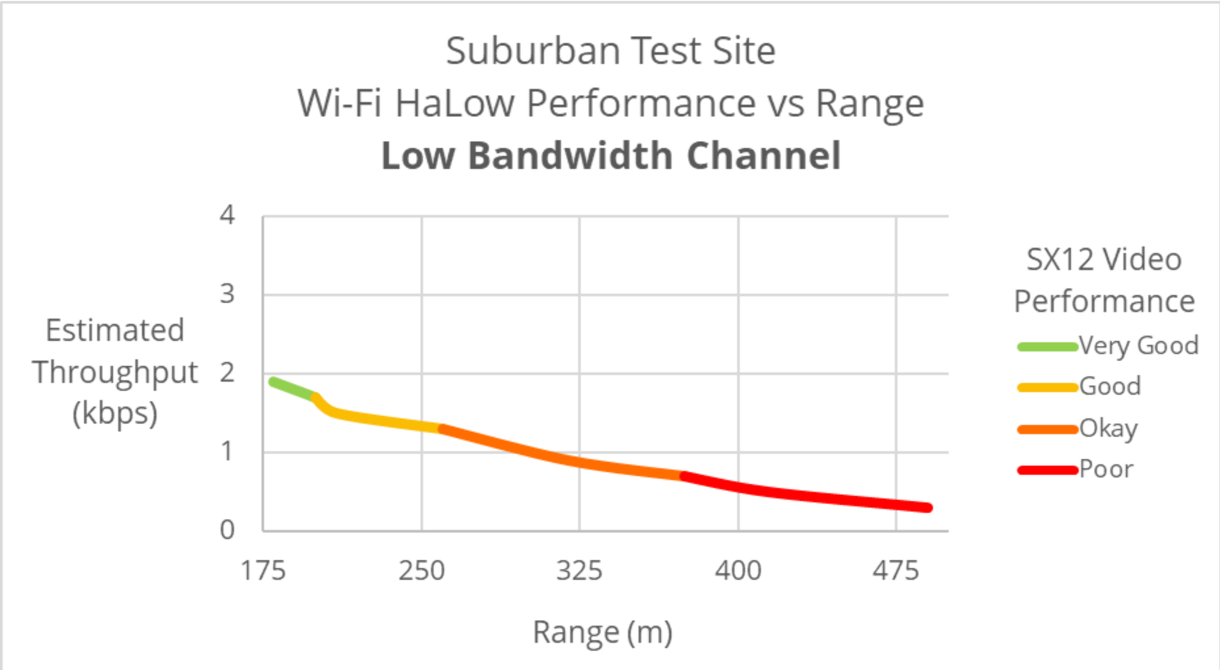
By default, Wi-Fi HaLow radio should be configured to operate on a High Bandwidth channel to provide the best performance. High Bandwidth channels are superior for transferring large amounts of data, which includes transferring scans and panoramas, as well as streaming video.

However, it should be noted that Wi-Fi HaLow radio can also be configured to operate on Low Bandwidth channels. These channels have almost half the performance capacity of the High Bandwidth channels, however, they can provide additional range when the radio link is not heavily loaded with video data traffic. If the High Bandwidth channel frequencies are experiencing localized interference, using the Low Bandwidth channels may provide better performance.

The following graph is an example of how Wi-Fi HaLow radio could operate in a suburban test environment. In this example, it is expected that the Wi-Fi HaLow radio would provide a good user experience up to about 400m range when the video is used. If the user does not need the video they can switch to a Low Bandwidth Channel and continue using the radio for approximately another 100 - 150 meter range.

***Note: The radio performance is highly dependent on the environment where it is operated, as explained throughout this whitepaper. The following is just one example, and the user experience could be better or worse depending on the environment where they use the radio. The following figure is meant to be used as a guideline and is NOT a product specification. No warranty, expressed or implied, is made regarding the accuracy, adequacy, completeness, legality, reliability, or usefulness of any <u>information</u> contained herein, either isolated or in the aggregate. The information is provided "as is".***



# Best Practices for Wi-Fi HaLow Radio Links

Wi-Fi HaLow is an impressive and robust communication solution for the Trimble SX12, though as we covered in the section above, no radios are immune to every possible challenge. In this section learn what the best practices are to make sure your radios are working the way they should.

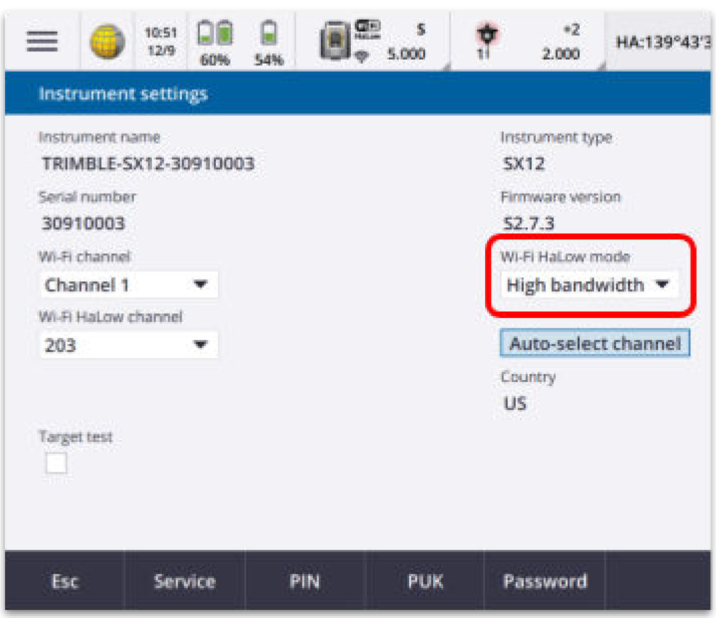
***Tip:** Start your day by checking your Trimble Access radio settings: we recommend using the High Bandwidth channels and running the Automatic Channel Selector*

## Best Practices: Ensure Radio is set to a High-bandwidth channel

For scanning workflows or when video is used, a high bandwidth channel should be selected in Trimble Access under Instrument Settings.

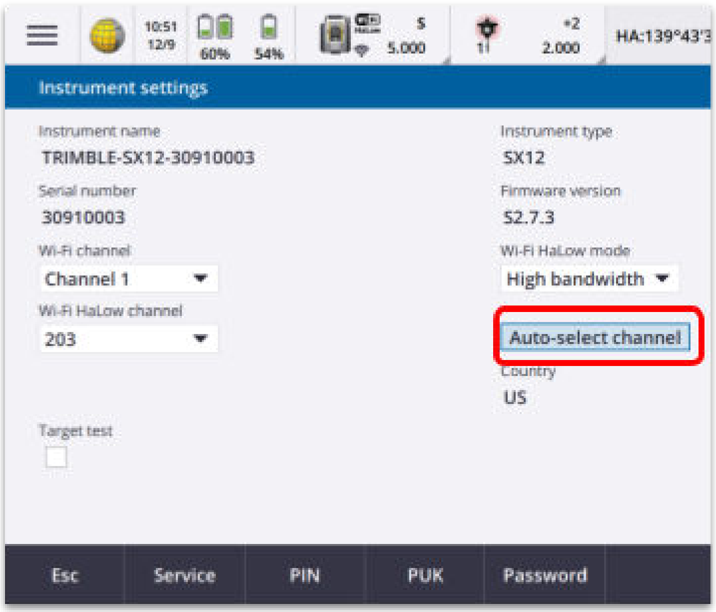
*Tip: to quickly get into Instrument Settings, press-and-hold the SX12 icon in the status bar:*


In the Instrument Settings, you can select "High bandwidth" in the Wi-Fi HaLow mode drop-down:



## Best Practices: Auto-Select Channel Tool

The Auto-Select Channel tool is provided within the Instrument Settings in Trimble Access. This tool helps you select the optimum channel for wherever you currently are located.




Since the Wi-Fi HaLow radio operates in license-free ISM bands, it is possible that other radio devices that use the ISM band cause interference issues which could be perceived by laggy video when the signal bar in the application indicates a strong signal.

In these scenarios, the user has the option of changing the Wi-Fi HaLow channel to move away from the jammed channel and improve the performance. When the Auto-Select Channel is executed, the application will provide a recommended channel to the user based on an radio frequency scan on the environment.

Trimble recommends that when using the system at a new site, use the Auto-Select Channel tool at a low-mid range (about 10-50 meter range) and configure the Wi-Fi HaLow radio to use the recommended channel.

*Note- The Auto-Select Channel tool will only scan the channels of the currently selected Wi-Fi HaLow mode (either High Bandwidth or Low Bandwidth).*

## Troubleshooting Tips

If you are already using High Bandwidth mode, and you already ran the Auto Select Channel tool, but notice your video performance is not what you expect, try these steps:

### 1. Check the Received Signal Strength Indicator (RSSI)

The Received Signal Strength Indicator (RSSI) is an indicator that shows the radio signal strength at the receiver device. Similar to your cell phone, this is displayed in the Trimble Access status bar next to the SX12 instrument symbol.

In case of radio issues, check the radio signal bars in Trimble Access. If there is one bar, the radio could have reached the fringe of operating range. If there are no bars, then the radio performance on High Bandwidth channels using video is not reliable. In this case, it could be possible to get additional range by using Low Bandwidth Channel and turning off the video.



If the signal bar shows 2-4 bars but the user experiences radio issues as perceived by a laggy video or slow responsiveness to commands, an external localized source of radio interference could be the reason for radio issue.

### 2. Look for possible source of interference or environmental effects

In case of radio issues, it is important for the user to pay attention to possible sources of localized interference as explained earlier in the white paper. Watch for proximity of Trimble SX12 or Data Collector+EM130 module to any of the following:

- Power transformers
- High power lines and/or substations
- Large mining site
- Cell towers
- Smart utility meters or other similar IoT devices
- Weather station
- Airport or airfield
- Another nearby Trimble SX12+EM130 setup
- Other known 900MHz radios such as UHF base station radios used for GNSS correction

When surveying, it's not always possible to move away from sources of interference, but if you notice one of the towers/antennas listed above, try moving further away from it.

### 3. Change Channels

Besides the Auto-Select Channel tool, you can change the Wi-Fi HaLow channel manually. If you perceive laggy video but the signal bars in the application indicate a strong signal, you may suspect a radio interference issue. In this case,you can try out different channels and from trial and error take note if a particular channel shows significant improvement.

### 4. Reduce the zoom level or Turn off Video

When the video is enabled and zoom level is set to one of the levels 5 through 8, this usually demands the highest throughput from the radio link. If you experience radio issues as perceived by laggy video, if possible you can change the zoom level to 1 or turn off the video and this should improve the user experience by reducing the data traffic demand on the link.

### 5. Switch to Standard Wi-Fi

Sometimes there could be broadband sources of radio frequency noise in an environment causing interference issues for Wi-Fi HaLow radio such that the Auto-Select Channel tool or changing channels doesn't provide a sufficiently improved experience.

In these scenarios, switch to standard Wi-Fi radio. This may provide improved performance, especially at low-mid range (below about 100 m).

# Glossary of Terms

| Term | Description |
|---|---|
| Receiver | The receiver end of a wireless communication link.<br>In this whitepaper, this refers to EM130 module on the Data Collector. |
| Transmitter | The transmitter end of a wireless communication link.<br>In this whitepaper, this refers to the Trimble SX12 instrument. |
| Wi-Fi HaLow | Wi-Fi HaLow is the trademarked name for the wireless technology defined as part of IEEE 802.11ah standard. |
| EMI | Electromagnetic Interference<br>Refers to when a source of electromagnetic wave radiation causes performance issues on a desired signal or communication link |
| RSSI | Received Signal Strength Indicator<br>An indicator of the power of radio frequency waves received at receiver end of a wireless communication link.<br>The unit is dBm and usually a negative value. The lower value indicates a lower power. |
| ISM | Industrial, Scientific, Medical<br>In the world of radio engineering and regulation, it refers to devices that have application in any of industrial, scientific, and medical applications as defined by radio communication regulatory bodies.<br>ISM band refers to a portion of the radio spectrum that is allocated by radio communication bodies to devices within industrial, scientific, and medical applications. |

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