GWS5000 SERIES USER GUIDE

19th July 2019

6HARMONICS
CONNECTING PEOPLE & THINGS

Contents

Revision History

Revisions	Author	Date	Status	Notes
1.0	Mike Davies	14th January 2019	Draft	Initial release for internal review
1.1	Mike Davies	15th February 2019	Draft	Changes to Nominet Database Settings: OFCOM Operation following database testing.
1.2	Mike Davies	7th May 2019	Draft	Changes after RED and EMC testing to define normal performance and operating specifications. P21, 51 & 123.
1.3	Mike Davies	7th June 2019	Draft	Updated FCC AGL limit, compliance standards, max antenna gain in manufacturers declaration for UK.
1.4	Mike Davies	9th July 2019	Draft	Added antenna and power supply approved components for FCC
1.5	Mike Davies	16th July 2019		Added MPE Technical Brief and RF Exposure Compliance Declaration for Canada.
2.0	Mike Davies		First release	

Copyright Notice

FCC Regulatory Notice

This device complies with part 15 of the FCC Rules. Operation is subject to the following two conditions: (1) This device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation. Any changes or modifications not expressly approved by the party responsible for compliance could void the user's authority to operate the equipment.

Part 15 TV Band Device Notice

This equipment has been tested and found to comply with the rules for TV bands devices, pursuant to CFR 47 Part 15 Sub-part H of the FCC rules[1]. These rules are designed to provide reasonable protection against harmful interference. This equipment generates, uses and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:

- Reorient or relocate the receiving antenna.
- Increase the separation between the equipment and receiver.
- Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.
- Consult the manufacturer, dealer or an experienced technician for help.

Caution: Exposure to Radio Frequency Radiation

To comply with FCC RF exposure compliance requirements, for fixed configurations, a separation distance of at least 75 cm must be maintained between the antenna of this device and all persons.

This device must not be co-located or operating in conjunction with any other antenna or transmitter.

Expert Installer

To comply with FCC interference protection requirements for TV Band Devices this equipment should only be installed by an expert installer.

[1] https://docs.fcc.gov/public/attachments/FCC-15-99A1.pdf

Approved Components:

Only the following components in the table below are approved for use.

GWS Radio	FCC Certificate Number	Also approved for:	Approved Components / Supplier
Power Supplies[2]			
GWS-5002		GWS-5002E	Microsemi 9501 POE[3]
GWS-5002		GWS-5002E	Ubiquiti POE-54-80W
GWS-5002		GWS-5002E	Netonix POE switch configured to 48VH 1.5A
GWS-5002		GWS-5002E	Ubiquiti POE-50-60W
Antennas[4]			
GWS-5002		GWS-5002E	9dBi Dual Polarized LPDA KP Antennas PN: KP-TWDPLP9
GWS-5002		GWS-5002E	9dBi Dual Polarized LPDA Wireless Instruments PN: WiLPDA M0406-65-9X
GWS-5002		GWS-5002E	9dBi Dual Polarized LPDA Wireless Instruments PN: WiLPDA M0608-65-9X
GWS-5002		GWS-5002E	8dBi Single Polarized LPDA 6Harmonics PN: GWS-SL14174A
GWS-5002		GWS-5002E	12dBi Panel Dual Polarized Wireless Instruments SA MO4706-65-12 (Non-congested areas only)
GWS-5002		GWS-5002E	12dBi Panel Dual Polarized KP Antennas PN: KP-TWDP65S-12 (Non-congested areas only)
GWS-5002		GWS-5002E	12dBi Panel Single Polarized KP Antennas PN: KP-TWVP65S-12 (Non-congested areas only)
GWS-5002		GWS-5002E	12dBi Panel Single Polarized 6Harmonics PN: GWS-SL12948B (Non-congested areas only)
GWS-5002		GWS-5002E	11dBi Panel Dual Polarized MTI PN: MT006D11VH (Non-congested areas only)
GWS-5002		GWS-5002E	8dBi Panel Dual Polarized Wireless Instruments PN: WiBOX PA M0407-8X
GWS-5002		GWS-5002E	9dBi Panel Dual Polarized KP Antennas PN: KP-TWDPFP9
GWS-5002		GWS-5002E	8dBi Panel Dual Polarized Lanbowan PN: ANT0407D8Z-DP
GWS-5002		GWS-5002E	7.5dBi Panel Dual Polarized MTI PN:MT006D07VH
GWS-5002		GWS-5002E	7dBi Panel Single Polarized 6Harmonics PN: GWS-SL12948A
GWS-5002E		NA	6dBi Omni Vertical Polarization 6Harmonics PN: GWS-SL13304A
GWS-5002E		NA	2dBi Omni Vertical Polarization 6Harmonics PN: GWS-SL13319A

[2] FCC allows the use of other power supplies to FCC certified radios as a Class 1 Permissive Change (no filing required) under the permissive change policy (https://apps.fcc.gov/oetcf/kdb/forms/FTSSearchResultPage.cfm?id=33013&switch=P) so long (i) as they are electrically equivalent and (ii) there is no degradation in emissions.

[4] FCC 15.204.(c).(4) Any antenna that is of the same type and of equal or less directional gain as an antenna that is authorized with the intentional radiator may be marketed with, and used with, that intentional radiator. No retesting of this system configuration is required. The marketing or use of a system configuration that employs an antenna of a different type, or that operates at a higher gain, than the antenna authorized with the intentional radiator is not permitted unless the procedures specified in §2.1043 of this chapter are followed.

Safety Notice

In order to avoid RF Exposure risk installers and operators must be aware of the following minimum distances.

Mode	Max Antenna Gain	Power per RF Port	Minimum distance to avoid exposure
MIMO	12dBi	29dBm	75cm
SISO	12dBi	29dBm	75cm

Deployment Guide Summary

This deployment guide provides an overview of the 6Harmonics GWS5000 product portfolio and how specific units can be employed to establish a wireless radio network with the intended performance. The guide is intended to allow installers, applications engineers and technical sales to understand all aspects of the 6Harmonics TVWS solution. This document contains information to specify, install and set-up basic operation of a GWS series base station with a client station for point-to-point or point-to-multipoint networks.

The guide covers:

- A description of the GWS series radio units, associated antennas and mounting hardware
- An overview of deployment considerations when using 6Harmonics products for a TV Whitespace based wireless network. Understanding Coverage and Capacity are essential for a successful wireless network deployment
- Installing and initiating the GWS radio units including (i) operating mode, (ii) channel selection and (iii) establishing a reliable link between a base station and a client station
- Basic trouble shooting and best practices.

Advanced operation, such as mobility or mesh networking mode, is covered in separate documentation and should only be performed by technicians that are trained and approved by 6Harmonics. For advanced configuration information for GWS deployments please contact 6Harmonics.

GWS5000 Series Product Description

Best in class TV Whitespace wireless solution with industry leading throughput and range to meet the most demanding of deployment challenges. The GWS5000 series is the most advanced TV whitespace solution available and is the 5th generation of TV Whitespace radio developed by 6Harmonics. Throughput with a 24MHz and a single spatial stream can achieve 72Mbps UDP and 50Mbps TCP/IP. Conducted transmit power up to 39dBm per spatial stream (8W) is available (regulatory permitting).

Based upon the globally accepted robust WiFi protocol, the GWS5000 series radios are able to maintain NLOS data links in the most challenging of TVWS deployments when faced with in-band noise & interference, multipath fade, trees or other obstructions.

With a Mobility software option, the GWS5000 is unique amongst TVWS radios. Mobility software option allows fast soft hand-over between base stations and enables mobile mesh operation. The mobility option can be used in UK on an unlicensed basis if the CPE is restricted to GOP mode. Mobility and MESH operation are covered in a separate document.

The SOP Direct proprietary database query process ensures that CPE can utilize SOP operation directly without the GOP intermediate step, which enhances spectrum availability from a TVWS database (UK only).

In the USA & Canada: the base station model number is GWS-5002 and has two transmit / receive chains; the client station model number is GWS-5002E has a single transmit chain and receive diversity.

In countries that require CE Mark; the base station model number is GWS-5002 and has single transmit chain and receive diversity; the client station model number is GWS-5002 has a single transmit chain and receive diversity.

Applications

- Rural broadband internet for residences and businesses
- NLOS backhaul to community, educational or retail WiFi hotspots
- Maritime networks
- Video surveillance & security
- Public safety communications in remote locations
- Rural IoT & Precision Agriculture
- In-building networks

Key Features

- Operates on TV channels from 14 to 51 inclusive (470MHz-698MHz) in Channel Plan 0 (USA, Canada, etc.)
- Operates on TV channels from 21 to 58 inclusive (470MHz-774MHz) in Channel Plan 1 (UK, EU, Africa, etc.)
- Base stations: single or dual spatial stream in transmit, dual spatial stream in receive
- Client station: single spatial stream in transmit, dual spatial stream in receive
- Dual spatial stream in receive provides MIMO or receive diversity with STBC to enhance link stability and SNR.
- LDPC forward error correction code ensures link stability even in noisy environments
- Point-to-Point, Point-to-Multipoint or Mesh
- Suitable for both access and backhaul links
- L2 connectivity enables management of residential access points directly from an edge-router behind the base station.
- Internal GPS geolocation
- Software defined channel width from 1MHz to 32MHz, typically 6-12-18-24MHz or 8-16-24MHz.
- All stations dynamically optimize throughput based upon minimizing packet retries
- Low latentcy, typically <5mS round trip delay
- Client station scan and auto-connect
- Intuitive GUI minimizes user training and simplifies operation
- Client station beacon reading allows quick determination of base station signal strength and SSID
- Link by link throughput status including RSSI, noise, SNR, MCS, station geolocation
- Remote transmit power control of client stations from base station GUI
- Djinni tool ensures rapid login and network configuration, even if IP address lost
- Auto roll-back of IP address if not confirmed after reconfiguration, prevents loss of access
- Remote firmware upgrade via GUI
- Firmware image backup to onboard memory or save to external memory
- Map feature in combination with GPS geolocation simplifies visualization of actual network layout
- Spectrum noise scan enables optimal choice of operating channel
- Nominet database for USA & UK unlicensed operation
- LAN/WAN diagnosis tool to ensure internet access and database access are valid
- Radius client for network access validation
- Powered by readily available low-cost POE switches or single POE midspans, simple to integrate onto existing hybrid networks using either 5GHz or 3.5GHz radios
- DC powered options available
- IP67 enclosure operates over wide temperature range and withstands moisture and precipitation
- Custom enclosures available
- Depending on the deployment scenario, links in excess of 20km can be established

Standards and Regulatory Compliance

Canada	RS-222; RSS-GEN
Europe	EN 301 598 V1.1.1, EN 301 598 V2.1.1(partial); EN 301.489-1
USA	FCC CFR 47 Part 15 Sub-part H
CE Mark	• Electromagnetic Compatibility Directive (2014/30/EU) • Radio Equipment Directive 2014/53/EU • Restriction of Hazardous Substances in Electrical and Electronic Equipment (RoHS) • General Product Safety Directive 2001/95/EC

Power Specifications

Power supply	50-56V Passive POE++ 1/2, 4/5 (+); 3/6, 7/8 (-)
Power consumption	33dBm maximum transmit power: 35W boot, 30W on transmit, 15W receive. Average power consumption 25W, traffic pattern dependent.
Recommended power supplies	CPE: Ubiquiti POE-50-60W
	BTS: Ubiquiti POE-54-80W or Netonix POE switch configured to 48VH 1.5A
	BTS (DC): Ubiquiti EdgePower EP-54V-150W
Surge suppression	Ethernet surge suppression at both client and base stations is required.

Other custom radio configurations may require DC power. Contact 6Harmonics for details.

Mechanical

Dimensions	Base Station	Client Station
Weight		
Housing		
Mounting	1 Female RJ45 IP67 RJ45 connector. Auto-sensing 10/100-T Ethernet.	
Antenna	2 Female IP67 N-type connector	
Other	Pressure equalization vent	

Custom enclosures available for 8W, vehicular or maritime applications.

Environmental

Operating Temperature	-40C to +50C (external); -40C to +85C (internal)	
Storage Temperature	-50C to +90C (non-condensing)	
Humidity	5%-100%	
Electrostatic Discharge	15kV air, 10kV contact (power cycle may be required)	
Altitude Temperature De-rating	Altitude (m)	Temperature (C)
	0	0 to +50.0
	1500	0 to +47.3
	3000	0 to +44.3
	4500	0 to +41.1

Deployment Planning for GWS5000 Radios

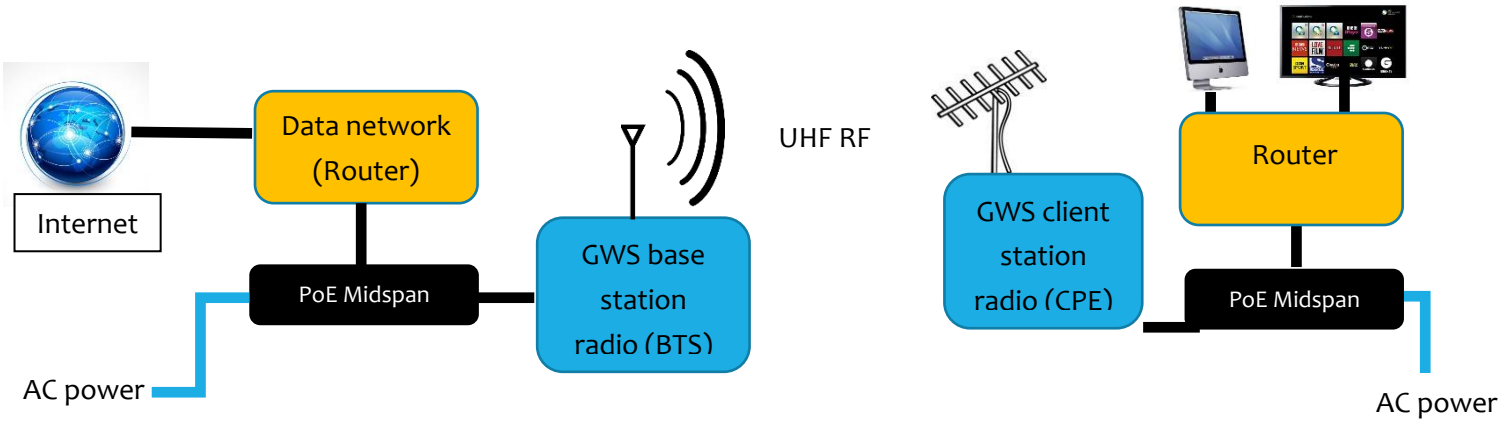
TV Whitespace or Super Wi-Fi are terms often used to describe wireless network solutions that utilize VHF / UHF spectrum that has become available as TV broadcast signals have moved from analog to digital. Because a digital TV signal uses less spectrum than an analog TV channel these "TV Whitespaces" (TVWS) have become available for unlicensed use. TVWS refers to unused & unlicensed blocks of frequency (channels) across the VHF and UHF spectrum that fall between TV broadcast signals. The UHF spectrum is relatively 'clean and idle' in many countries and is ideal for mobile & fixed broadband applications. Depending on geo-location, each channel is 6-8MHz wide. Unlike unlicensed Wi-Fi spectrum, TVWS signals propagate extraordinarily well with low loss. Non-line of sight (NLOS) penetration through trees and around buildings is readily achievable.

From a technology perspective, key to the deployment of TVWS wireless solutions is that the TVWS radios must be "cognitive". This means they must; (a) know where they are located, (b) they must know what channels are available at their location, and (c) they must assess the channels available at their location & choose an available channel that maximizes throughput and minimizes interference.

In USA, Canada, UK, Colombia & South Africa to ensure that a GWS radio is using a legally available channel a GWS radio must know its longitude and latitude co-ordinates and present these co-ordinates to an approved database for the region where the radio is deployed. This requires that the GWS radios have access to the internet. In some regions the channel may be set manually without access to a database (see regulatory section in Appendix).

WARNING: Any installer of GWS radios must ensure that regulatory compliance is strictly adhered to for the region where the GWS radios are operating

The basic deployment of a TVWS / Super Wi-Fi network using UHF is shown below:



Point-to-Point Links

In the preceding diagram if the link is between two stations only, it is a point-to-point link. Point-to-point links are used for bridging / extending networks or as a network backhaul. In this case we expect both to have the same configuration to ensure the link is reciprocal. Both stations will likely have directive antennas-as the link is to connect two points only. Directive antennas help avoid interference and maintain signal to noise ratio.

Point-to-Multipoint Links

In point-to-multipoint links a central base station is used to cover a wide area, typically with a sectorized antenna. The client stations lying in the coverage zone then have directive antennas pointing at the base station. Here, the client stations operate with the central base station in a master-slave arrangement. The client stations do not connect to each other, they only connect to the central base station.

For any deployment scenario three initial questions must be answered:

- What coverage is required?
- What capacity is required in the coverage area for the user applications at the client stations?
- What is the RF environment?

Coverage

Identify potential base station tower locations.

- Check the potential height of the antenna on the tower and the GPS co-ordinates.
- Consider the availability of TVWS spectrum from the database
- Consider the risk of noise or interference form TV or other signals.

Coverage and Propagation Estimation

There are numerous propagation models that can be used to estimate coverage[5].

For a simple estimation choose:

- Transmit power: 23 dBm (0.2W conducted)
- Transmit line (co-ax) loss: 1 dB for every 5m of coax cable.
- Transmit antenna gain: 10 dBi
- Receive antenna gain: 10 dBi
- Receive line (co-ax) loss: 1dB for every 5m of coax cable.
- Receive line threshold (µV): 3µV (equivalent to noise of -98dBm)

The numbers chosen should consider regulatory restrictions for:

- Maximum antenna height above ground level. The higher the antenna, the more expensive a tower install.
- Maximum energy in radiated power (EIRP).

Outdoor Propagation Considerations

The combined antenna gain and transmit power cannot exceed regulatory limits for a given geolocation. Typically, a higher antenna gain has a narrower beam-which will in effect focus the coverage area. This may, or may not, be desirable.

The model may, or may not, consider vegetation or high building coverage. These can have significant impact on the received power. Understand what other elements are present in the coverage area. Check Google Earth.

[5] A simple and free online tool can be found at http://radiomobile.pe1mew.nl/ . This downloaded version tool can use TVWS frequencies but a reasonable first order estimation can be performed by using the online tool and selecting 902MHz or 450MHz as the operating frequency. Because TVWS has different propagation characteristics than 902MHz/450MHz, the actual coverage / link budget will be different. 902MHz / 450MHz can viewed as a min-max performance assessment for point-to point links or wide area coverage from a central base station.

Line of Sight (LOS) propagation from a client station towards a high tower may suggest that a strong link can be established but if the link lies within the Fresnel zone problems may occur.

Non-Line-of-Sight (NLOS) propagation is feasible at these frequencies, the RF can often have sufficient power to penetrate buildings, woodland and propagate over hills. However, if several steel and concrete buildings lie within the antenna sector, even high-power signals will not be sufficient to establish a connection.

Link Margin and Expected Throughput Performance

Once an estimate of the received power coverage from a base station has been completed, we can now estimate the link performance. In the coverage estimation we assumed an antenna gain at the receiver.

Depending on the received signal strength at the client radio, the client radio will be able to decode the data at varying data rates as expressed as a modulation coding scheme (MCS) level. The higher the MCS the higher the data rate the channel can carry-known as spectrum efficiency. This assumes a noise floor in the RF environment at the client radio receive circuitry, typically this is -98dBm for a dual channel radio. If the received power is -88dBm then the signal to noise ratio is 10dB.

If the receive power falls below -98dBm, received power the link will be lost. It is unreasonable to assume that the link will be forever static. Trees grow, buildings are built, road traffic may increase. For this reason, an additional link budget margin must be added over the minimum target received power. 6Harmonics requires a minimum link budget fade margin of 6dB. In other words, the design rule for received power at the client station should be at least -72dBm to maintain MCS7.

Between -97dBm and -80dBm received power the throughput will vary as per the following table:

The GWS5000 series throughput performance:

6MHz DTT channel & SISO Operation

Connection MCS level	Received power (dBm)	Modulation supported	Spectral efficiency (b/s/Hz)	Theoretical PHY rate (Mbps)	UDP rate (Mbps est.)	TCP/IP rate (Mbps est.)
MCS 7	>-78dBm	64 QAM 5/6 rate	5[6]	25	16.5	12
MCS 6	-80 to -79dBm	64 QAM ¾ rate	4.5	22.5	14.7	10.9
MCS 5	-82 to -81dBm	64 QAM 2/3 rate	4	20	13.0	9.7
MCS 4	-84 to -83dBm	16 QAM ¾ rate	3	15	9.8	7.3
MCS 3	-89 to -85dBm	16 QAM ½ rate	2	10	6.5	4.8
MCS 2	-90 to -92dBm	QPSK ¾ rate	1.5	7.5	4.9	3.6
MCS 1	-93 to -95dBm	QPSK ½ rate	1	5	3.3	2.4
MCS 0	-96 to -98dBm	BPSK ½ rate	0.5	2.5	1.6	1.2
No connection	<-98dBm	NA	NA	NA	NA	NA

[6] 802.11n radios using a short guard interval of 400ns with a 20MHz channel at MCS 7 has a PHY rate of 72.2Mb/s which equates to a spectral efficiency of 3.61 b/s/Hz.
https://en.wikipedia.org/wiki/IEEE_802.11n-2009 and https://en.wikipedia.org/wiki/Spectral_efficiency

24MHz DTT Channel & MIMO[7] Operation

MCS Index	Received Spatial Streams	Modulation Type	Coding Rate	PHY Rate	UDP Rate
0	1	BPSK	$^1/_2$		
1	1	QPSK	$^1/_2$		
2	1	QPSK	$^3/_4$		
3	1	16-QAM	$^1/_2$		
4	1	16-QAM	$^3/_4$		
5	1	64-QAM	$^2/_3$		
6	1	64-QAM	$^3/_4$		
7	1	64-QAM	$^5/_6$		
8	2	BPSK	$^1/_2$		
9	2	QPSK	$^1/_2$		
10	2	QPSK	$^3/_4$		
11	2	16-QAM	$^1/_2$		
12	2	16-QAM	$^3/_4$		
13	2	64-QAM	$^2/_3$		
14	2	64-QAM	$^3/_4$		
15	2	64-QAM	$^5/_6$		

[7] Even though the transmit may have two spatial streams the link may down grade from true MIMO to SISO with receive diversity. The above table is a receiver perspective the transmitter could be MIMO or SISO with transmit diversity.

The previous tables are just guidelines. In reality, the "data throughput" depends on several factors such as the application, the packet length etc etc. When deploying 6Harmonics products, a wireless network design should include an estimate of the traffic patterns and traffic type. Customers and installers must be aware of all aspects of their requirements to ensure a successful deployment.

Based on the above the operator should determine:

- The ease of deployment of the base stations
- The signal levels at the proposed client stations
- The expected throughput at the proposed client stations, is it good enough for service?

MCS Level: Modulation Coding Scheme

The GWS radios use a WiFi protocol which itself uses a dynamic channel state algorithm to set an MCS level that maximizes packet transport, specifically by minimizing the number of packet retries needed to transport a packet over the wireless link.

If there is little traffic, the MCS level may drop, the reason is simple, only a low MCS level is needed for minimal packet transport, so errors are minimized at a low MCS.

The links are **constantly and dynamically adjusted in both uplink and downlink for all client stations**. This means a distant client with poorer SNR will receive data at a lower rate than a client closer to the base station with a high SNR. This also means that any client with noise or interference will not force the base station transmit to reduce the downlink transmit data rate to that of the weakest client. **All links are independently self-optimized for maximum packet transport.**

Making the Link Reciprocal

The preceding sections are focused with choosing the base station and associated antenna to deliver sufficient EIRP to get sufficient coverage with an assumed receive sensitivity at the client station. The link must also be designed to ensure sufficient EIRP at the client station so that the base station has a similar receive power (RSSI) when in receive mode, as does the client station. Generally speaking, the base station has a broader beam and higher transmit power than the client station (more power over more area). The client station has a lower transmit power but a more directive antenna (less power in a focused beam). In combination this ensures the link budget between the uplink and the downlink is within 6dB. If the uplink-downlink link budget is greater than 6dB then the link may not be able to sustain MCS7 in both directions. If the MCS level is different in uplink and downlink then for

an equivalent amount of data to be transmitted, the link with the lower MCS will require more airtime (or access to the radio channel). The uplink and downlink will have asymmetric throughput. If this happens poorer performing stations can degrade the overall network throughput. This problem is mitigated by the proprietary 6Harmonics airtime fairness algorithm, but it is preferable to ensure the link is as symmetrical as possible by considering RF propagation, transmit power and antenna performance at the design stage.

6Harmonics recommends that before implementing a deployment an experienced wireless networking professional be engaged by customers to ensure the RF propagation model is realistic and the required received power and application related throughput for the target client stations within the coverage area can be met.

GWS5000 Installation

The GWS5000 radios are generally mounted on a pole or mast that shares the antenna. It is recommended that the pole or mast be metal (galvanized steel or aluminum). When the radio units are attached to the mast using the brackets supplied a good electrical connection is made to the mast. Therefore, the mast or pole itself should also have a good earth as ground for the RF. Any other radios at the same location should utilize the same ground.

If the mast/pole/bracket is not directly grounded to earth, say as a side bracket on a wall or a roof-top tripod, then suitable conducting strapping should be employed. Typically, a ground strap is always in place as a mitigation against lightning. If different combinations of metals are used galvanic effects may lead to corrosion.

Plastic masts are not recommended. If plastic masts are used, separate grounds should be used for both the antenna and the radio unit.

Antenna Installation

The antenna should be securely mounted to a pole / tower, or wall that can withstand the wind loading associated with the surface area of the antenna at a wind speeds appropriate to the weather conditions at the deployment location[8]. Certain locations may experience high wind gusts. It is unlikely that mechanical brackets will be an issue, but the tower or pole must be strong enough to sustain the worst expected weather conditions.

The co-axial RF cable that runs from the antenna to the GWS-radio unit should be tied to the pole with cable ties or other suitable UV weather resistant fixtures. An installation will be exposed to wide variations in temperature with extended UV exposure. Use good quality materials at all times. The co-axial cable has a loss of approximately 0.5dB for a 4ft cable with connectors. If longer cables are used the impact on the uplink-downlink link budgets should be assessed before installation.

All co-axial connectors must be tightened but not overtightened. Problems will occur if there are loose fittings in the RF section between the antenna and the radio. Remember these fittings will reside outdoors for an extended period of time and will be subject to thermal cycling daily and seasonally as well as rain, snow and ice build-up. The use of waterproof tape is essential on all exposed connections. For USA, Canada and UK installations a professional installer must provide the correct antenna gain and antenna

[8] http://www.va3cco.com/towersheight.pdf

height above ground to the radio to ensure regulatory compliance is met via the database query.

GWS Radio Unit Installation: Grounding

When a GWS radio is installed outdoors, the enclosure must be properly grounded to allow a discharge path in the case of a nearby lightning strike. In the event that the radio housing is not grounded through the mounting bracket, the radio enclosure has a self-tapping screw hole provided on the bottom of the rear facing side of the module for the attachment of a separate ground wire. A ground wire with a Lug nut properly sized should be used to ground to the housing. The ground wire must be at least 14 Gauge and be connected to a good ground. If the GWS unit is mounted on a metal pole that is properly grounded this ground wire is not required. For client station installations, it is often difficult to ground the radio properly. In the event the radio enclosure is allowed to float, then strict attention should be paid to the installation of ethernet surge protection (see below).

GWS Radio Unit Installation: Lightning Surge Protection

For a base station installation, a lightning suppressor (polyphaser) must installed on the co-axial cable on the GWS radio unit[9]. Such suppressors are not protection against a direct hit but provide some mitigation against proximity / indirect lightning strikes. With the mast/pole grounding approach previously described the suppressor will conduct lightning related surges directly to ground via the mast/pole. The purpose is to protect the Tx /Rx circuitry of the radio. A base station is typically mounted much higher AGL (above ground level) than a client station and as such is much more at risk of lightning. A client station is typically mounted much lower. For this reason, **lightning surge suppressors are mandatory for base stations but optional for client stations.**

GWS Radio Unit Installation: Ethernet Cable Requirements

The ethernet cable running from the POE switch / POE injector should be good quality outdoor Cat5e cable. The cable must have ground shield and be 24AWG. The outer sleeve should be UV resistant. Good quality grounded (metal shield) RJ45 connectors should be used. The GWS radio comes with an IP67 waterproof RJ45 connector. The waterproof gland (5 pieces) is provided separately within the kit. The waterproof gland is designed to provide a water tight interface for cables with an outer diameter between 5mm and 7mm. For connections to the radio and outdoor ethernet surge suppressors the waterproof gland

[9] For example: http://www.polyphaser.com/SiteMedia/SiteResources/EngineeringSpecDocuments/TUSX-NFM.pdf

must be tight and fitted properly. The connectors must be taped with good quality waterproof tape. Care must be exercised to ensure none of the threads are crossed so the waterproof seal is tight.

GWS Radio Unit Installation: Ethernet Surge Protection

Ethernet surge suppressors are essential to ensure protection of the data port on both the radio and the data port of the POE unit.

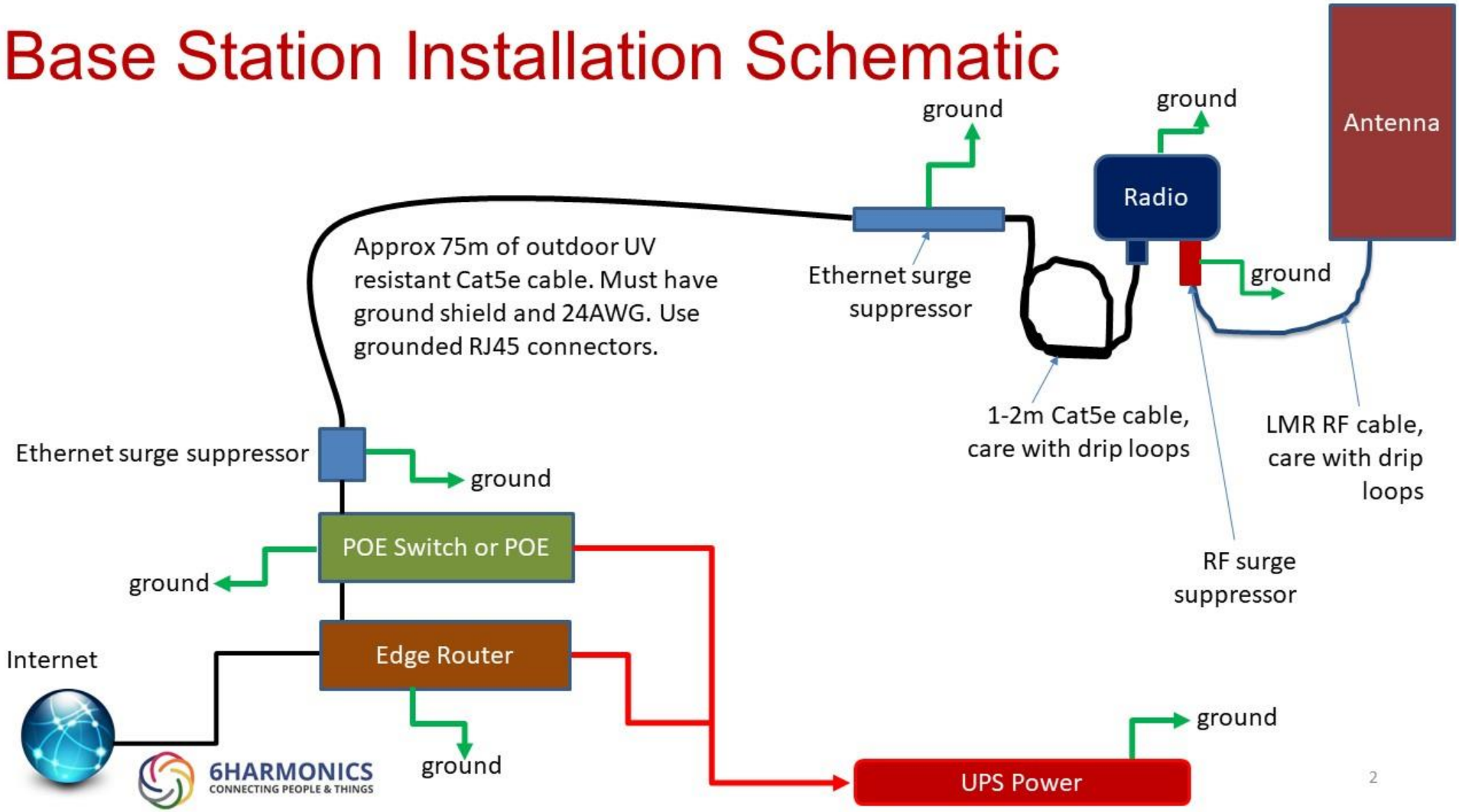
For a base station a high quality outdoor ethernet surge suppressor should be mounted within 2m of the radio and must be properly grounded. The purpose of this surge suppressor is to prevent spurious signals picked by the ethernet cable getting into the radio. This cable can easily be 75m in length, and in effect can act as antenna to any RF. In addition, the POE at the base of the tower should also have surge protection to ensure spurious signals do not go into the switch or edge router that provides the data connection to the internet. Both ends need protection on a base station.

For a client station, an outdoor ethernet surge suppressor is required. This surge suppressor maybe mounted indoors or outdoors. It must be grounded properly. Outdoors is preferred as this allows access to the radio by a service technician without going inside the residence.

In this case the surge protector provides surge protection to the radio from the POE, and equally provides protection to the residential router behind the client station radio POE. The distance between the radio and the residential router is much less than in the case of the base station, so only one surge suppressor is needed.

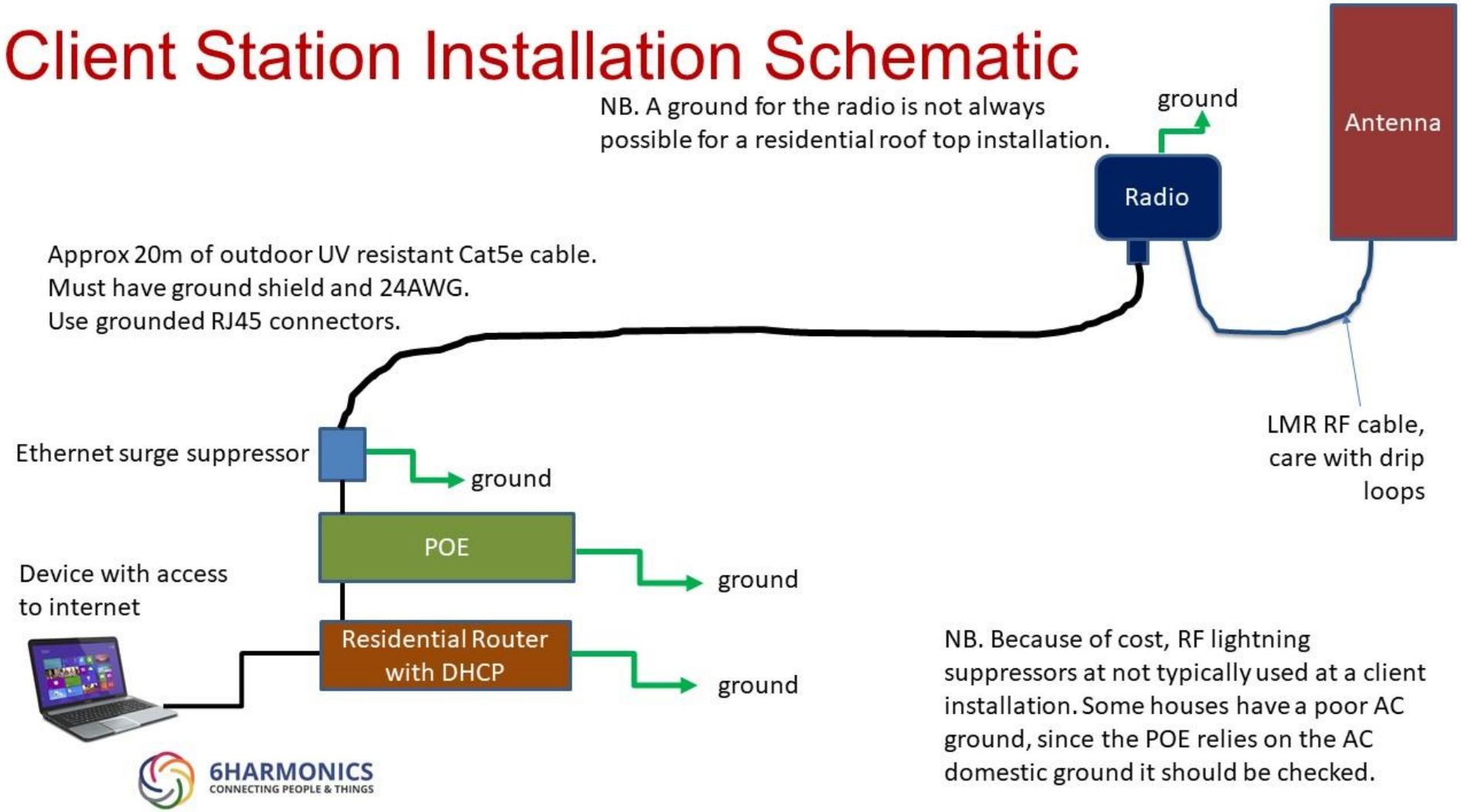
WARNING: In many rural locations power can be of poor quality and significant power surges can occur when the power comes back on after a power cut. For this reason alone, the client station installation should have a surge suppressor as described above. Installers should also check, using a suitable GFCI tester, that the power outlet in the residence that drives the GWS radio POE is grounded properly. Typically, in the event of a power surge a client station will re-boot and automatically re-connect to the base station. In the event that the radio (base station or client station) does not automatically reboot after a power surge, remove the power cord from the POE unit, wait 1 minute. Re-insert the power cord to the POE, and the radio should reboot within 1 minute and reconnect within 5 minutes. This is the hard re-set procedure.

Base Station Installation Schematic



Base Station Installation Example

Client Station Installation Schematic



Client Station Installation Examples

Power over Ethernet (POE) Units

6Harmonics has qualified the following Power-over-Ethernet (PoE) midspan units to power the GWS radio units.

GWS Radio	POE Unit	Output Max	Data rate (Mbps)	Power	Notes
GWS5000 BTS	Ubiquiti POE-54-80W	54V, 1.5A	10/100/1000	80W	Use with cable runs >30m
GWS5000 CPE	Ubiquiti POE-54-80W	54V, 1.5A	10/100/1000	80W	Use with cable runs >30m
GWS5000 CPE	Ubiquiti POE-50-60W	50V, 1.2A	10/100/1000	60W	Use with cable runs <30m
GWS5000 BTS	Netonix POE switch configured to 48VH 1.5A	48V, 1.5A	10/100/1000	72W	Can be used to power non-GWS radios
GWS5000 BTS	Ubiquiti EdgePoint EP-R8 / EP-S16	54V, 1.4A	10/100/1000	75W	Can be used to power non-GWS radios

The PoE midspans are typically located indoors to remotely power GWS radios that are located outdoors. The GWS radios require 48-56V Passive POE++ 1/2, 4/5 (+); 3/6, 7/8 (-).

WARNING: Power is supplied over 4 pairs and as such it is critical to test any cables for continuity before testing. A data connectivity test is insufficient. A continuity tester that tests all pairs and the ground shield must be used.

In a base station install the length of Cat5e cable is typically much longer than in a CPE install. In this case the POE midspan must account for the additional power losses in the cable run. If other PoE midspan units than those listed above are used 6Harmonics reserves the right to refuse warranty support the GWS radio units. Please contact 6Harmonics before using any other POE midspan[10].

Warning: Follow the connection procedure in the Network Configuration of GWS5000 Radios when connecting the GWS-radio unit, the PoE midspan and AC power. Do not hot swap the RJ45 connectors on the POE midspan. To power down the radio remove the power cord to the midspan. To power-up the radio check the midspan is not powered i.e. power cord removed, connect the midspan to the radio and then power-up the midspan.

[10] FCC allows the use of other power supplies to FCC certified radios as a Class 1 Permissive Change (no filing required) under the permissive change policy (https://apps.fcc.gov/oetcf/kdb/forms/FTSSearchResultPage.cfm?id=33013&switch=P) so long (i) as they are electrically equivalent and (ii) there is no degradation in emissions.

Network Configuration of GWS5000 Radios

Preparation

Hardware

Use a Windows (version 7 or later preferred) or Linux PC, configure the ethernet adapter to be on the same subnet as the default IP configuration of the GWS radios.
Default IP address for base station (CAR) and client station (EAR) is the same:

IP address	192.168.1.1
Network mask	255.255.255.0
Gateway	192.168.1.1
DNS	8.8.8.8

WARNING: The DNS setting default is 8.8.8.8[11] which is a public DNS. For most deployments the default public DNS will be fine. However, if the GWS radios are behind firewalls or other internet security solutions the network may need a private DNS that must be used in order for the GWS radio to access the internet. If the GWS radio cannot make a successful DNS query it will not be able to access the internet and, in the case of networks that require a successful database query before the radio can turn on, the GWS radio will NOT operate.

The ability to set a private DNS is provided to ensure the radios can always access the database.

NOTE: a base station and a client station are not required to have the same DNS, both radios must simply have a *valid* DNS.

[11] An alternative public DNS to 8.8.8.8 is 8.8.4.4

Software

OS: Windows 7 or later

Mac: OSx v10.10 or later

Web browser: Chrome Web Browser Version 52.0 or later

WARNING: Only Chrome is fully verified, some browsers such as Mozilla will NOT work.

TIP: If Chrome is slow to load, clear the cache.

Other

- Network with Internet access
- Ethernet cables that have been tested for continuity.

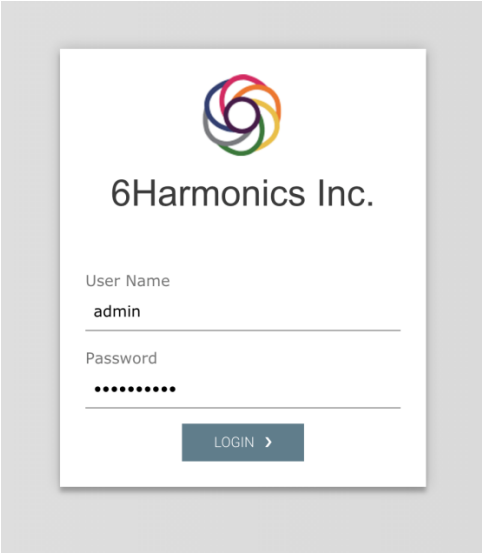
Configuring the GWS Radios

GWS Radio GUI Login

To access the configuration utility, open the Chrome web-browser and enter the default IP address 192.168.1.1

If user is shown a warning that web certification or private network is not safe, please proceed to the web page until login page appears.

In the login page, use the default “admin” as username and “6harmonics” as password to login.



If username and password are correct, the Monitor page will appear and the status of the GWS radio will be displayed.

Network Configuration Parameters

To allow database access, the GWS radio must have internet access.

User must ensure that network parameters such as IP, network mask and gateway are correct.

The user must also ensure that firewalls or other network security features do not inhibit network access for the radio.

Below is an example for network configuration.

Assume we intend to assign network parameters to the base station which can access the internet:

IP address	192.168.0.22
Network mask	255.255.255.0
Gateway	192.168.0.1
DNS	8.8.8.8

The IP address of client station must be within the same subnet of the base station:

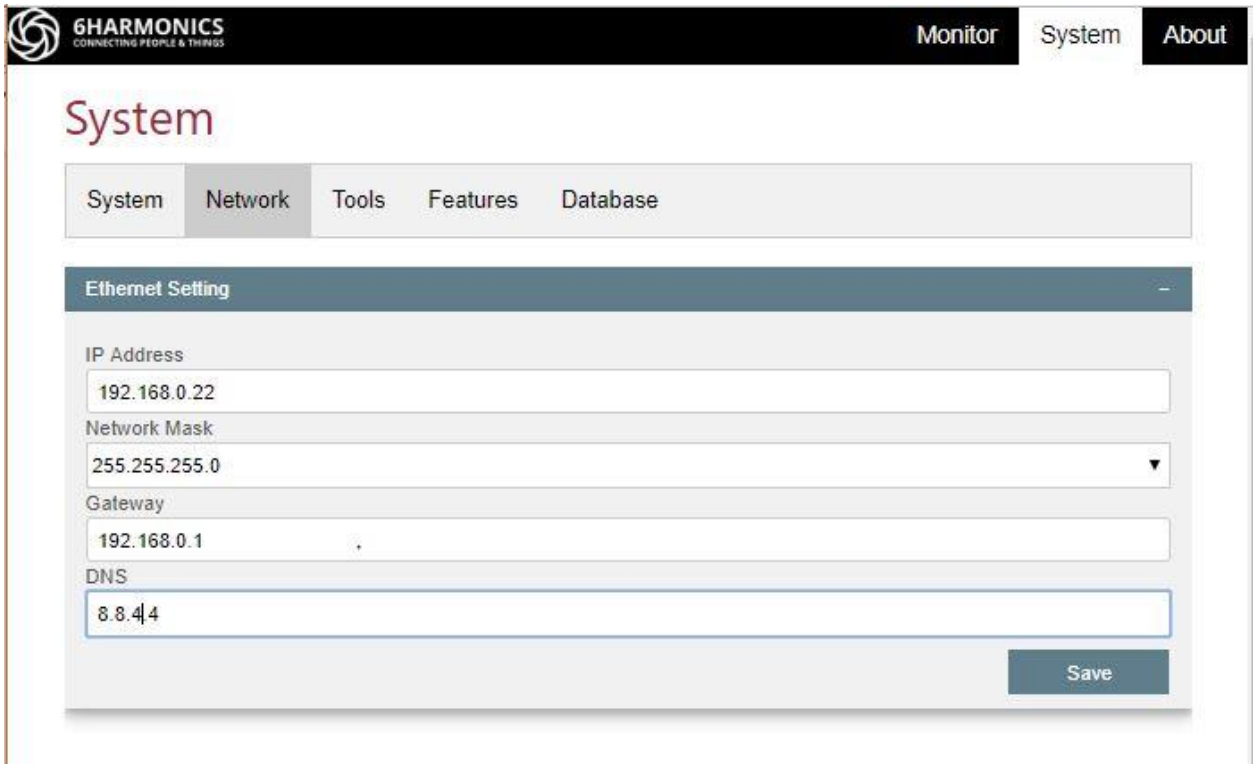
For example:

IP address	192.168.0.100
Network mask	255.255.255.0
Gateway	192.168.0.1
DNS	8.8.8.8

Setting Network Configuration Parameters

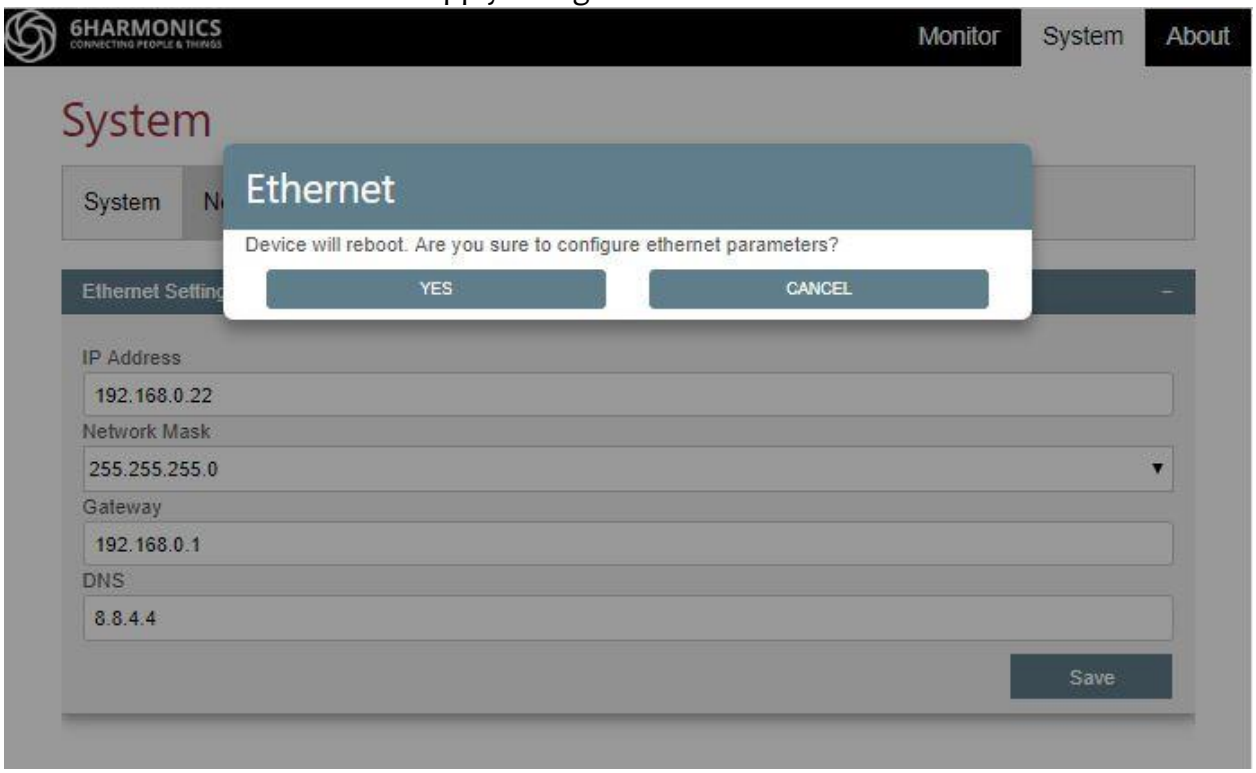
In the Monitor page, click **"System"** tab to access the "**System"** page.

Click "**Network"** tab.



Input the required network parameters and click "**Save**" button to apply the settings.

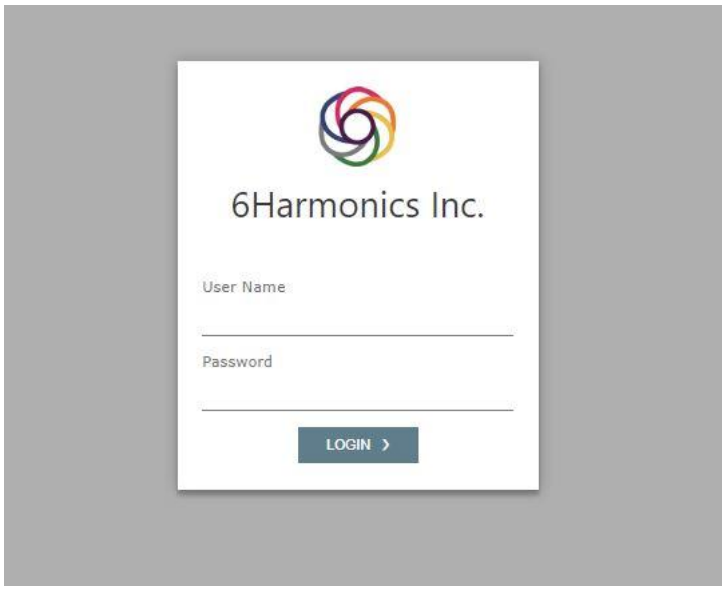
Confirm "**Yes**" to reboot device and apply changes.



The Chrome browser will automatically return to the login page after reboot. Make sure your PC is on the same subnet as the GWS radio.

WARNING: The GWS radios have a Roll-back Feature which ensures that the IP configuration cannot be erroneously entered. Unless the user successfully logs back into the GWS radio within 10minutes of changing the IP configuration the GWS radio will roll-back to the previous IP configuration.

Login and confirm the new IP setting to confirm the successful implementation of a new IP configuration.



Using the Djinni Tool to Configure the GWS Radios

What is the purpose of this tool?

Frequently installers may have difficulty finding the IP address of the radio, and as a consequence they are unable to login to the radio. This is particularly frustrating at a CPE install which ends up taking much longer than it should.

When a GWS radio, either a BTS or a CPE, is powered up ***Djinni program*** will run on the radio for 10 minutes. The ***Djinni tool*** should be used within 10 minutes of power up or the radio must be power cycled by powering down the POE midspan. Do not power cycle the GWS radio by hot-swapping the Cate5e cable / RJ45 connector to the radio.

Installation

The computer used must have a standard RJ45 ethernet port and preferably NOT a firewire or USB to ethernet emulator/adapter.

WARNING: some USB-Ethernet emulators do not work.

For the Djinni tool to work you must install WinPCap first.

https://www.winpcap.org/install/default.htm

Computer should be Windows 7 to 10 and support the WinPcap version used.

Please note that the later versions of Windows may take longer to authenticate an ethernet port on a network so be aware of this.

Enabling a WiFi connection allows for simultaneous access to the internet as well as the GWS radio.

Preparation

Set the Ethernet port to DHCP or to a known fixed IP configuration.

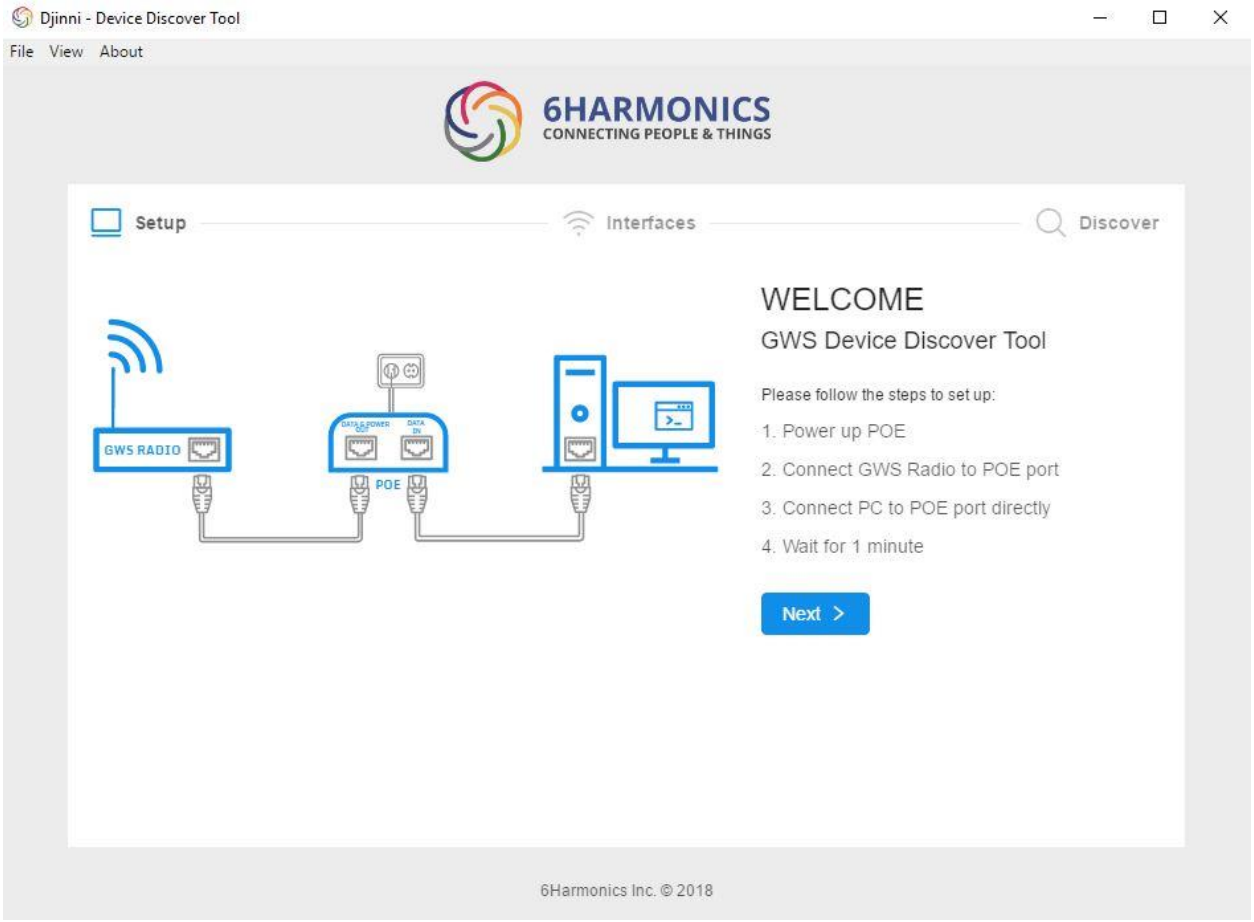
Disable then Enable the ethernet adapter to ensure it is on the correct IP domain.

Connect the computer to the data port of POE midpsan that is powering the radio.

Check the POE lights are on = radio is powered up. If the radio has been powered up for more than 10 minutes the tool will not work. Generally, it is best to first power cycle the radio by removing-inserting the AC power cable[12] to ensure you have 10 minutes of Djinni time.

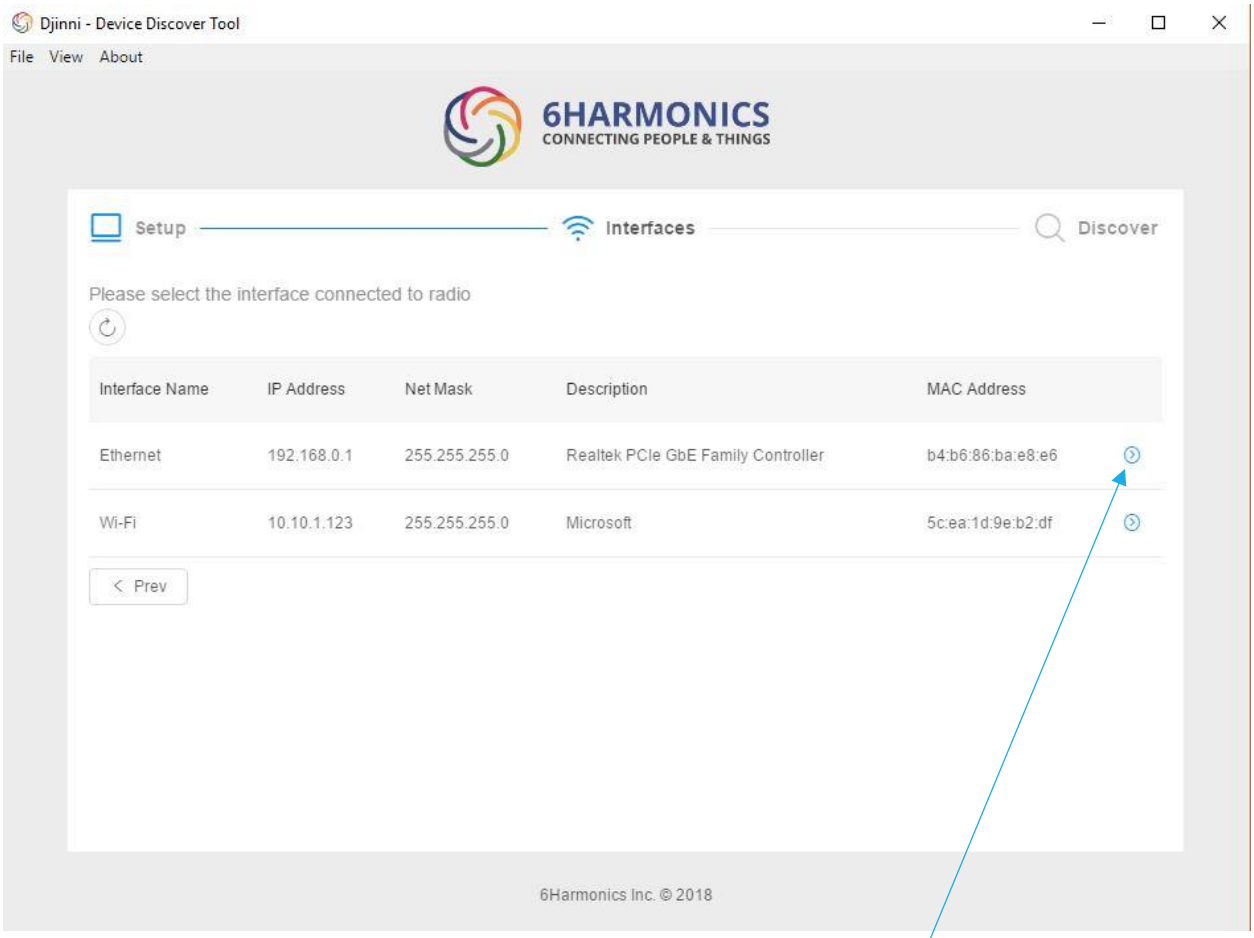
Using the Djinni Tool

Run the Djinni tool.



Click on Next

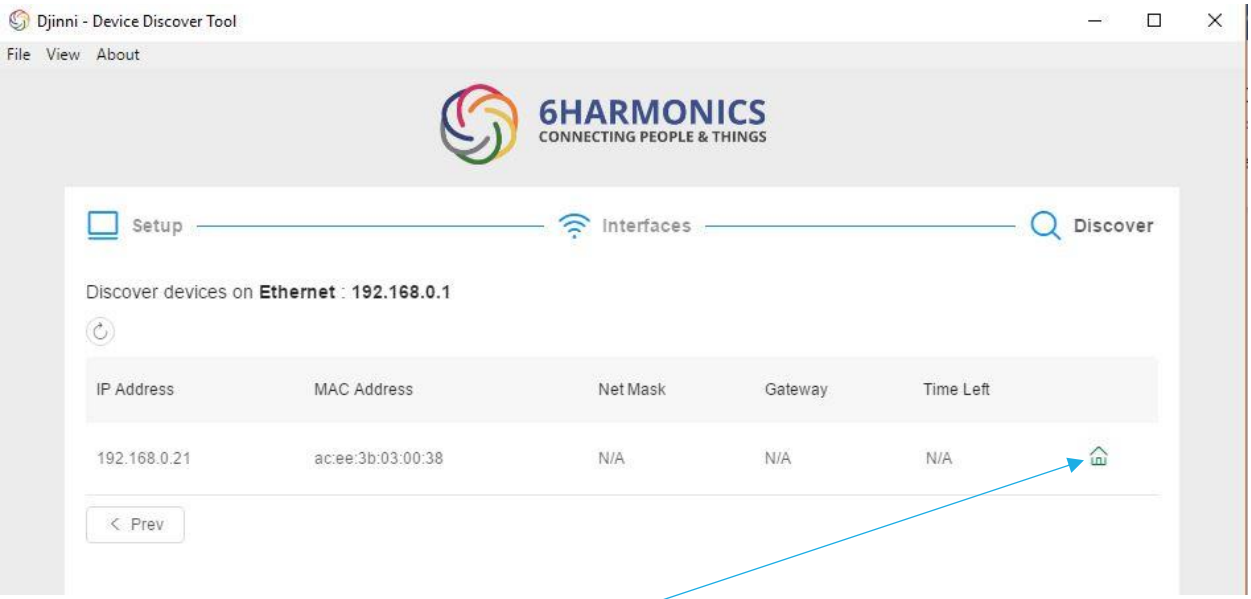
[12] Do not power cycle by hot swapping the RJ45 to the radio.



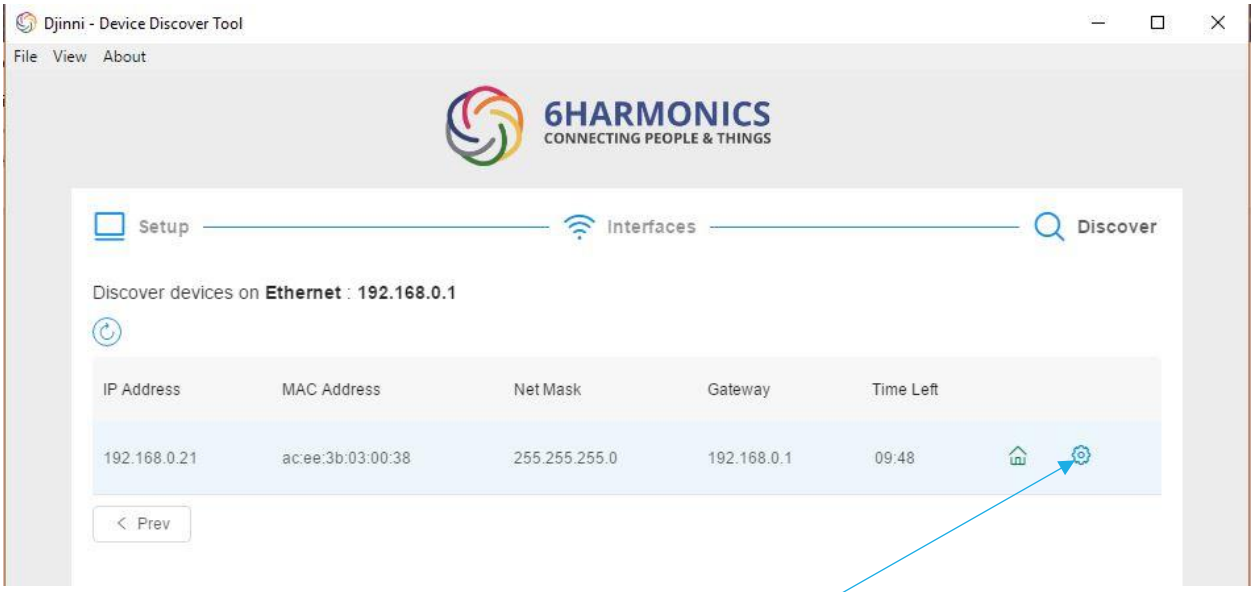
The IP address is the IP address of the ethernet adapter on the PC. The MAC address of the ethernet adapter of the PC is also displayed. If the ethernet adapter is set to DHCP then you may have to change the IP network configuration of the PC after the GWS radio is configured so that both the PC and the GWS radio are on the same subnet.

Choose the adapter (ethernet) by clicking on the blue arrow.

The radio IP will be displayed. In the case displayed below the Djinni time on the radio has expired.



If the laptop and the radio are on the same subnet (as above) you can click on the GUI icon and it will open the radio GUI. (GUI icon only appears if on same subnet as PC).

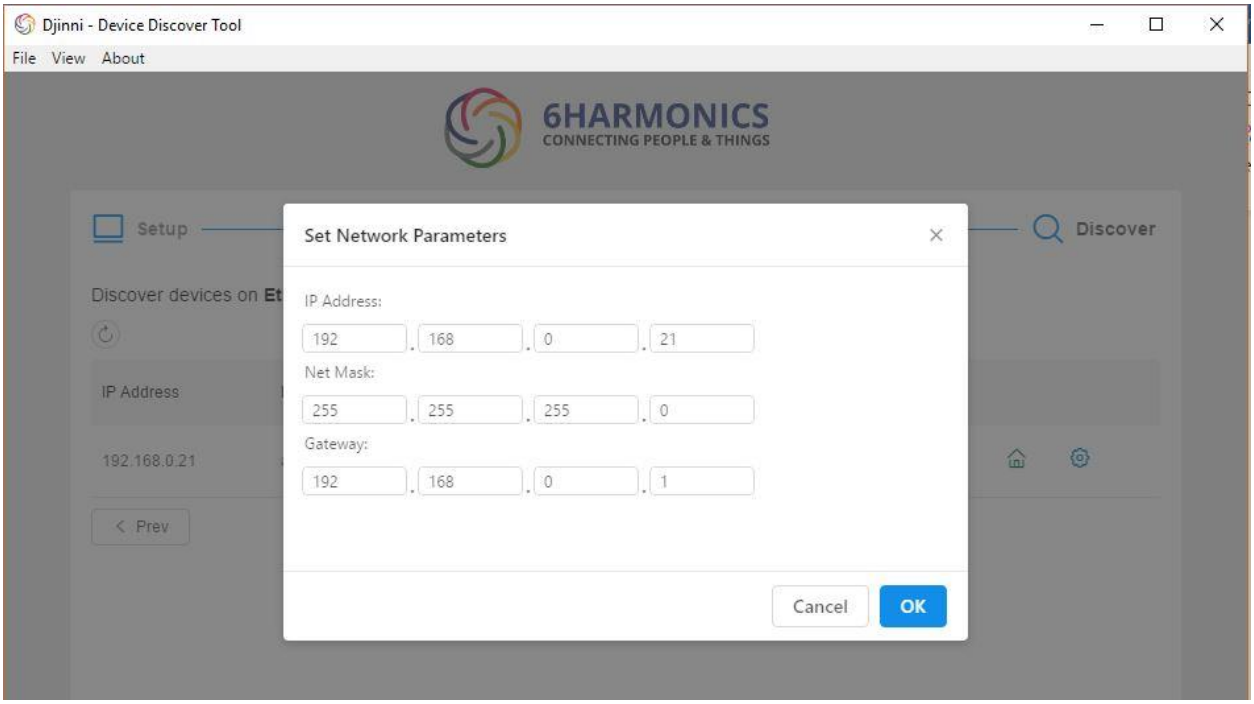


If the laptop is not on the same subnet you must reboot the GWS radio.

Repeat and the configuration icon should appear.

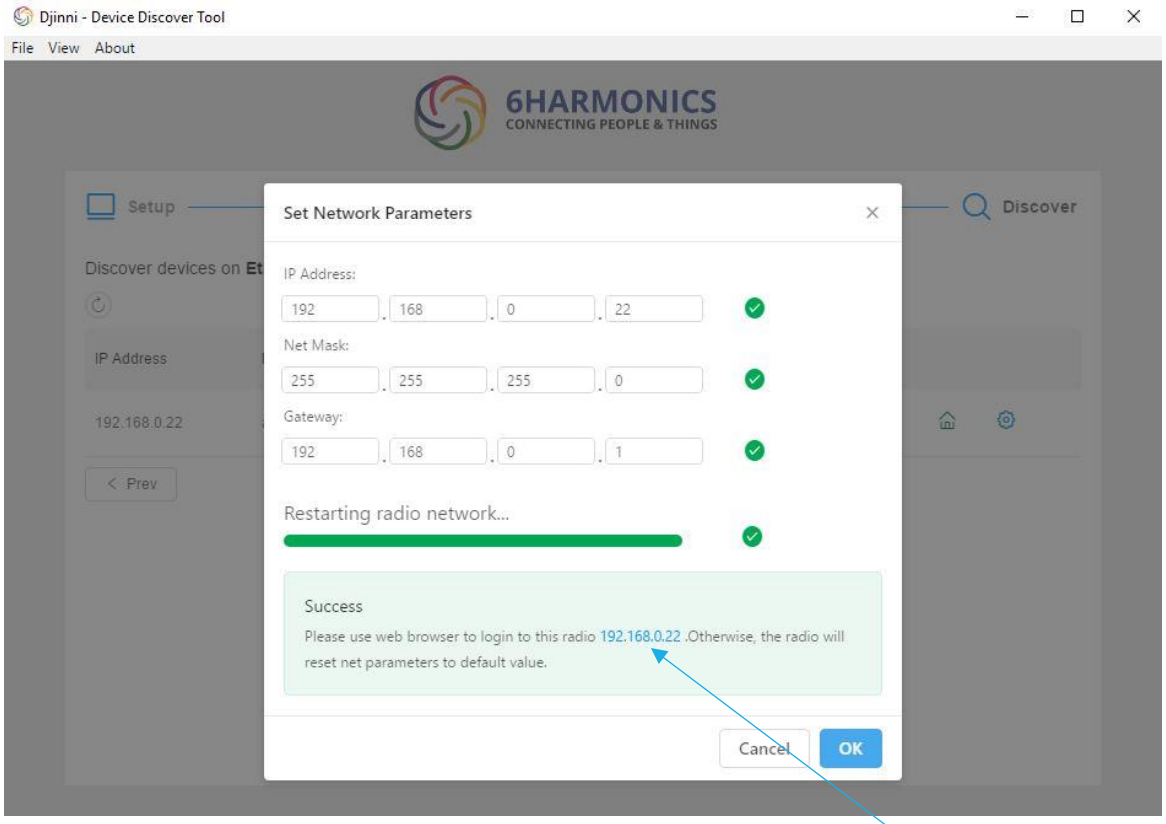
Note “Time left” refers to the amount of time that remains for the Djinni tool to run on the GWS radio. Even if the laptop and the GWS radio are on completely separate subnets you will still be able to login into the GWS radio. Click the configuration icon.

The window below appears:



Set the IP address, the network mask and gateway to the required values.

Please note that you know from the earlier Djinni pages what the configuration settings of the ethernet adapter are. Therefore, you have confirmed both the GWS radio and PC will be on the same subnet. Click on OK.



The radio will restart and overwrite the Network Parameters.

In this example the IP address has been changed from 192.168.0.20 to 192.168.0.22

Roll-back Feature

IMPORTANT: Once you save the IP configuration YOU MUST RELOG BACK INTO THE RADIO TO CONFIRM THE IP CONFIGURATION WILL BECOME PERMANENT.

If you simply save the IP configuration and the CPE makes a link to the BTS, then data will flow giving the impression all the IP settings are good. But after 10minutes the roll-back feature will become enabled. In this case the IP configuration will roll-back to whatever it was previously-and the data connection to the internet will be lost.

This roll-back feature is to ensure that in the event of a change in IP address and a mistake being made, a user will still be able to access the radio if the Djinni tool is not available.

For example, if you are setting the IP configuration from the default to a specific setting but a typo error is made the radio will roll back to the default and you can login.

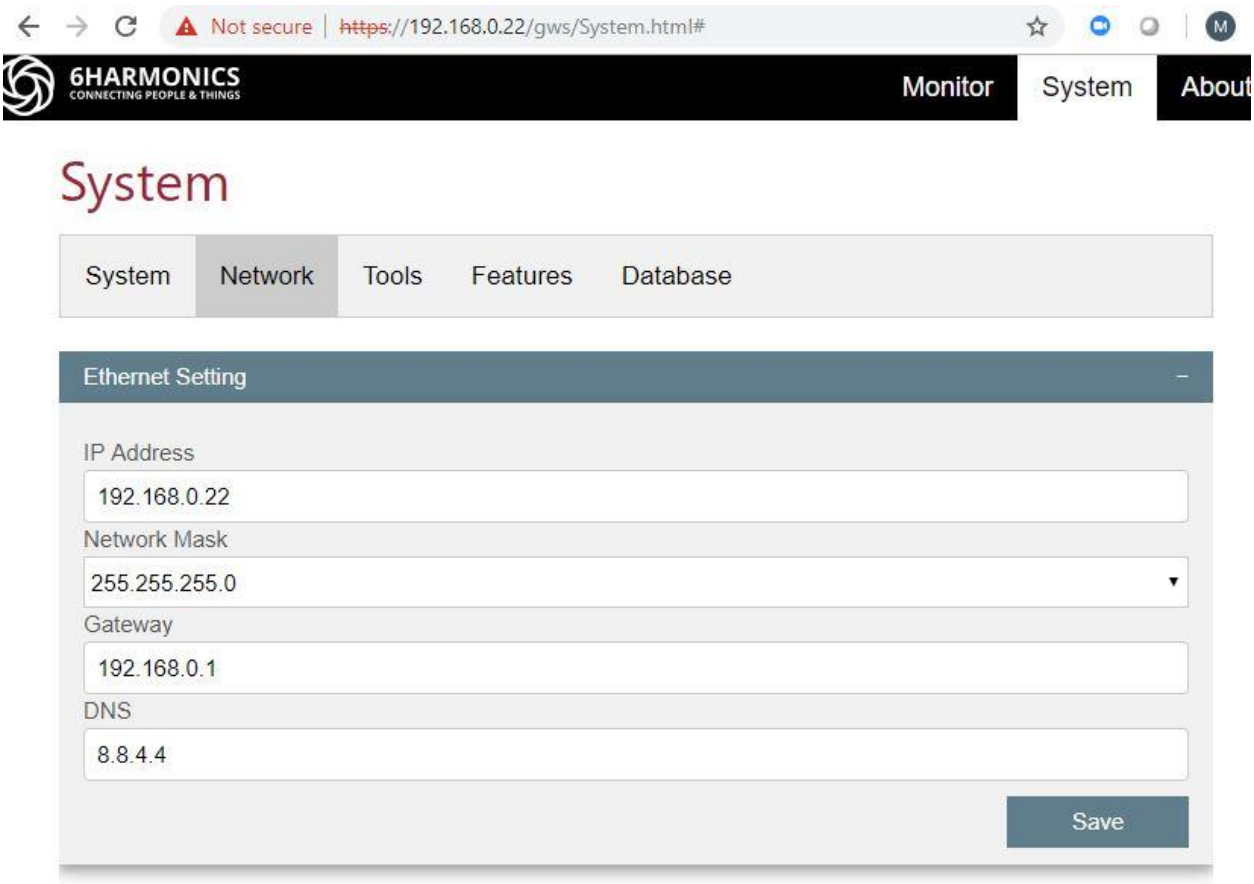
If users do not have access to a Windows based PC the GUI method must be used rather than the Djinni method. In this case the roll-back feature is essential in case of an input error.

Login to the radio as normal and check the IP configuration on both the Monitor Tab and the Network Tab.

Monitor Tab, note the IP address.

	Status
Radio Type / MAC	GWS5002 / AC:EE:3B:03:00:38
Connected Stations	No station connected
IP / SSID	192.168.0.22 / gws20185002

Network Tab, validate the mask, gateway and DNS are correct.



This completes using the Djinni Tool to set the Network Parameters of the GWS radios.

Setting up a Radio Link

All GWS radio units share the same GWS host software. It is essential to ensure that all GWS radios are correctly configured for the deployment scenario.

Establishing a Wireless Link between Two GWS Radios

For the purposes of this section we assume that the GWS radio is in manual mode and a database is not used to determine the allowable operational channels.

From the proceeding section we have successfully set the IP configuration of the radios.

As the radios establish Layer 2 connections over the wireless link it is possible to have the GWS radios on a separate VLAN for management from the service VLAN.

Typically, the service VLAN will have a DHCP server on network edge router behind the base station to provide IP addresses to the residential routers.

The edge router port will therefore typically support:

- A management VLAN with static (fixed) IP configurations for the GWS radios
- A service VLAN with DHCP for the residential routers that provide internet connectivity on the client side.

The residential routers will be configured with DHCP of non-routing IP addresses as normal.

Therefore, the IP configuration of the GWS radios is for two reasons only:

- Management
- Internet access to obtain channel availability from a database.

Bench Testing

If the user wishes to become familiar with the operation of the GWS radios prior to a full installation, then a simple bench test set up is as follows:

Cable Test:

1) Connect the antenna ports of the client station and the base station radio using LMR cables. At least 60dB of isolation should be inserted in the link to simulate the losses of an over the air link.
2) Do not connect power to the POE midspans.
3) Connect each radio to the POE midspans using pre-tested Cat5e cables. Insertion of ethernet surge suppressors are strongly recommended.

4) Connect a PC or laptop to the data port of each midspan using pre-tested Cat5e cables.
5) Power up each midspan by inserting the AC power cord into the POE midspan.

WARNING: Do not hot swap the Cat5e cables between the radio and the POE midspan. The radios use 4 pair POE++ and can be damaged.

6) Login and configure the radios as explained previously. Follow the steps in the following section to establish a radio link. If the radios require database operation use the internet connection sharing method to get access to the database.

If the radio is GPS enabled, it must be placed near a window so as to access GPS satellite signals.

Over the Air Test:

The GWS radio should be connected to an antenna with 50 Ohm impedance.

Ensure there is sufficient space between the two radio antennas so that the receive chains of the GWS radios cannot saturate. Placing the client station radio and the base station radio in adjacent rooms can work well. Do not use high gain antennas that are in close proximity to each other and simultaneously pointing directly at each other.

Over the air bench set up example using a low gain omni antenna.

Follow the same steps as the Cable Test.

6Harmonics recommends either cable or over the air benchtop testing as practice prior to field install and set-up.

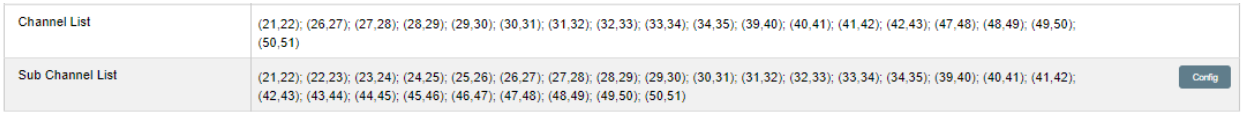
GWS Radio RF Parameters to Establish Radio Link: Base Station

We assume that a base station has been carefully installed and that the PC and GWS radio IP addresses are set to a predetermined configuration, then we need to set:

(a) the channel number (we assume a dual channel bandwidth of 12MHz)
(b) the transmit (T_X) power
(c) the receive gain

Settings chosen should be consistent with the modelling that was performed previously.

On the base station System tab, check the channel list:



The sub channel list is the list the radio can physically operate at. If you access the list using the Config button, the list can be edited by clicking each channel to remove certain channels.

In this case, the channel list has been manually edited to eliminate 18,19; 19,20 & 20,21 as available options in the channel list. If the channel list is edited in this manner the channels will not appear in the pull-down menu in the Radio Status section of the Monitor tab.

Why would you do this?

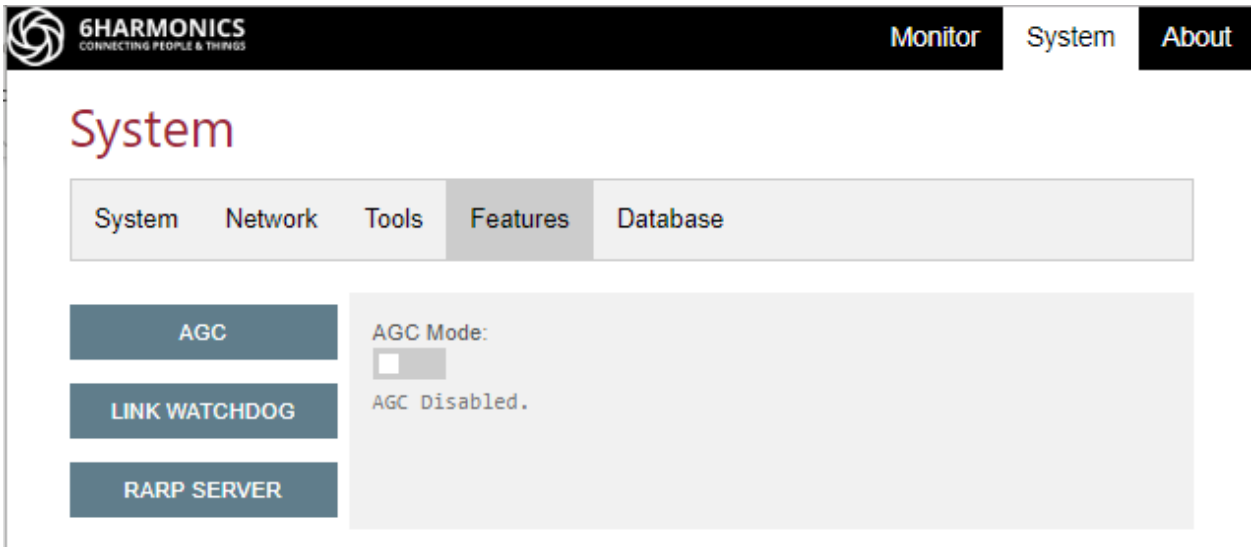
(a) To stop this particular base station roaming onto a particular channel in the event of the database making the preferred channel unavailable.
(b) To stop this base station operating on a channel that is known to suffer high levels of noise or interference.

Having checked that the appropriate channel list is available we now set the channel on the Monitor tab.

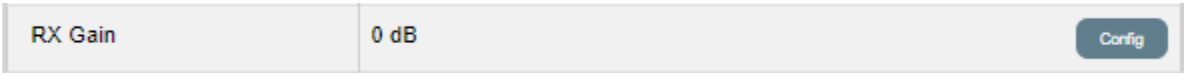
However, before we choose an available channel, we need to check the channel quality.

Go to the Features sub-tab from the System tab.

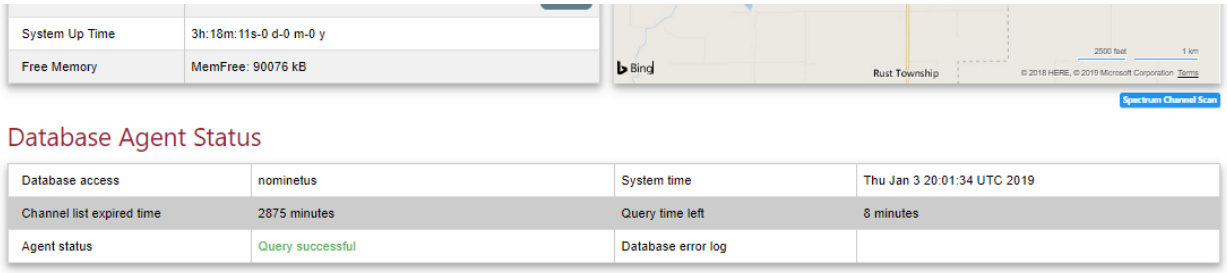
Disable AGC.



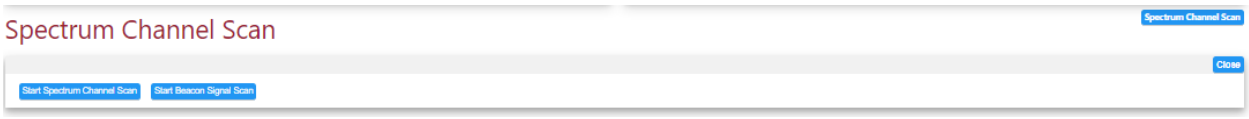
On the Radio Status section of the monitor tab, use the Config button to set the Rx gain to zero and Save. The RX Gain should display zero as below.



Click on the Spectrum Channel Scan button on the Monitor tab:



The Spectrum Channel Scan window appears:

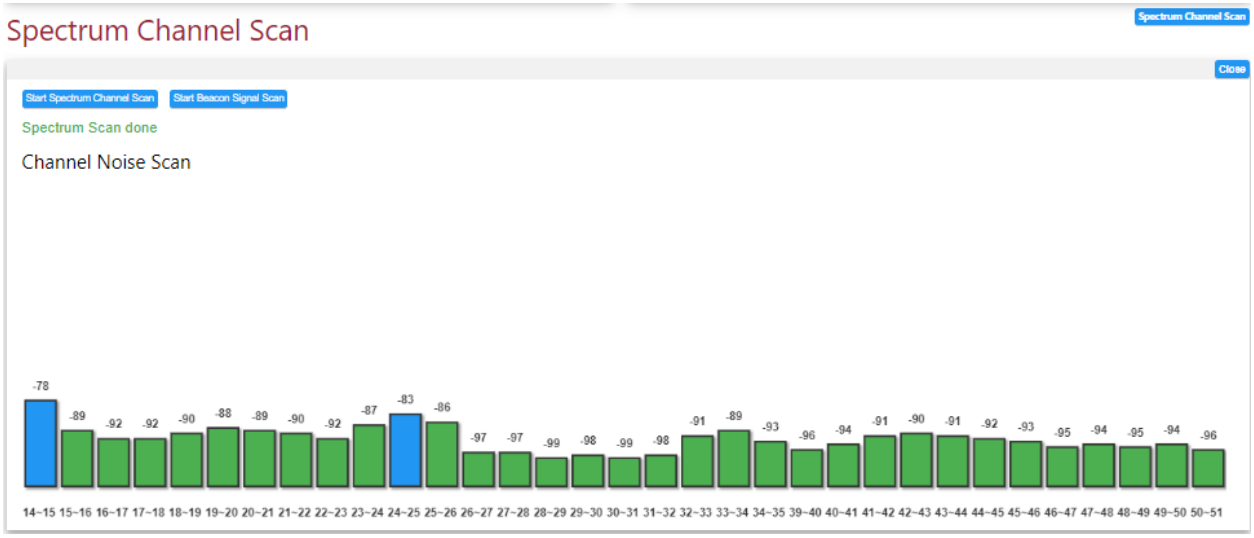


Click on the Start Spectrum Channel Scan.

The radio will then check the noise in all channels, even though the database or the sub-channel list may not allow use of some channels.

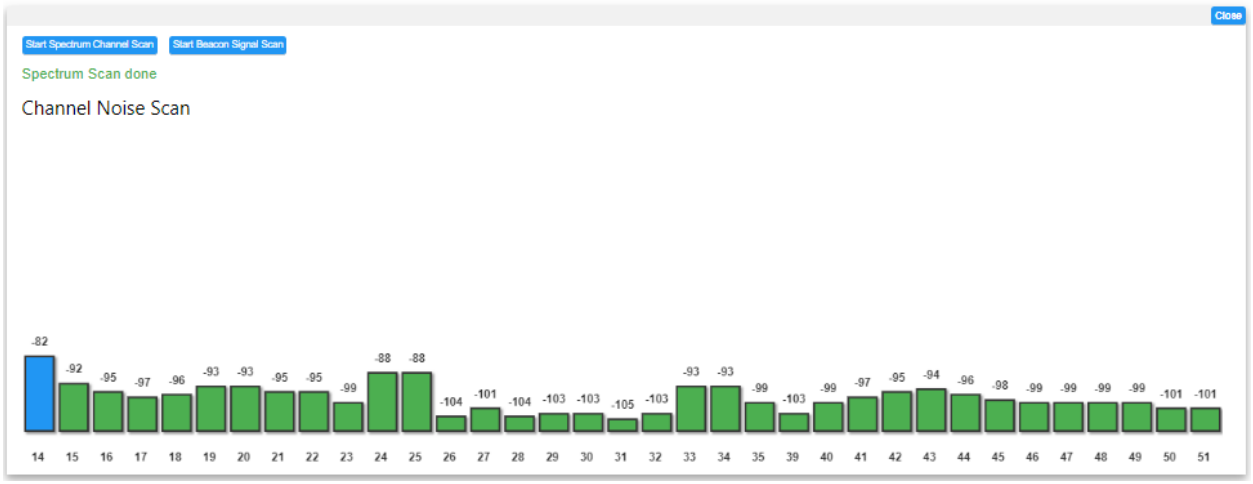
A very clean scan example (12MHz channel width):

A scan with some other signals (12MHz channel width):



The scan suggests TV signals on channels 14 and 24, maybe 23 or 25, that impact the noise floor in 14,15 and 24,25. Because TV signals are very strong, and their emissions mask is not perfect we also see bleed in to 15,16 as well as 23,24 & 25,26.

We can check this further by reducing the channel bandwidth to 6MHz and repeating the scan.

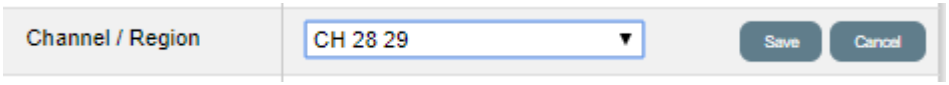


Now we can see the TV signals on 14, 24 and 25. Maybe 33 and 34 also.

TIP: Always save these scans for a base station and a client station at time of install. If noise or interference arises at a later date it will be obvious if any changes in RF environment have impaired the link. Secondly, the TV signal acts as a marker to show the antenna and associate receive circuitry of the radio are fully functional. If, for example, water gets into one of the RF connectors because of poor waterproof taping, you will see a loss of receive signal strength of the TV channel transmission[13]. TV channel transmissions tend to be very stable[14] and so can be used as receive signal markers.

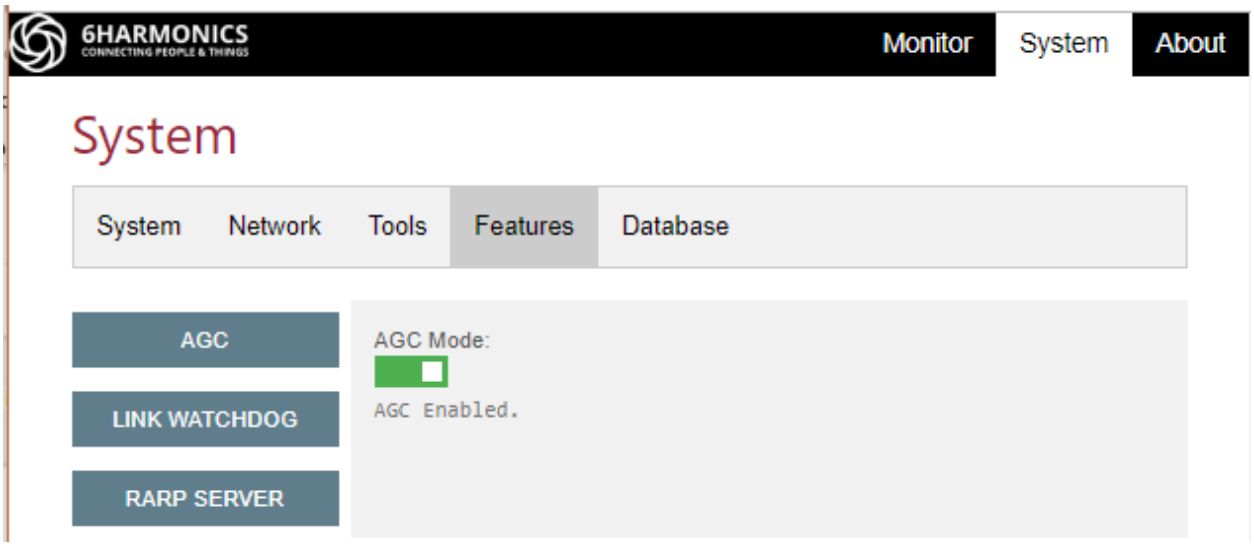
Based on these scans channel 28,29 looks a good choice for 12MHz transmission bandwidth.

We set the channel to 28,29 and click on Save.



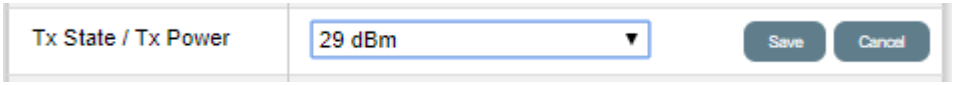
[13] If, for example, there is water in the RF chain of a base station, the values of the TV signals markers on the channel scan at the base station will diminish. The RSSI at the client station will also diminish. But the TV signal markers at the client station will not change. This procedure allows identification of which end of the link has a problem in the RF chain-but this is only feasible if a baseline status of the RX signals is recorded at install.
[14] This assumes direct propagation as opposed to tropospheric propagation which can vary widely during the day or with weather conditions.

We re-enable the AGC on the Features sub-tab of the System tab.

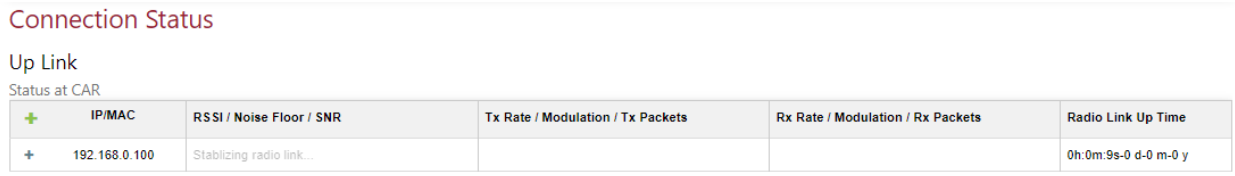


Radio Status section on the Monitor tab will now show Rx Gain setting as Auto.

We set the transmit conducted power to a high value, say 29dBm (assuming the database allows this conducted power / EIRP value). Click on Save.

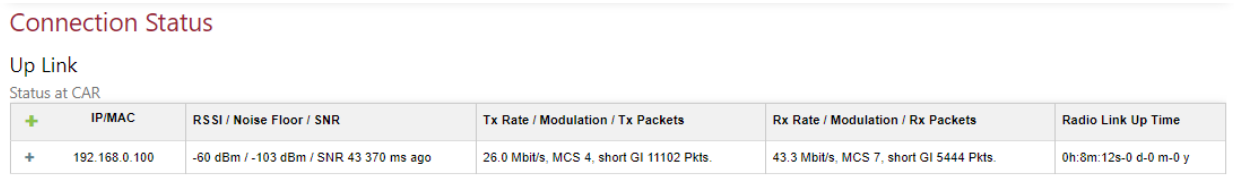


If the client station scans onto this 12MHz transmission, the link will appear as below:



The status will display “stabilizing radio link” for approximately 2 minutes. This is because the channel state algorithm has to run for a sufficient period of time so that the data displayed is valid. Any data displayed immediately after connection is erroneous.

After two minutes we see:



Connection Status

Up Link

Status at CAR

+	IP/MAC	RSSI / Noise Floor / SNR	Tx Rate / Modulation / Tx Packets	Rx Rate / Modulation / Rx Packets	Radio Link Up Time
+	192.168.0.100	-60 dBm / -103 dBm / SNR 43 370 ms ago	26.0 Mbit/s, MCS 4, short GI 11102 Pkts.	43.3 Mbit/s, MCS 7, short GI 5444 Pkts.	0h:8m:12s-0 d-0 m-0 y

This says we have:

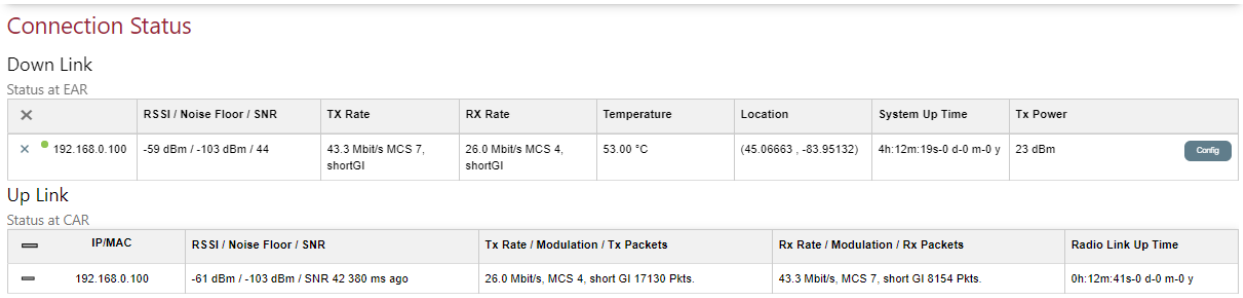
-61dBm receive signal strength, -103dBm noise; SNR 43 dB

In downlink (the base station transmission) MCS 4

In uplink (the base station receive) MCS 7

The link has been connected for 8 minutes and 12 seconds

If we click on the green cross we can also see the data at the client station displayed on the base station Monitor tab:



Connection Status

Down Link

Status at EAR

×	RSSI / Noise Floor / SNR	TX Rate	RX Rate	Temperature	Location	System Up Time	Tx Power
× 192.168.0.100	-59 dBm / -103 dBm / 44	43.3 Mbit/s MCS 7, shortGI	26.0 Mbit/s MCS 4, shortGI	53.00 °C	(45.06663 , -83.95132)	4h:12m:19s-0 d-0 m-0 y	23 dBm Config

Up Link

Status at CAR

—	IP/MAC	RSSI / Noise Floor / SNR	Tx Rate / Modulation / Tx Packets	Rx Rate / Modulation / Rx Packets	Radio Link Up Time
—	192.168.0.100	-61 dBm / -103 dBm / SNR 42 380 ms ago	26.0 Mbit/s, MCS 4, short GI 17130 Pkts.	43.3 Mbit/s, MCS 7, short GI 8154 Pkts.	0h:12m:41s-0 d-0 m-0 y

For further details on the display see Connection Status section of the Monitor tab

GWS Radio RF Parameters to Establish Radio Link: Client Station

We have now manually configured GWS radios base station channel, transmit power and receive gain.

In this test set up we can see the link has been successfully established.

However, in a real deployment the base station will be pre-configured based on:

- Channel availability
- Channel quality
- Simulations to determine the required coverage/range

The simulations will include the antenna gain of both the base station and the client station and the antenna height above ground level (AGL).

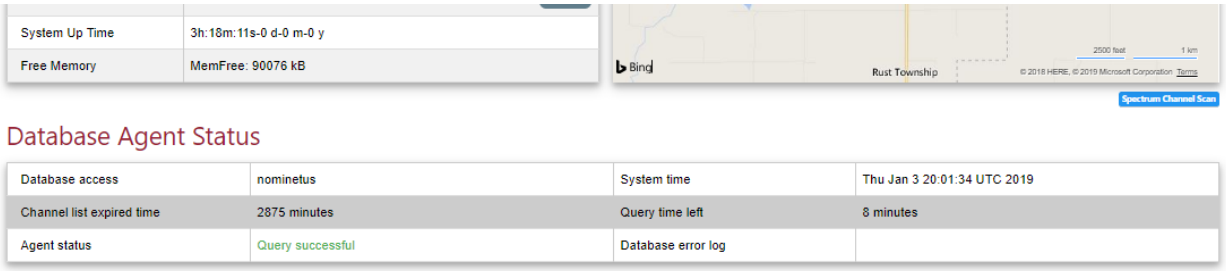
Assuming the simulation shows that sufficient signal can be obtained at a prospective client location a truck roll is initiated, and the client station radio and antenna installation will be performed.

The following procedure explains how to connect to the base station when logged into a client station.

Login to the GWS radio and configure the IP as described previously.

Base station towers typically have multiple base station radios on a sector type architecture. As the client station radio has a scan function, we need to pick the correct base station by looking for the beacon signal from the preferred base station.

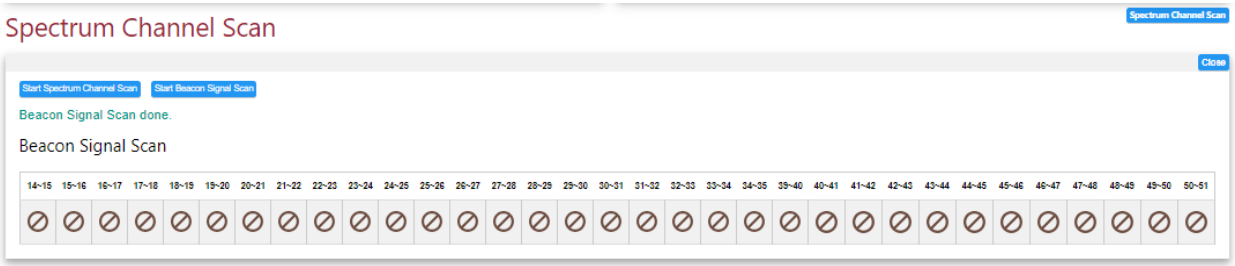
Click on the Spectrum Channel Scan button on the Monitor tab:



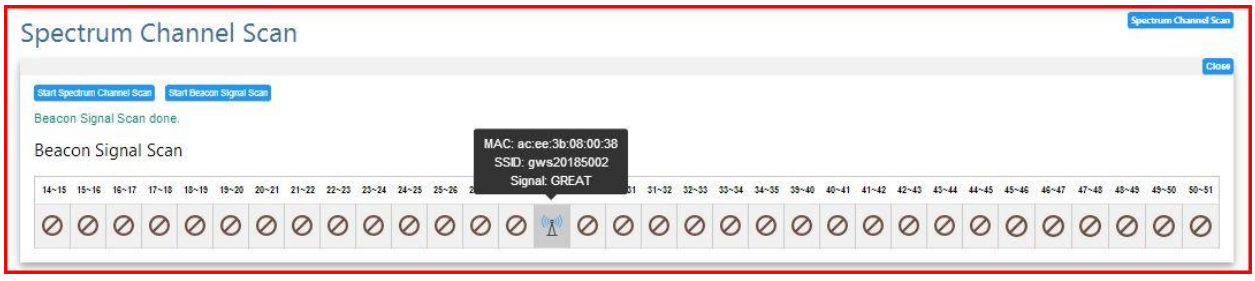
The Spectrum Channel Scan window appears:

Click on the Start Beacon Signal Scan.

Below, a scan with no visible beacon:



Below, scan with a beacon on Ch 28,29:

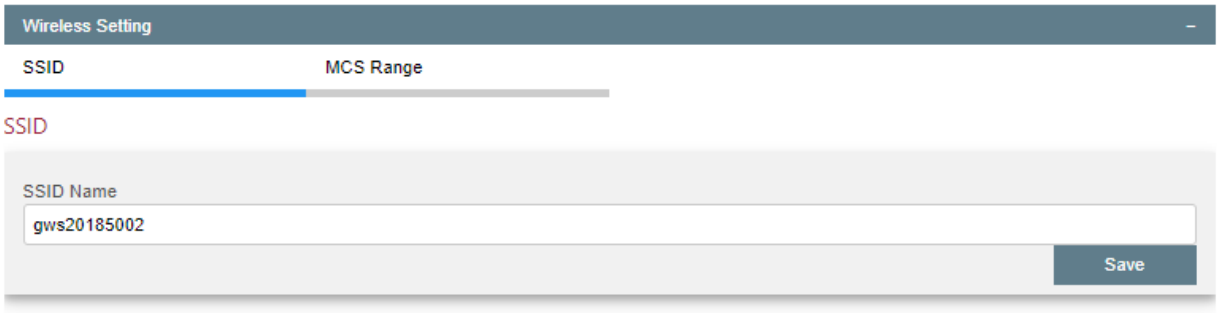


The client station radio beacon scan will show all the beacons it can see, displaying the relative signal strength, the MAC address and the SSID of each base station.

Place the cursor on the signal strength icon to display the MAC address, the SSID and the signal strength from the base station on given channel.

Once you have determined which base station you want to connect to, set the SSID on the Network sub-tab of the System tab.

Click on Wireless Setting to display the wireless settings window.



Enter the SSID of the base station you wish to connect to and click on Save.

Return to the Radio Status section of the Monitor tab and set the channel as displayed from the beacon scan. If you do not set the channel the client radio will automatically begin to scan and will connect to the base station once the channels/SSID are the same.

The client station radio should connect and will undergo the 2minute stabilization before the radio link parameters are displayed.

Repeat, if necessary, for alternative base stations.

The operator can then evaluate which base station this specific client station radio should connect to on the basis of optimal link performance.

WARNING: When a client station scans and connects to the base station the SSID and other network credentials must be validated before the connection will stabilize. This takes approximately one second. If a client station scans onto a base station and connects very briefly(~1second) this indicates a network authentication issue where the client radio isn't allowed to connect to the base station. Check the SSID settings on both the base station and the client station. Check IP configuration for the base station and the client station to see that they are on the same subnet.

Radio Link Performance Optimization

After the link is established if the information from the monitor window shows that the performance is not as expected by the simulation then we may need to tune the link to ensure good performance.

Causes of link asymmetry may include:

- Transmit power settings
- Receive gain settings
- Noise at the client station
- Noise at the base station
- Asymmetric antenna gain

Reduction in MCS can be caused by:

- Interference even though the SNR value appears good. In this case the MCS value will lower than expected as per the table of expected throughput performance.
- The transmit power is too strong, the signal may get saturated and the link will show poor throughput performance.
- If the link signal is too weak, for example if the RSSI is below -80dBm, then the T_X power should be increased until the RSSI is above -80dBm.

A RSSI of -50dBm to -80dBm and an SNR>25 are considered optimal.

Wider channels will, of course, have higher noise floor, and also the probability increases of picking up an interfering signal.

As explained previously if the link is not reciprocal i.e. where one receive RSSI is too high, and the other receive RSSI is too weak, then the T_X power at both GWS radios may need to be adjusted to balance both RSSIs to get a good overall performance in both uplink and downlink. In some cases an assymmetry of 6dB or two MCS levels is acceptable. However, it depends upon the relative uplink/downlink traffic patterns and the aggregate load of the base station.

Scan Function

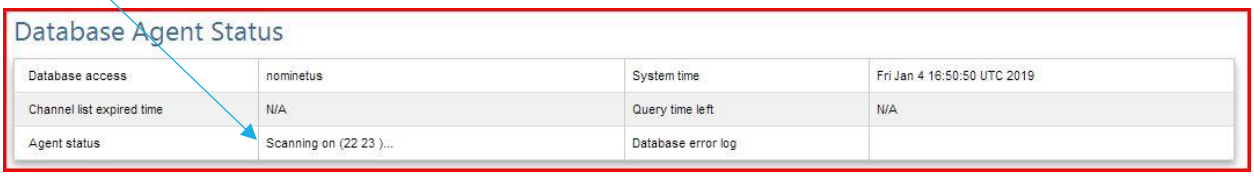
As mentioned previously, the GWS client radios have an automatic scan function.

On start up the client radio will automatically try the last valid configuration to estblish a link and if no link established, the CPE will go into scan mode and look for a base station to connect to.

The Radio Status display is as follows:

The user will see the channel number change every few seconds.

If the radio uses a database, the user will also see that the channel scan function is operational in the Agent Status part of the Database Agent Status section on the Monitor tab.



TIP: If the radio link is broken for more than 5 minutes, for example due to a power outage at the base station location, the client station will automatically go into scan mode.

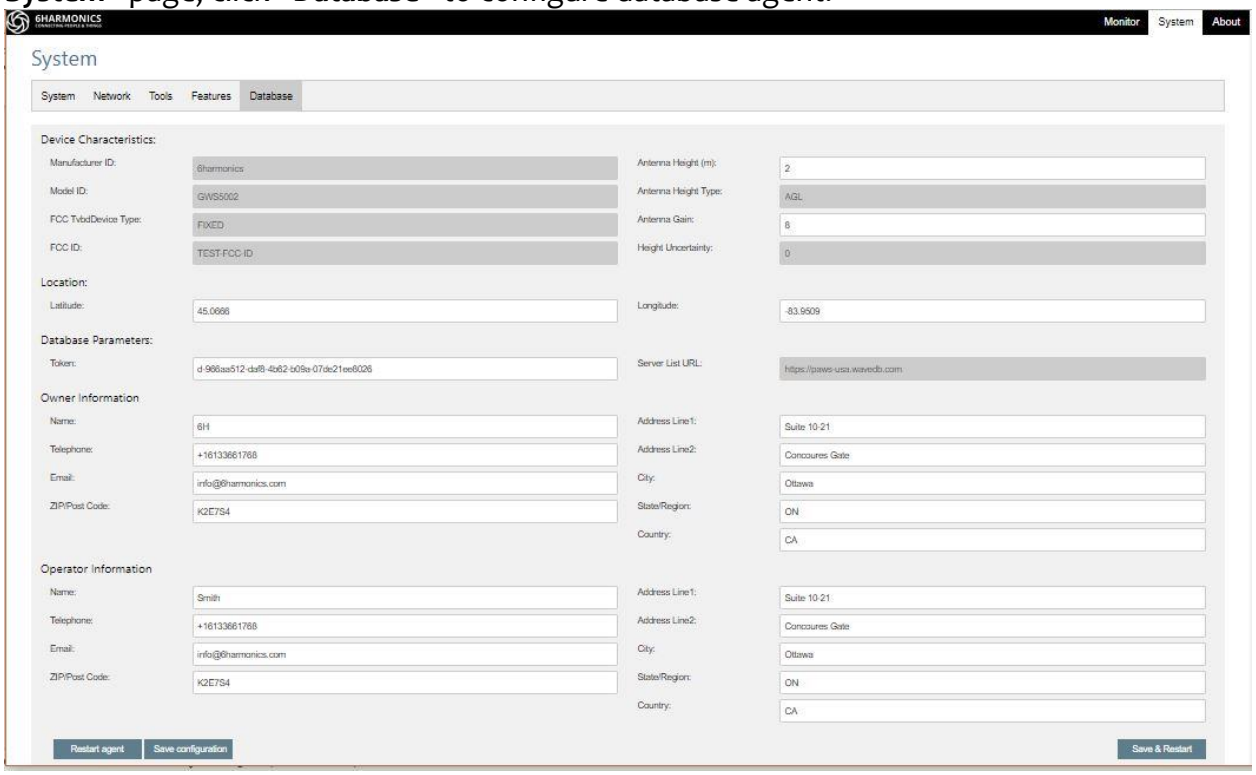
The client radio will continue to scan channels until it finds a base station with the same SSID and a sufficient signal strength provide enough data throughput to undergo a database query.

If there is more than one base station with the same SSID within range of the client station, then a client could possibly roam onto a different base station than the original connection. This arrangement can be used as a back up in case a base station fails. Conversely, in the event of a power outage or power cycle at the client station this may result in too many clients attaching to a single base station and will create a load balancing issue.

NOTE: In the event of a power outage the client radio will reboot to the last operational configuration, it will attempt to re-connect to a base station using the same SSID and channel prior to power down. If the attempt to connect to the base station using the last good configuration fails it will go into scan mode only after 5 minutes. This feature minimises the probability a client radio will connect to the wrong base station, even if multiple base stations have the same SSID.

Nominet Database Settings: FCC Operation

In "**System**" page, click "**Database**" to configure database agent.



Device Characteristics

The antenna height above ground level (AGL) in **meters** is required. The maximum legal height AGL is 30m (approximately 100ft).

The antenna gain, is the NET antenna gain and includes losses due to cables etc. The antenna gain is used to calculate the maximum EIRP allowed for the GWS radio at this specific location. If the gain of the antenna plus the conducted power exceeds the maximum allowed EIRP at this location the radio will not turn on.

Location

The longitude and latitude are entered as decimal degrees. Location should be specified to 6 decimal points. The location can be checked on the map on the Monitor tab. For locations west of the Greenwich meridian a minus sign is required. Please ensure no spaces or bad characters.

Database Parameters

The database token is inputted during manufacture and the token lifetime is activated after a number of database queries as determined by the database provider. The lifetime of the token is determined at equipment ordering and is typically 3 or 5 years.

WARNING: Changing parameters in this field may cause the radio to discontinue operation.

Owner Information

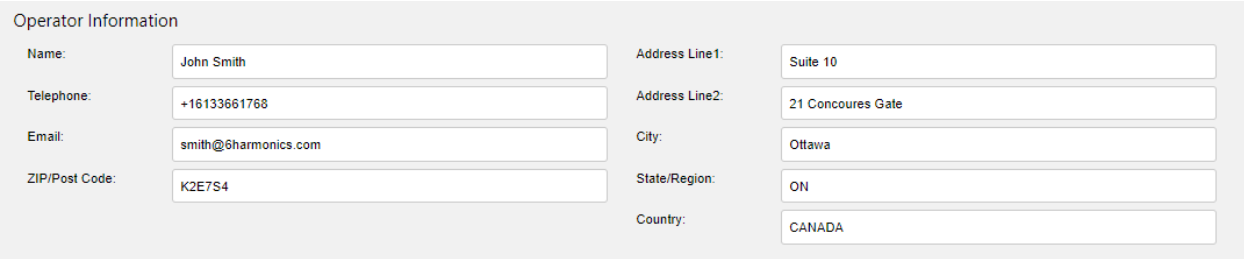
The owner information relates to the legal owner of the equipment, typically this is a company.

Be careful with the correct information as it is an FCC requirement to provide accurate information.

WARNING: Ensure the format is correct.

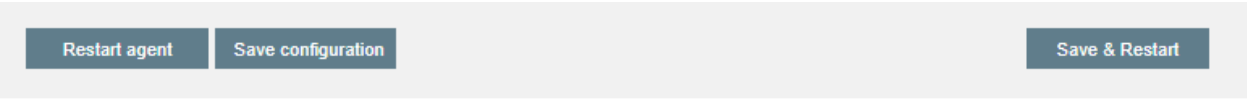
Operator Information

The operator refers to the person who is responsible for the actual operation of the radios. Typically, this is an employee of the company that owns the radios.



Ensure format is correct. The telephone number requires the international format of + and country code. (USA is +1 before the area code/local number)

There are three options to save & implement changes.

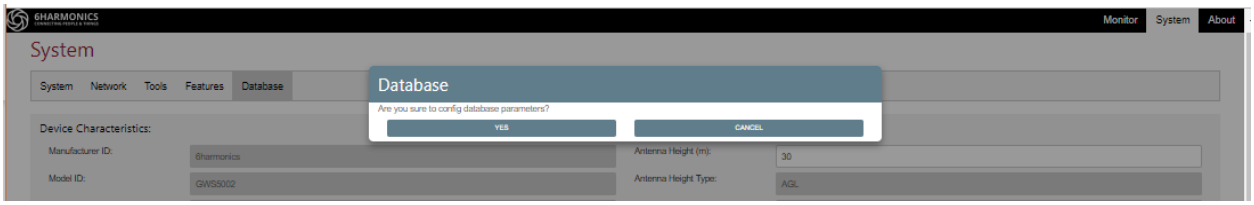


Restart Agent: Use this button if you are trying to check that the radio is able to reach the database.

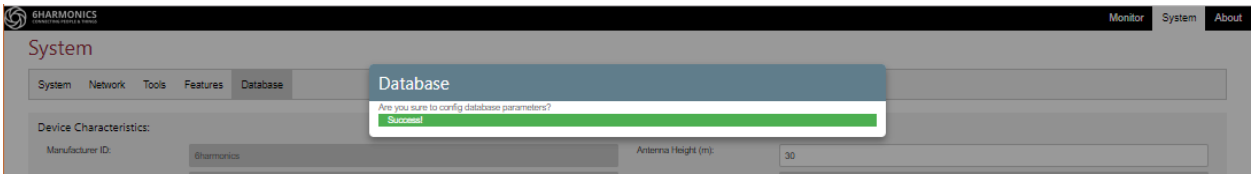
Save Configuration: This button will save changes to the database parameters but will not initiate a new database query. The radio will wait until the current channel list has expired and will then query the database.

Save & Restart: Saves all the changes and initiates a new database query, and if successful will restart the "Query time left" timer in the Database Agent Status section of the Monitor tab. If there are errors in the database parameter error messages will appear on the Database Agent Status section of the Monitor tab.

WARNING: It is preferable to always use the Save & Restart button to ensure that both changes are saved AND that the next database query will be successful.



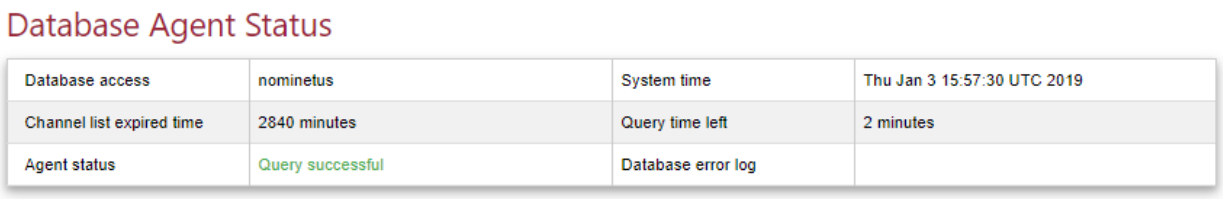
Click on YES, and then wait for confirmation that the changes have been successfully implemented.



Finally, go to the Monitor tab and check the database query was successful.

Database Operation: Base Station

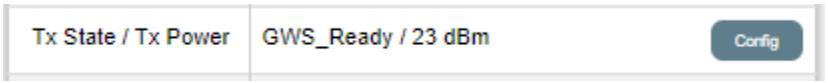
Click "**Monitor**" tab to access the **Monitor** page.



- **Agent status** shows "Query successful" which means the radio has successfully accessed the database and completed the query process.
- **Query time left** is the time to the next database query.
- **Channel list expired time** is a count down timer on the validity of the channel list on the database. The channel list availability is periodically updated (say 24 or 48 hours) at the database, typically the database pulls data from broadcasters or other regulator databases to ensure the database itself is valid. This value is a parameter that is returned form the database and is displayed as part of the database query process. It is regulatory domain specific.

The operator should observe the following:

T_X of the base station will not be turned on until the valid channel list is returned from the database. This is indicated by the Tx state indicating GWS_Ready or TX ON[15].

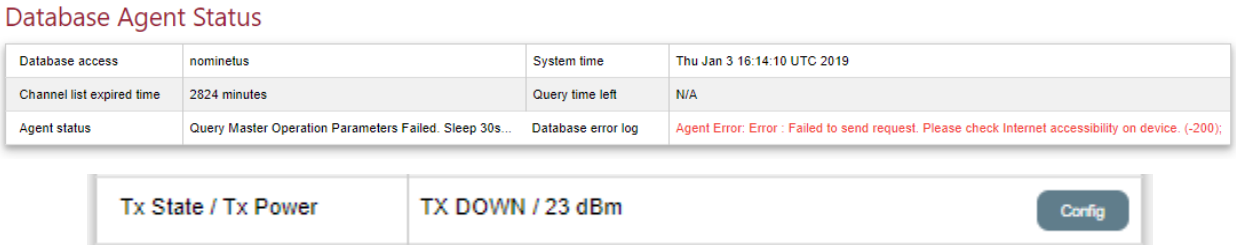


OR

If the current channel is within the channel list, the base station will start to transmit on current channel.

If current channel is not within the channel list, the base station will choose the next available channel to operate. Check the Channel List on the System Tab. Please note the base station has a channel list and a sub-channel list.

If an error is returned from database, the T_X status of the base station will be immediately changed to Tx Down.



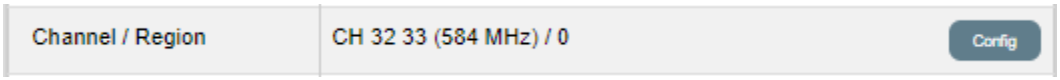
The operator must then determine the root cause of the failed database query.

[15] Earlier versions of software say "GWS_Ready", later versions say "TX ON"

Database Operation: Client Station

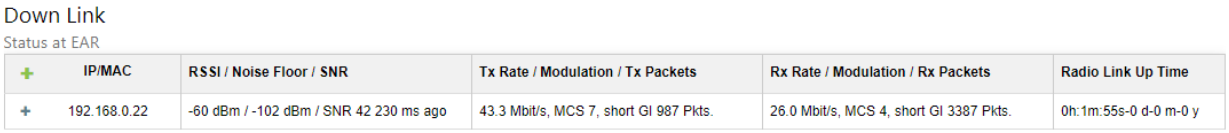
Follow the same steps as the base station to configure the database agent for the client station.

The operator should be able to observe on the Monitor Tab that the client station has started to scan the full channel list.



The user will see the channel number change every few seconds.

Once the client station is on the same channel as the base station, and assuming there is sufficient signal to make a connection, you will see the link details in the Connection Status section of the Monitor Tab of the client station.



Immediately, the client station will attempt to query the database through the radio link to the base station.

If the query is successful, the client station radio will operate on the valid channel (Tx state will become TX ON or GWS_Ready). If it is not successful after approximately 30-40 seconds the client radio will continue to scan for another base station.

WARNING: It is possible for a client station to implement a successful database query, but the client station may not be allowed to operate on the same channel as the base station. This base station-client station allowed channel mismatch is rare but does happen. Before deployment it is important to check that the proposed client station location can operate on the same channel as the base station using the Nominet Database Tool.

Check the Channel List on the client station radio System tab.

Please note on a client station radio only the channel list is displayed. See Radio Link Performance Optimization.

Nominet Database Settings: OFCOM Operation

Although most of the software for a GWS radio operating on an OFCOM database is the same as a radio operating on a FCC database there are several key differences which need to be understood.

- The channel plan is based on 8MHz channels not 6MHz channels.
- The maximum EIRP is always 36dBm per 8MHz channel, there is no allowance for higher antenna gain to increase to 40dBm per 6MHz channel as permitted by FCC in rural areas.
- The base station radio must be GPS enabled to comply with EN 301 598 V2.1.1[16], the White Space Devices (WSD) Harmonized Standard covering the essential requirements of article 3.2 of Directive 2014/53/EU i.e. a GPS is required under the applicable EN Standard under the Radio Equipment Directive 2014/53/EU.
- Under FCC the EIRP limit for an available channel depends only on antenna height and geolocation. It does not depend upon if the radio is a client station or a base station. Under OFCOM, channel availability depends upon if the radio is a base station (which must be GPS located) or a client station (GPS location is optional). The base station uses Master Operating Parameters (MOPs) from the database. If the client radio is GPS enabled, it may use Specific Operating Parameters (SOPs) or General Operating Parameters (GOPs). If the client station is not GPS enabled, it may only use General Operating Parameters (GOPs). Generally speaking, GOPs are more limited than SOPs[17].
- For OFCOM / ETSI, the emissions mask is classified into 5 levels, Class 1 to Class 5, with the most restrictive adjacent channel leakage ratio being achieved by a Class 1 device.
- For OFCOM / ETSI the device ***type*** also defines channel availability. A Type A TVWSD is a device that is intended for fixed use only. This type of equipment can have integral, dedicated or external antennas. A Type B TVWSD is a device that is not intended for fixed use and which has an integral antenna or a dedicated antenna[18].

[16] See Section 4.2.10 https://www.etsi.org/deliver/etsi_en/301500_301599/301598/02.01.01_60/en_301598v020101p.pdf

[17] Generally speaking, but in some locations client station GOPs have higher allowed EIRP than SOPs. Always check the database.

[18] See EN 301.598 V2.1.1 Section 4.2.2 "The equipment and the antenna shall be designed to ensure that no antenna other than that furnished by the responsible party shall be used with the device". This means for Type B operation only antennas form 6Harmonics may be used.

- The operating frequency range of the GWS radio is greater under OFCOM. 470-698MHz for FCC (Channels 14-51 inclusive); 470-774MHz for OFCOM (Channels 21-58 inclusive).

GWS radios have an emissions mask that is software defined. Both the base station and client station are GPS enabled. This ensures the maximum spectrum availability in the field.

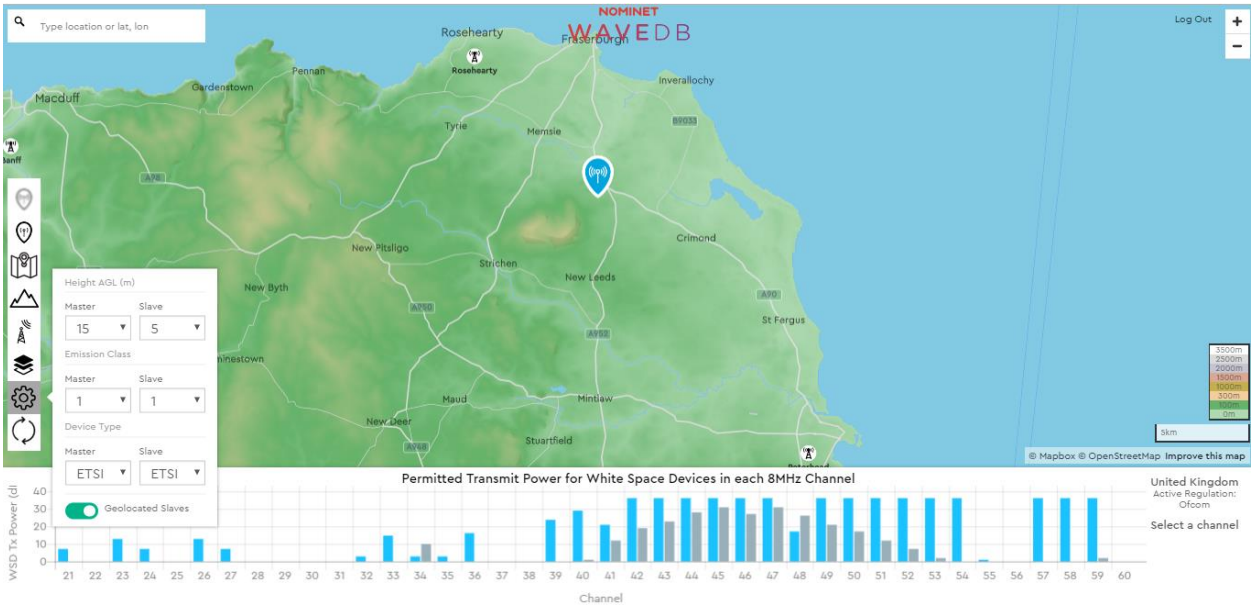
Understanding MOP, GOP & SOP Values from the Nominet Database

In order to fully comprehend how the MOP, GOP and SOP values determine network operation we can explore some examples using the Nominet database planning tool[19]. Understanding MOP, GOP and SOP is key to operating the radios.

Let us choose the following locations:

Base Station:	Latitude 57.6198; Longitude -2.0026
Client station[20] #1:	Latitude 57.6486; Longitude -1.9208
Client station #2:	Latitude 57.6600; Longitude -2.0080

We drop the base station pin on the map, and the tool generates the following spectrum availability:



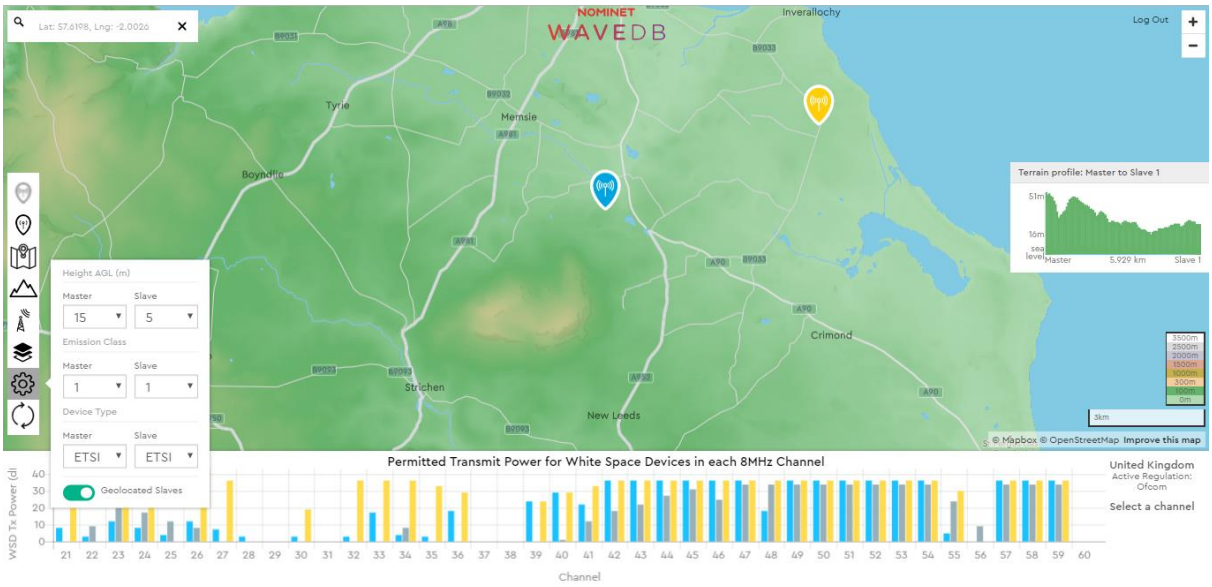
The blue bar chart shows the MOP channel availability, the EIRP per channel, with a 15m AGL antenna height. These are the MOPs at the base station location.

Since the client radio obtains GOPs from the base station, the tool also displays the GOP channel availability for the client stations. The grey bar chart is the EIRP transmit limit per channel with a 5m AGL antenna height. These are the GOPs, and the GOPs are **not client location dependent**.

[19] Contact Nominet for further information.
[20] The Nominet tool uses the terms Master and Slave for base station and client station respectively.

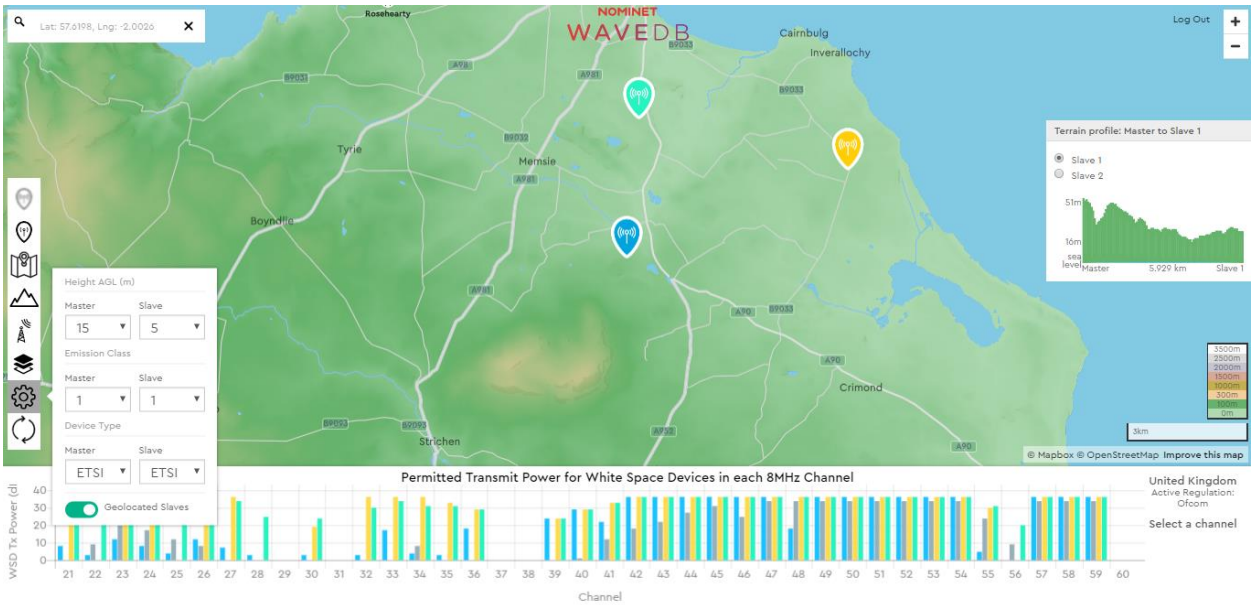
Consider Channel 43, the MOP transmit EIRP is 36dBm, the GOP transmit EIRP is 22dBm.

Now we add a potential client location at 57.6486, -1.9208 (yellow).



In addition to the MOP of the base station (blue), the GOP of any client station (grey), the tool also displays the SOP for specific geolocation of client#1 (yellow).

On Channel 43, we now know the allowed SOP transmit EIRP for Client #1 is 36dBm.

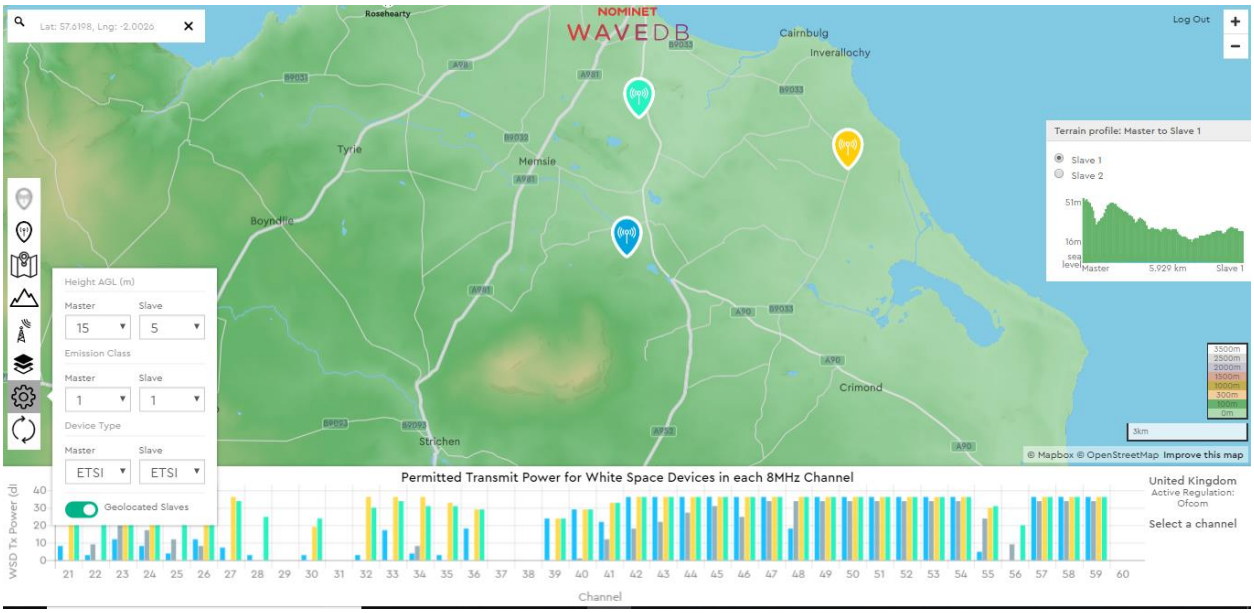


If the operator chose Ch 43 there is a significant potential mismatch in SNR in UL from client #1 depending on if client #1 uses GOPs or SOPs.

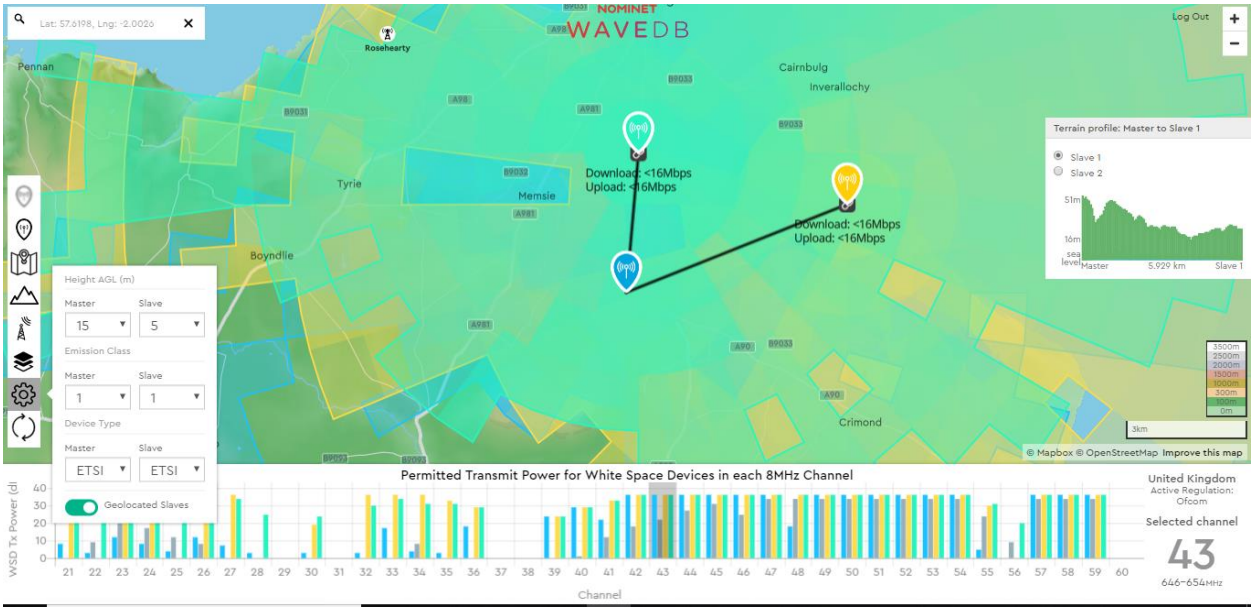
In summary;

- The base station can transmit at 36dBm on Channel 43
- The client station can transmit at 22dBm on Channel 43, if the client uses GOPs
- The client station can transmit at 36dBm on Channel 43, if the client uses SOPs.

Let us add another client location (pale green) at 57.6600, -2.0080.



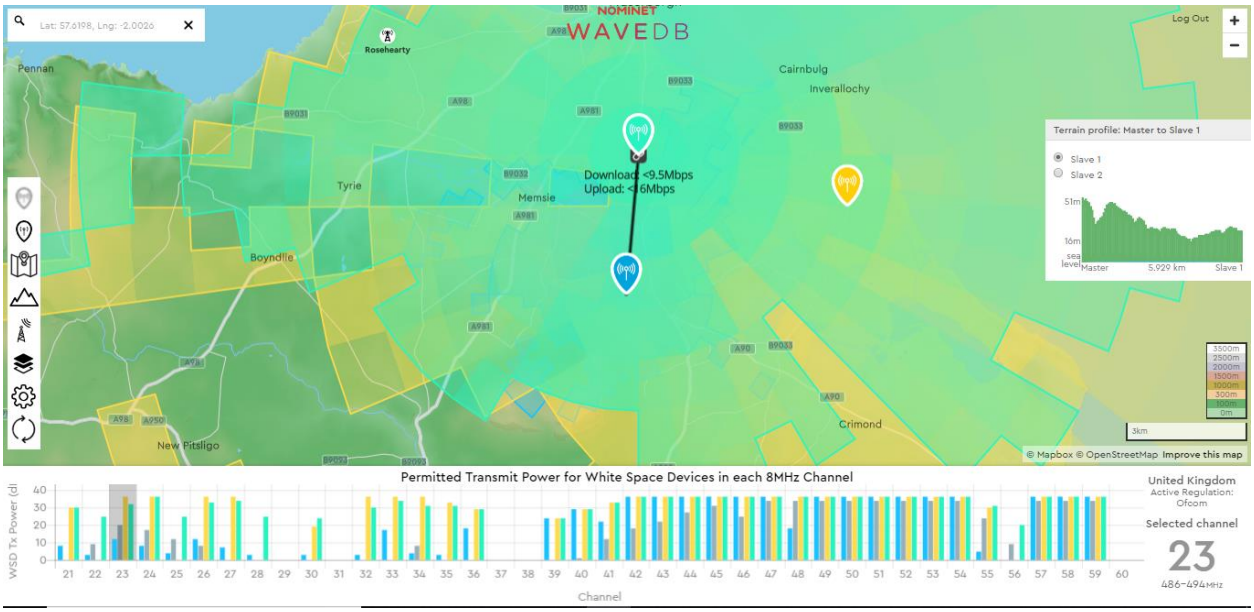
Similarly, for Channel 43, at the location for client #2, the radio is allowed to transmit at 36dBm EIRP (pale green). If we select Channel 43 on the channel bar chart, the tool then simulates the link performance.



Each link is symmetrical (i.e. UL & DL) because the EIRP for both clients and the base station is the same (36dBm). NB this does not mean both of the links will have the same performance.

WARNING: Always independently simulate the link using a tool such as Radio Mobile to determine the expected link performance.

Now we choose a different channel where this is not the case, such as Ch 23. The tool then calculates the link performance based on the best case of SOP or GOP for the client.



Now:

- The base station can only operate at 10dBm EIRP. Client #1 cannot hear the base station as the power is too low.
- Client station #1 (yellow) can transmit at 20dBm EIRP using GOP or 36dBm EIRP using SOP.
- Client station #1 (pale green) can transmit at 20dBm EIRP using GOP or 32dBm EIRP using SOP.

We have shown how the choice of channel and client location in combination of MOP, GOP and SOP can impact greatly how a network will perform. In this example:

- A link cannot be established to client #1 using Ch 23.
- The link from the base station to client station #2 is asymmetric using Ch23 and the DL is <9.5Mbps, the UL is <16Mbps. This is because using Ch 23 the EIRP limit for the base station is lower (20dBm) than the client station (32dBm).
- Links can be established to both clients using Ch 43, and each link is symmetric.
- There can be significant difference in EIRP between the allowed GOP and SOP for client stations.

Finally, in this example we used a 15m antenna height AGL for the base station, and a 5m antenna height for the client station. Changing these values will change the spectrum

availability and EIRP limits for each channel. The operator should understand the impact of these parameters before (i) installing the radios (ii) inputting these parameters on the database tab of the radio.

GPS Operation

As we have shown network performance greatly depends on the channel availability and associated EIRP limits per channel. For client stations, the best channel availability occurs when the client radio is GPS enabled. The following is an explanation of how both base station and client station GWS radios operate when enabled with GPS. Radios can be GPS enabled even if no database is being used as this greatly helps understanding the physical network architecture in real time. If clients are mobile such as a ferry for example, the location of the client station is available in real time.

When a GPS enabled GWS radio is powered up, the internal GPS[21] will geolocate and get a "fix". The time to achieve a fix depends on the number of satellites the radio can see; the distance the radio has moved and / or the duration since the last good fix. This can be as long as 15minutes, but typically is 2-3 minutes. As the radio is fixed the location accuracy increases with time. After a day or so the horizontal accuracy can be less than 5m with a 95% confidence level (CL). The radio must have a location accuracy of less than 50m with a 95% CL before it can transmit. Therefore, when the radio has determined its' location with an accuracy of less than 50m with a 95% CL, the radio is considered to have a good "fix". The location can then be used as part of a database query.

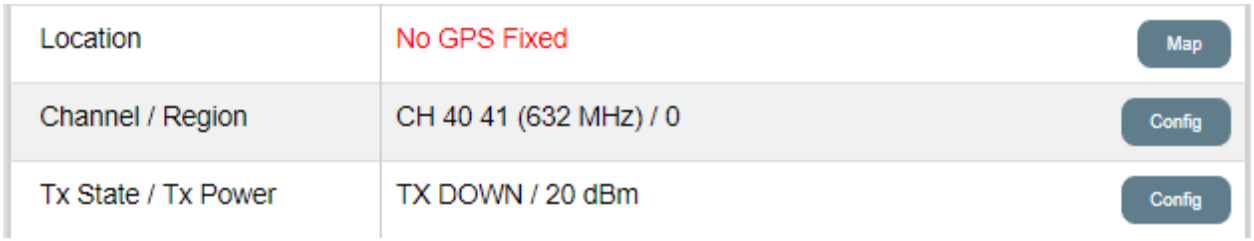
The GPS provides location data to the radio once per second. The location on the GUI is updated every 2 seconds. The location is overwritten to the database page every 3 seconds. For a slave device a user may enter Longitude and Latitude values manually. If the GPS is operational this manually written location will be overwritten within 60 seconds and the slave radio will operate on SOP (assuming an SOP channel list is available). If the slave does not have a GPS fix it will operate on GOP channels only, i.e using the manually entered location. If the slave does not have a GPS fix it will not attempt to obtain a SOP channel list and so operation will be restricted to GOP channels. Typically, this results in a reduction in transmit EIRP.

[21] A GWS radio can also operate with an external ethernet address enabled GPS unit. Contact 6Harmonics if external GPS operation is needed. This is useful if the actual radio is in a GPS denied environment and geolocation is still needed.

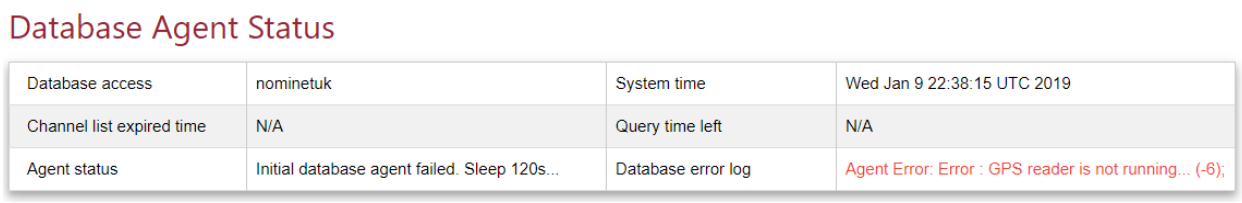
Under EN301.598 two types of TVWS device are defined, Type A which is fixed only, and Type B which is not restricted to fixed operation only. Because the location used for the database query is updated every 60 seconds the slave may be considered to operate as either a Type A device (fixed only) or a Type B device (not restricted to fixed only)[22].

Confirming GPS Fix

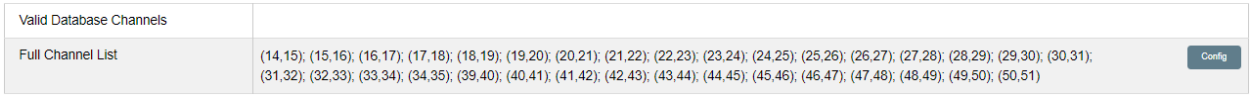
If the radio is GPS enabled, we can check if the radio has a location fix on the Location section of the Radio Status window on the Monitor tab. For simplicity we use a base station radio in this example.



In the situation above, the error message "No GPS Fixed" clearly shows the radio has not achieved a location fix. In addition, since there is no location fix the database query will fail and we will see the following error in the Database Agent Status window:



In addition there is no valid channel list on the System tab;



The database agent will try to restart every 2 minutes (120 seconds), but will continue to fail as no GPS fix.

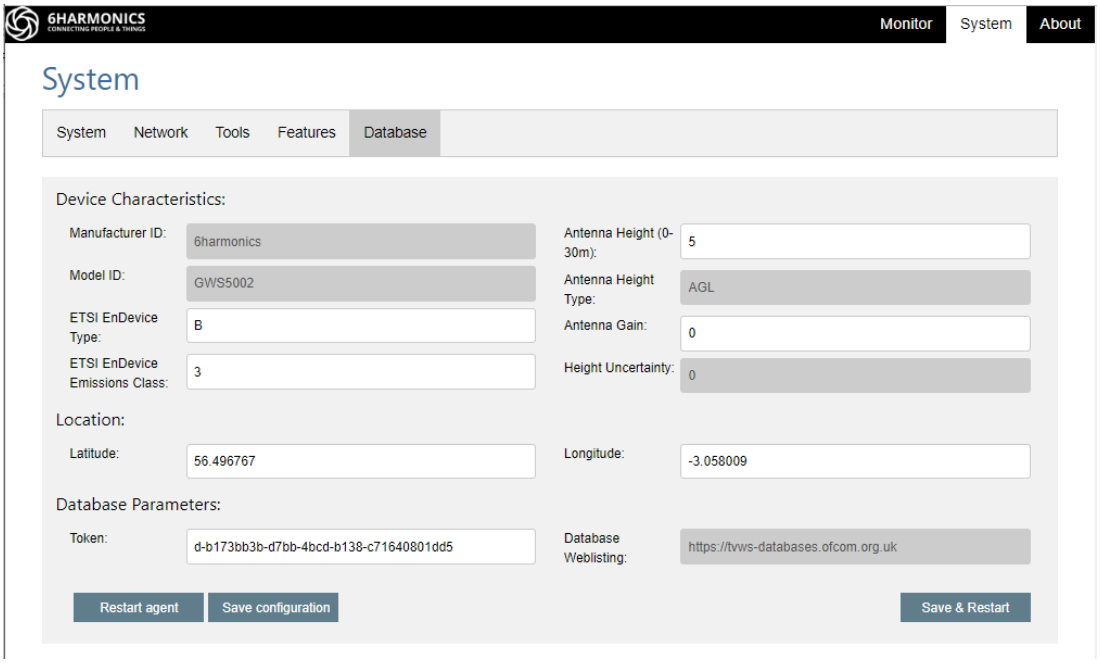
Since there is no successful query and vaild channel list the radio will not turn on and the **Tx State** is **"DOWN"**.

The GPS updates the location displayed on the Monitor Tab every 2 seconds. The GPS updates the location parameters used for the database query every 3 seconds.

[22] See EN 301.598 v2.1.1. Section 4.2.10.1

Database Tab: Nominet-OFCOM Operation

Below is the database tab for a base station when using the Nominet database for OFCOM:



The fields in dark grey cannot be set by the operator. Location values of **Latitude** and **Longitude** are read every 3 seconds from the GPS. The location cannot be manually entered on the database tab on the base station, even if the base station radio does not have a GPS fix. This is because GPS geolocation is a mandatory requirement for a base station (master) under EN 301.598[23].

The **Database Weblisting** URL[24] is the location where the radio will obtain the URL list of valid databases. Once it has a valid database URL the radio will go to said database URL and use the token to obtain a channel list. The radio is not permitted to use a database that is not listed on the regulator Database Weblisting

Device Class is an operator defined parameter and can be 1, 2 or 3. The maximum conducted power is higher for the radio as a Class 3 device than as a Class 1 device. But the channel availability and maximum EIRP per channel form the database may be worse for Class 3 than Class 1. The operator must decide what the optimum configuration should be.

Device Type is an operator defined parameter and can be A or B. A ***Type A*** device is for fixed use only. A ***Type B*** device is intended for portable or mobile use. For operation as a Type B

[23] See EN 301.598 v2.1.1 Section 4.2.10.2 "A master shall have a horizontal geo-location capability"
[24] For OFCOM see https://tvws-databases.ofcom.org.uk/weblist.xml

device only dedicated antennas specified by 6Harmonics may be used. The use of other antennas is prohibited[25]. Operational parameters returned from the database depend upon device type. A "TVWSD that has geo-location capability shall confirm its location at least every 60 seconds except while in sleep mode" to be allowed to operate as Type B device[26].

The GWS radios update their geo-location every 3 seconds so Type B operation is permissible.

WARNING: It is the responsibility of the operator/installer to determine if the installation is Type A or Type B.

Antenna Height (as AGL in metres) & **Antenna Gain** (in dBi) are also operator defined parameters. The geolocation location of a client station may be manually entered on the database tab . But if the GPS is active on the client station and a GPS fix obtained then the location values will be automatically over written by the GPS every 60 seconds on the client station database tab.

As explained previously, the database token is inputted during manufacture and the token lifetime is activated after a number of database queries as determined by the database provider. The lifetime of the token is determined at equipment ordering and is typically 3 or 5 years.

[25] See EN 301.598 v2.1.1 Section 4.2.2 Equipment Types
[26] See EN 301.598 v2.1.1 Section 4.2.10 Geo-Location Capability

We have now explained the key parameters the radio needs to complete a database query:

- The antenna gain
- The antenna height above ground
- The Device Type (A or B)
- The Device Class (1,2 or 3)
- The confirmation that the radio has successfully determined its geolocation to a sufficient accuracy to allow the database query to succeed.

For the purposes of clarity in the next two sections; Database Operation: Base Station and Database Operation: Client Station we check the database to obtain the following information:

- The base station is located at 57.619789, -2.002645 (57.619789 , -2.002645)
- The base station antenna height is 15m
- The base station transmission EIRP MOP limit for channel 43 is 27dBm
- The base station transmission EIRP MOP limit for channel 23 is 12dBm

Given this information from the database tab input parameters, in conjunction with the Nominet database planning tool, we now consider the actual EIRP that the base station and client station may actually transmit at.

Database Operation: Base Station

Once the GPS is able to achieve a fix the Location display will display the actual Latitude and Longitude values[27]:

Location	(57.619812 , -2.002577)	Map
Channel / Region	CH 41 42 (638 MHz) / 1	Config
Tx State / Tx Power	TX ON / 4 dBm	Config

The database agent has attempted a query which was successful. The radio has a valid channel list and the radio has turned on.

The channel list can be viewed on the System tab:

Valid Database Channels	(22,23); (23,24); (24,25); (25,26); (41,42); (42,43); (43,44); (44,45); (45,46); (46,47); (47,48); (48,49); (49,50); (50,51); (51,52)	
Full Channel List	(21,22); (22,23); (23,24); (24,25); (25,26); (26,27); (27,28); (28,29); (29,30); (30,31); (31,32); (32,33); (33,34); (34,35); (35,36); (36,37); (37,38); (38,39); (39,40); (40,41); (41,42); (42,43); (43,44); (44,45); (45,46); (46,47); (47,48); (48,49); (49,50); (50,51); (51,52)	Config

In addition, we can see the Database Agent Status:

Database Agent Status

Database access	nominetuk	System time	Thu Jan 31 19:26:02 UTC 2019
T-validity	1436 minutes	T-Update	327 seconds
Agent status	Query successful	Database error log	

Here T-Validity is time to expiry of the *database validity*, the time the operational parameters in the database are valid. The radio also communicates with the database every T-Update to validate the operational parameters for this radio in this location i.e. *the radio channel list validity.* T-Validity and T-Update are defined by the database server[28]. Different regulatory domains may have different values for T-Validity and T-Update.

[27] Note these are very close locations to the locations used in the preceding sections.
[28] For OFCOM, T-Validity is 1440 minutes, T-Update is 15 minutes. N, the weblisting validity is also 1440minutes.

Base Station Radio EIRP

We know that the EIRP limit for the base station is 27dBm on Ch 43 and 12dBm on Ch 23.

To understand how the radio operates within regulatory limits for each channel, first set the bandwidth to MHz and Save.

On the database tab, the antenna height is 15m and the antenna gain[29] is 1dBi.

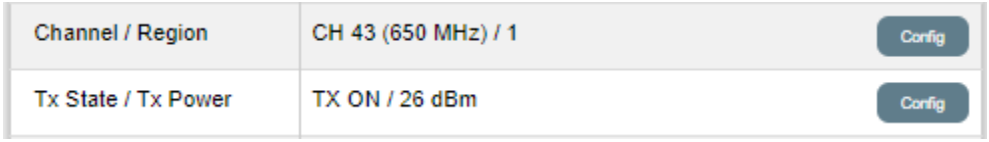
In this case the maximum conducted power for a channel should be 1dB less than the EIRP.

Since we know the EIRP limit for the base station location (MOP) on Channel 43 is 27dBm then we select channel 43. Ch 43 is a valid channel:

Valid Database Channels	(23); (26); (41); (42); (43); (44); (45); (46); (47); (48); (49); (50); (51)

We can test the response by setting the conducted power to 33dBm.

When we try to save the TX power setting of 33dBm we see the following response:



The radio has limited the conducted power to 26dBm and since we specified 1dBi of antenna gain and the EIRP limit for channel 43 is 27dBm, then the EIRP maximum value specified by the database.

Similarly, for channel 23 the EIRP maximum for the base station and with an 1dBi antenna the conducted power maximum is 12dBm.

[29] Antenna gain assumes inclusion of any cable losses between the radio and the antenna.

Again, we can test the radio response by setting the conducted power to 30dBm.

We can see that the radio software will not allow the base station radio to operate at an EIRP value that exceeds the combined value of the conducted power and the antenna gain.

An incorrect entry of the antenna gain will impact the allowed conducted power.

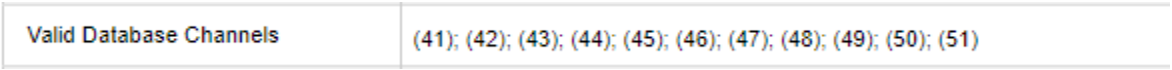
Because the radio is GPS geolocated, the channel list and associated EIRP are set by the database and cannot be overridden. In some locations, the EIRP limits can be quite sensitive to location so the operator must validate the expected EIRP for a channel as above.

Finally, we consider the impact of changing the antenna height on the valid channel list:

With 15m antenna height we have the following channel list:

We change the antenna height on the database tab, Save & Restart.

Check the valid channel list on the System Tab and we see Channels 23 and 26 are no longer available.



WARNING: The channel list on the base station (master) is restricted to channels that have both a valid MOP and a valid GOP. This is because the client station must first connect to the base station using a GOP channel. Unless a GOP channel is also available for a client then the master cannot connect to a client. There is no point allowing the base station to transmit if no client can transmit on a valid GOP. Consequently, usable channels on the master are restricted to channels that have both a valid MOP and a valid GOP. Repeat: if there is no GOP the channel will not appear in the base station channel list. This issue is addressed in SOP Direct Operation.

Database Operation: Client Station

Manual Geolocation

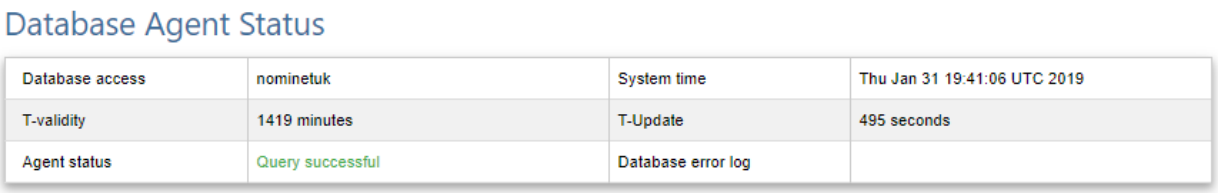
Similar to operation under FCC, the client station radio will scan until it sees a signal from a base station radio, and then it will try to connect. Assuming the IP and SSID configuration allow the client radio to connect to the base station and the client radio will query the base station for GOPs and then the database for SOPs. However, for this two-step process to successfully complete, the base station and a client station must use a channel that has valid MOPs for the base station and GOPs for the client station first. The data exchange[30] is not allowed using a channel that is only valid as an SOP channel at the client. Importantly, as we have shown previously the EIRP values for SOPs are usually higher than for GOPs. This creates the possibility that a client radio cannot connect to a base station using GOPs, but it could with SOPs. In that case, the client may only receive SOP data t using another GOP channel.

Even if the client station radio has downloaded both GOP and SOP channel lists, operation is further restricted depending on whether the client is GPS geolocation or not. If the location of the client is manually defined then the client station can only use GOPs, i.e. the GOP channel availability and the EIRP limits as described previously.

GPS Geolocation

If the client station does not have a GPS fix it may use a manually entered location and will be restricted to GOP only. As explained previously, if the client station radio is able to determine its' location via a GPS it may also choose between the best of GOP or SOP channel availability and associated EIRP limits.

Once a GOP based connection has been established to a base station, the client station will then obtain the SOP channels. Depending on location, channels will appear in the client station channel list[31].



[30] A data exchange requires the client station to transmit. Until it has downloaded the SOP channel
[31] It is unlikely an operator will observe this process as it is too fast.

The client station radio now has an updated channel list, for each channel the radio may use **the higher EIRP limit of the GOP or SOP**. In this case the client station channel list appears as follows on the System Tab:

Valid Database Channels	(21); (23); (24); (26); (27); (30); (32); (33); (34); (35); (36); (39); (40); (41); (42); (43); (44); (45); (46); (47); (48); (49); (50); (51)

Client Station Radio EIRP

We can now check that the radio is operating within the EIRP limit per channel, either GOP or SOP.

The client station is located at 56.648578, -1.920739 (57.648578 , -1.920739)

On the database tab of the client radio we set the antenna height to 5m and the antenna gain to 14dBi.

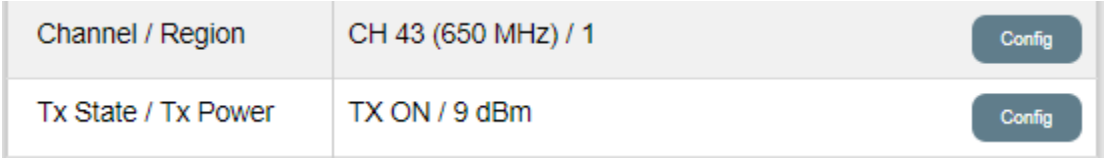
We choose 14dBi antenna gain purely for purposes of explanation.

Click on Save & Restart.

The GOP EIRP limit for Channel 43 is 20dBm.

The SOP EIRP limit for Channel 43 is 35dBm.

Immediately after restarting the database agent we try to set the conducted to 30dBm and the radio responds as follows:



The client radio is only able to use the GOP EIRP limit of 23dBm (9dBm conducted plus 14dBi antenna gain).

The client radio has not yet had enough time to pull an SOP list from the database, so the client station operation is limited to GOP EIRP limits. Wait 2 minutes.

After >2 minutes the client radio should have pulled a new SOP list from the database[32] and we can try again to set the conducted power to 30dBm, the radio responds as follows:

Channel / Region	CH 43 (650 MHz) / 1	Config
Tx State / Tx Power	TX ON / 21 dBm	Config

The client radio is now able to use the SOP EIRP limit of 35dBm (21dBm conducted plus 14dBi antenna gain) for channel 43.

In the event of a loss of power at the client radio, on reboot the radio must follow the initial connection process using GOPs before it can use SOPs to be regulatory compliant. If the client radio cannot connect using GOPs it will not download SOPs and will continue to scan.

If the GPS on the client station loses the location fix, the EIRP limit will be restricted to the GOP limit.

SOP Direct Operation

RESERVED

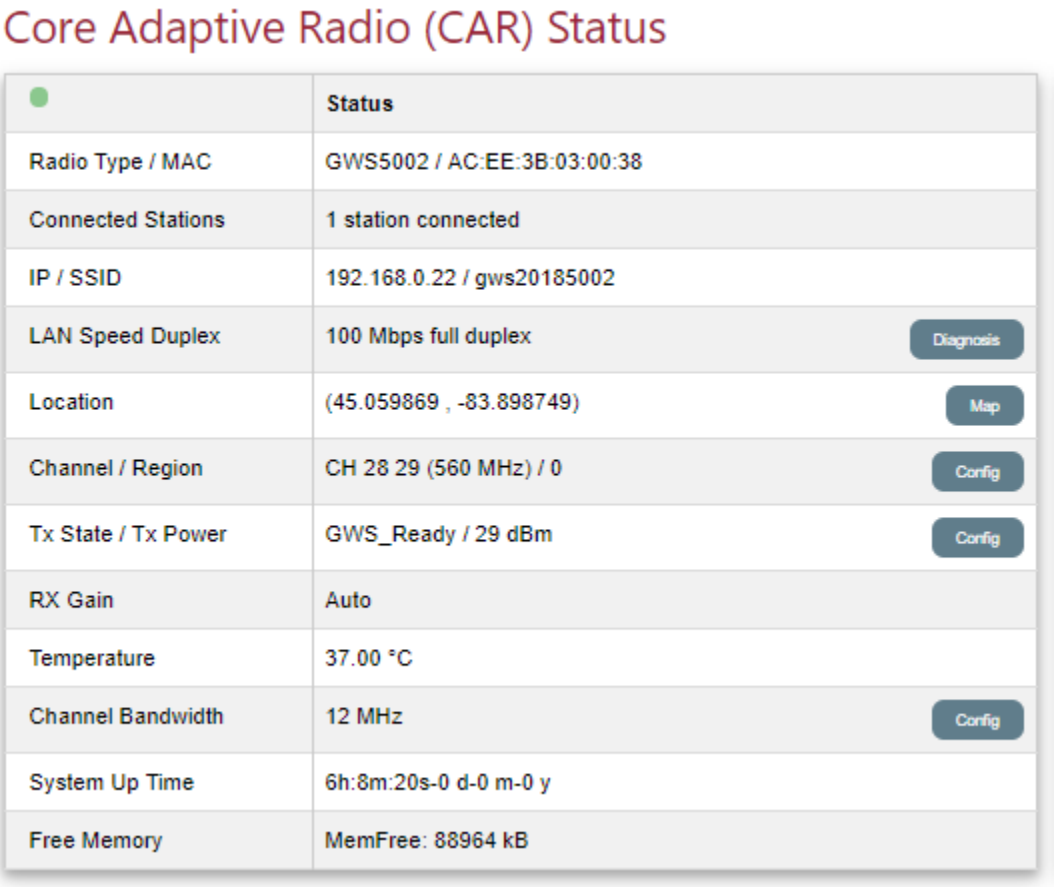
[32] Restarting the database agent means the client radio pulls a new SOP list that overwrites the previous list.

GUI Details

In this section we provide a detailed description of the various Tabs, Sections & Windows of the GUI.

Monitor Tab

Radio Status



Core Adaptive Radio (CAR) means this radio is a base station. If the display shows Edge Adaptive Radio (EAR), the radio is a client station.

Radio Type is the model number, in this case it is a GWS5002.

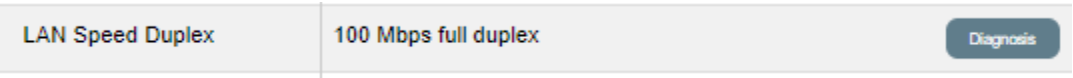
MAC Address is the MAC address of the radio. As mentioned previously, the radio needs internet access to get to a database. Some networks have MAC address filtering, and if that is the case, the operator needs the MAC address to ensure the radio can access the internet.

Connected Stations, as a base station multiple client stations can connect to this base station in a point-to-multipoint architecture.

IP / SSID is the IP address and SSID of the radio.

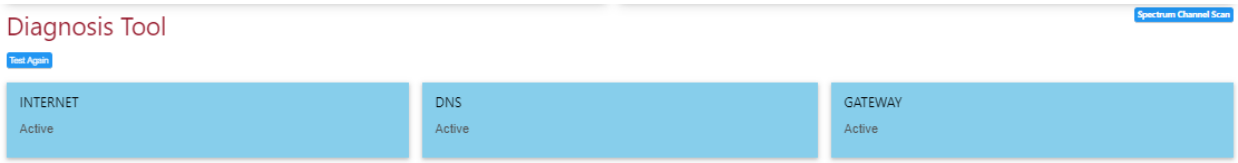
LAN Speed Duplex shows the status of the LAN port on the GWs radio. If there is no data connection to the data side of a client station it will show "Ethernet down". This status setting is useful to see if there are any issues with the data connection on the radio. If a port on a switch that is connected to a base station has become faulty, say 100M half-duplex versus 100M full-duplex the display will indicate this fault. The LAN port of the GWS radio is always in Auto negotiation and displays whatever the status is.

LAN Diagnosis button.



This button is to the right of the LAN Speed Duplex display.

Base Station: Click on the diagnosis button. The LAN Diagnosis tool window appears.



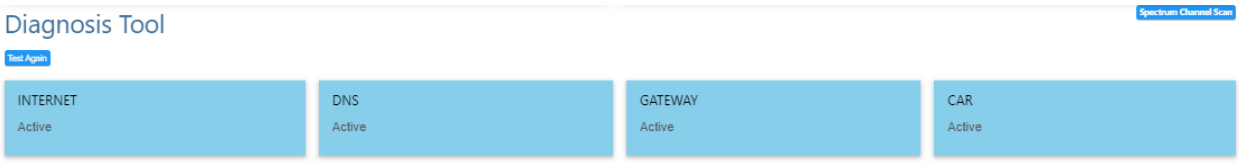
Blue=success, yellow =failure.

Internet means a ping to an internet address, the default is Google.

DNS means the DNS setting is valid.

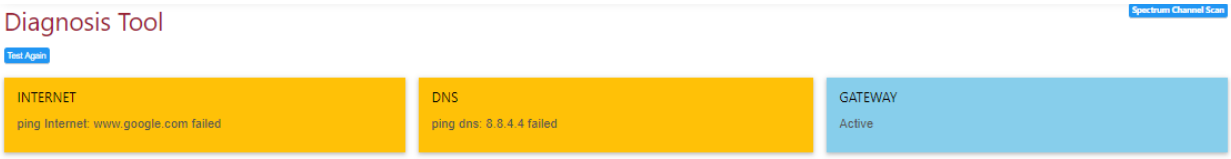
Gateway means the Gateway setting is valid.

Client Station: similarly click on the diagnosis button, and the LAN Diagnosis tool window appears.



CAR active means that the client station is able to ping the base station successfully. Before attempting to analyze any issues with throughput or database connectivity, the user should check that the Diagnosis Tool shows all network requirements are active.

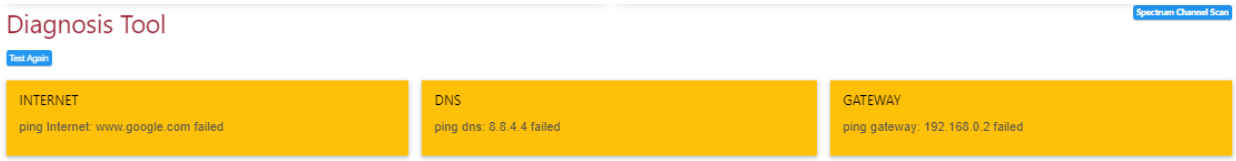
If for example, there is a break in internet backhaul to a base station then the INTERNET display will go yellow.



Because the internet connection is lost, and this radio is using a public DNS then the DNS display also goes yellow. If the DNS was private, it would stay blue.

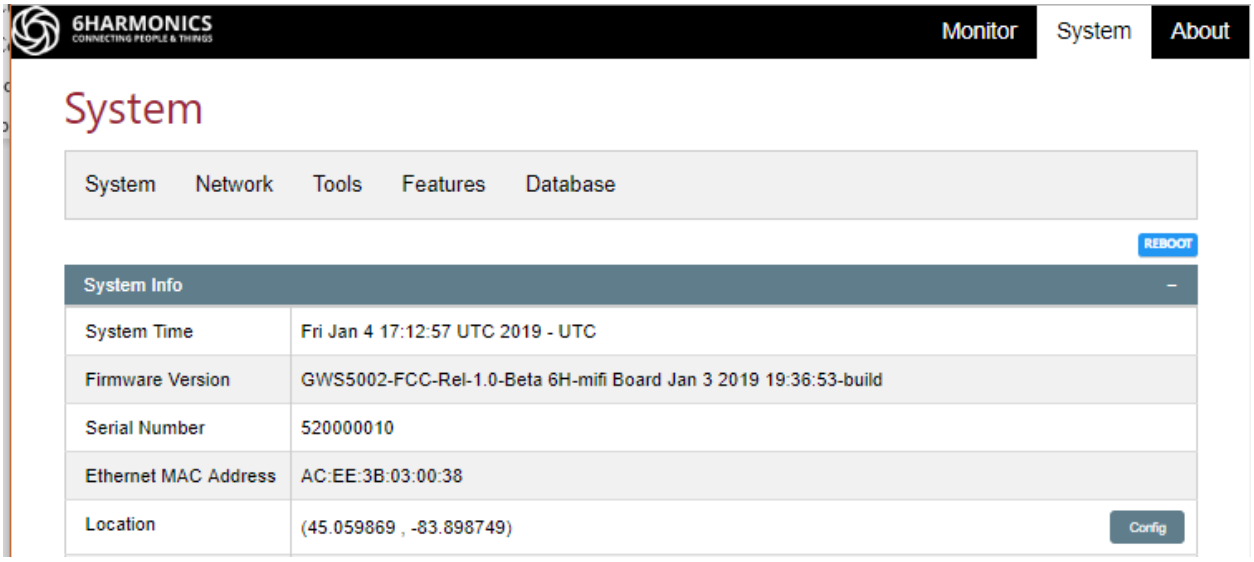
The GATEWAY stays blue because the radio can still see the gateway to the internet but there is no internet access behind the gateway.

If there was internet access, but the gateway setting on the radio was incorrect we would see:

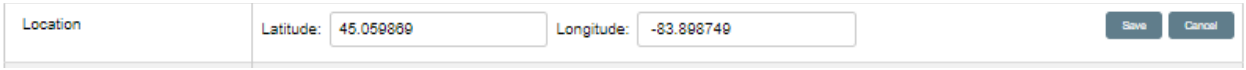


Here you can see that the radio attempted to use 192.168.0.2 as a gateway IP address, which is incorrect.

Location is the latitude and longitude in decimal degrees. These values are used on the map. Depending on the radio model, the location may be user defined on the System tab:



Click on Config button to enter the radio latitude and longitude. Six decimals should be used to ensure location accuracy.

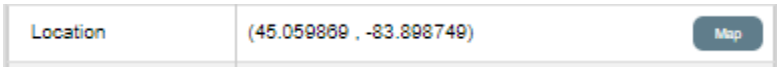


WARNING: if the values are incorrect the map display will be erroneous. Check the location using the Map feature.

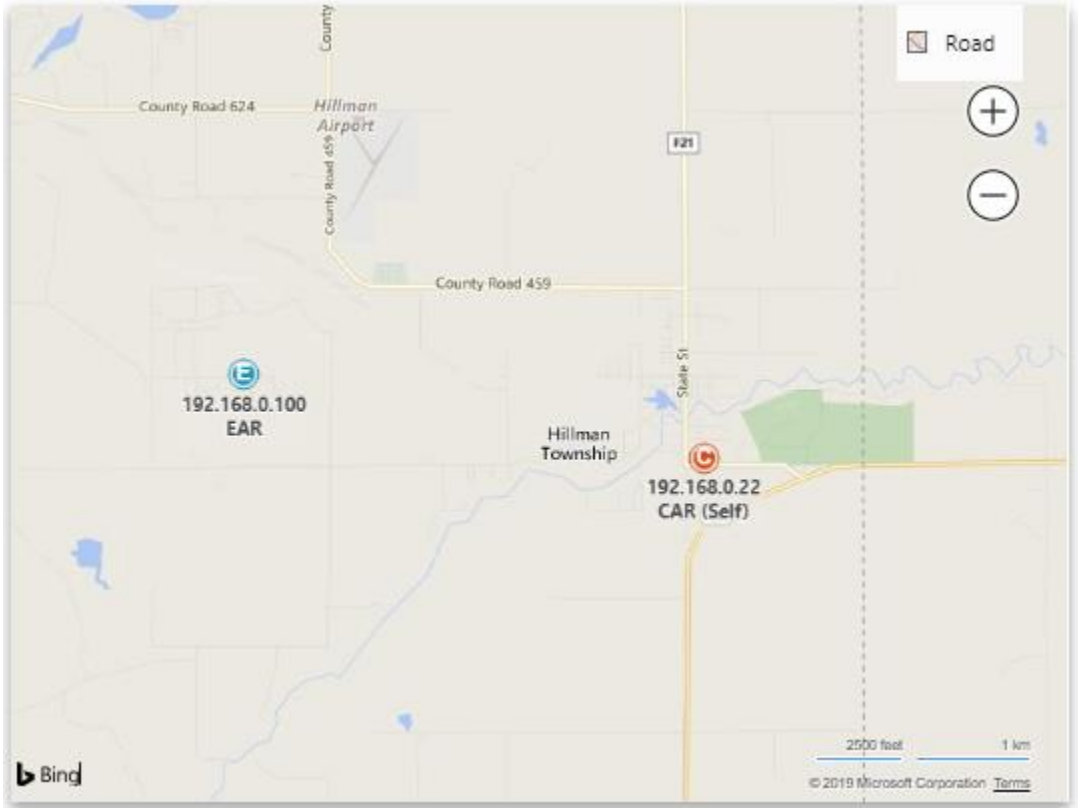
If the radio is equipped with GPS geolocation, the latitude and longitude are determined by the GPS and there is no user defined location input field.

Map

To the right of the Location field is the Map button



Clicking on this button will toggle the display / non-display of the map.



The map is not on the radio, it is on the PC being used to access the radio. It will only appear if the PC has access to the internet. The PC uses the Location values to display the radio locations.

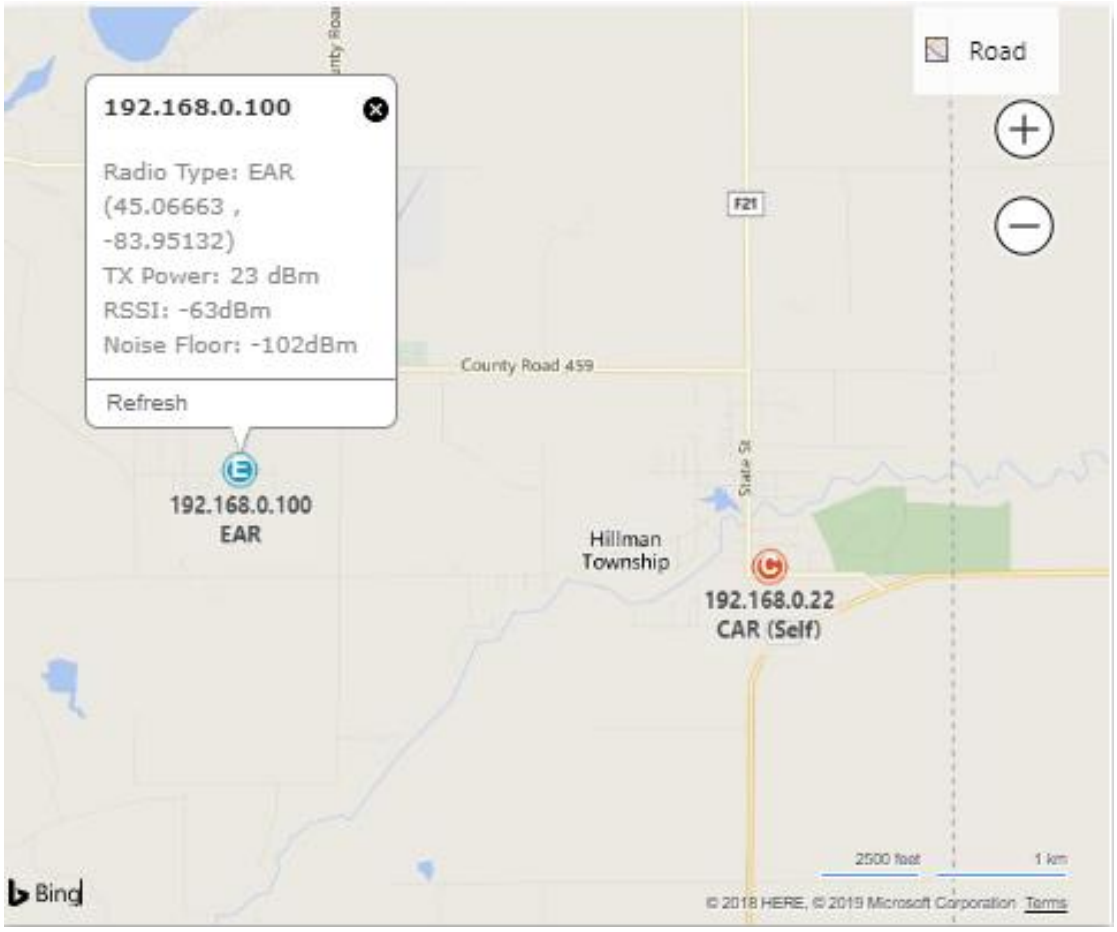
- Red is a base station.
- Blue is a client station.

The IP addresses are also displayed.

"Self" is the radio GUI that the PC is logged into.

The map format and zoom can be changed using the map tools in the top right of the window.

In addition, clicking on the blue client station icons will display key parameters of the client station radio. See below.



This tool enables the user to see:

- the overall network architecture
- the range of the clients from the base station
- the azimuth of the client from the base station and if the client station lies within the azimuth range of the base station antenna
- the signals at various client stations-are there clusters of noise / interference? Do the signal strengths make sense?
- if obstructions or tree cover are an issue by using the satellite map mode.

Channel / Region (Channel plan) refers to the channel the radio is operating on. The pull-down menu is used to set the channel number manually. Don't forget to save.

Channel plan 0 (6MHz) is used in the Americas (most countries), South Korea, Taiwan, Philippines and Japan.

Channel plan 1 (8MHz) is used in the United Kingdom, Ireland, Hong Kong, Macau, Falkland Islands, Western Europe, Eastern Europe, Greenland, most countries in Asia and Africa, most of Oceania, the former Soviet Union and French overseas territories.

TX State / Tx Power: if the TX state shows TX ON or GWS_Ready then the conducted transmit power can be selected from the pull-down menu (don't forget to save). If the radio is manual and the channel list is not specified by a database, then the maximum conducted power will be 33dBm (2W). If the radio does use a database to obtain a channel list, then the database will also determine the maximum EIRP allowed at the Location and at the antenna AGL. The radio will automatically limit the conducted power to ensure the radio operates within the parameters defined by the database. It is the operator's responsibility to ensure antenna AGL and antenna gain are correct.

RX Gain: see Automatic Gain Control.

Temperature: The GWS radio has an internal temperature sensor. This sensor is only accurate to 5C. Any operating temperature comparisons between radios in the same location should recognize the accuracy of the value.

×		RSSI / Noise Floor / SNR	TX Rate	RX Rate	Temperature
×	10.146.0.68	-70 dBm / -93 dBm / 23	7.2 Mbit/s MCS 1, shortGI	19.5 Mbit/s MCS 4	51.00 °C
×	10.146.0.34	-66 dBm / -94 dBm / 28	10.9 Mbit/s MCS 2, shortGI	28.9 Mbit/s MCS 5, shortGI	34.00 °C
×	10.146.0.62	-61 dBm / -91 dBm / 30	19.5 Mbit/s MCS 4	19.5 Mbit/s MCS 4	51.00 °C

In the example above, 10.146.0.68 and 10.146.0.62 indicate 51C and 10.146.0.34 indicates 34C. 10.146.0.34 is outdoor, the others are indoor and as such the temperature values make sense.

Channel Bandwidth: Most GWS radios provide a selectable bandwidth which are typically multiples of the TV channel bandwidth e.g. 6-12-18-24MHz. This allows an operator to compromise between throughput and range, depending on the performance requirements

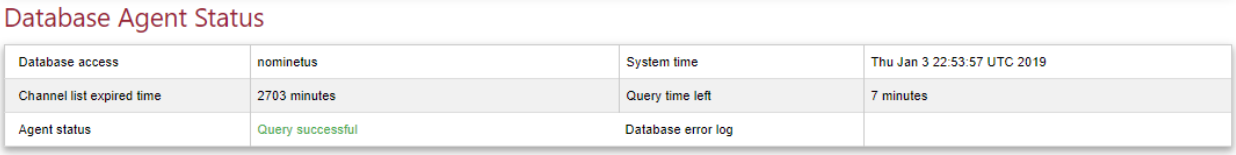
of the link. The bandwidth can be set using the pull-down menu (don't forget to save). Some GWS radios have narrower custom bandwidths[33] which are used for extended range links where range is more important than throughput.

System Up Time: indicates the time that the GWS radio has been powered up. In conjunction with a client station System Up Time and the Radio Link Uptime timers, a base station System Up Time can be used to indicate power outages or interference that has broken the link. For example, if both the client and the base station have been "Up" for a week but the Radio Link Uptime is a few hours then likely interference or noise broke the link for a few seconds and then the link was re-established. Issues such as base station power supply stability, residential power outages, noise or interference hot spots can be identified using the System Up Time and Radio Link Uptime timers.

Free Memory shows the GWS radio free memory remaining. This may change after a firmware upgrade.

[33] The minimum custom modulation bandwidth is 1MHz. The maximum is 32MHz.

Database Agent Status



Database access is the database provider.

Channel list expired time is the time the radio will continue to operate with a valid channel list. It is the time (in minutes) between the System Time and when the Channel List will expire on the database. On the version for EN 301.598 this field is labelled T-Validity[34].

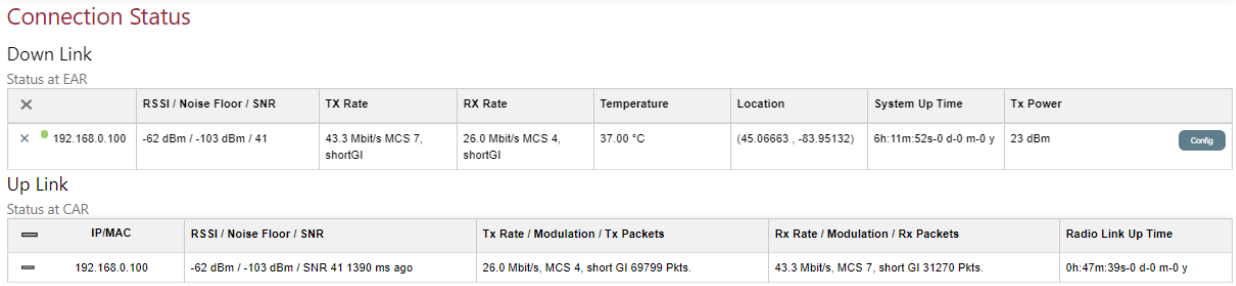
Agent status shows status during or after a database query.

System time is needed to ensure the database query exchange is successful as the exchange is time stamped. The GWS radio needs access to NTP for System Time to ensure success.

Query time left is the count down time to the next database query. Typically, the query occurs every 15 minutes. On the version for EN 301.598 this field is labelled T-Update.

Database error log in the event of database query errors, error messages appear here.

Connection Status: Base Station



On the **Down Link** window, the TX Rate is the transmit from the client station to the base station (MCS 7).

On the **Up Link** window, the TX Rate is the transmit from the base station to the client station (MCS 4).

On the **Down Link** window, the RX Rate is the received rate from the base station at the client station (MCS 4). On the **Up Link** window, the RX Rate is the received rate from the client station at the base station (MCS 7).

[34] EN301.598 uses T-Validity and T-Update as specific parameters as part of the database query process.

The MCS values of an RX (say client) and a TX (say base station) should be the same, but they may also fluctuate with time due to traffic flows.

Status at EAR=Status at Client Station.

Status at CAR=Status at Base Station.

In the TX power box of the Down Link section if you click on Config the user can set the transmit power of the client station, i.e. you can set the transmit power of a client station radio form the base station GUI without logging into the client station radio.

Radio Link Up Time refers to the time the radio link has been passing data.

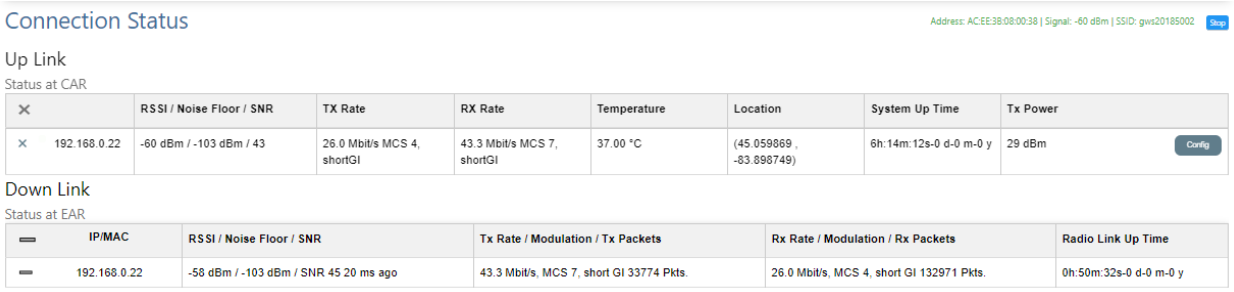
NOTE: If the link is broken for more than 1 second the clock will restart. If the link is broken for >5 minutes the client will commence to scan for a base station.[35]

IP / MAC if clicked can be used to toggle the display between IP address and MAC address of all the connected radios.

Tx Packets and **Rx Packets** indicates the packet traffic. It is useful to discriminate uplink or downlink centric traffic at each client station.

Modulation, maximum throughput occurs when MCS 7, short GI[36] is displayed.

Connection Status: Client Station



At the client station the status windows are reversed but Up Link and Downlink retain the same meaning.

RX at base station is MCS 7 & RX at client station is MCS 4.

---

[35] Networks typically use a ping test as a heartbeat to see if a connection is "up" and to determine network reliability e.g. 98.7% uptime. Such pings are typically every 30-120 seconds, a time interval much longer than 1 second. Expect a discrepancy between the Radio Up Link timer and the period between loss of network ping to a client radio.

[36] Short GI = short guard interval

Beacon button

On the client radio there is a Beacon button on the right side of the Connection Status window.

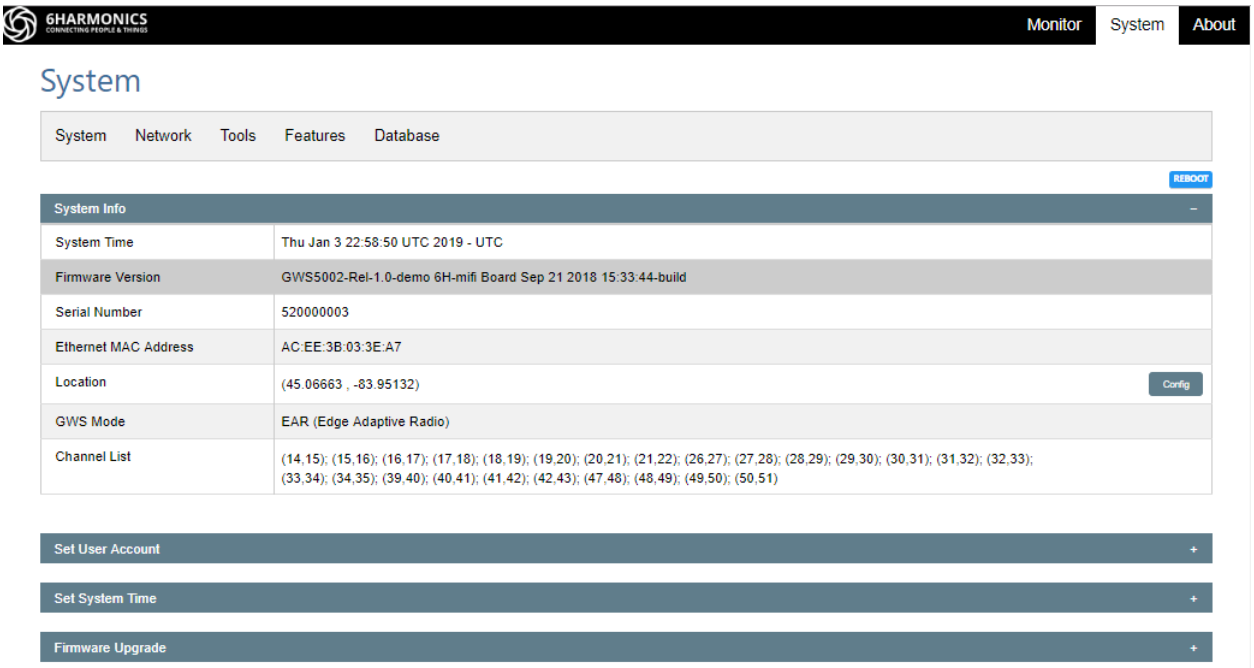
Click on the button; the MAC address of the base station, the unprocessed signal strength at the client station, and the SSID of the base station will be displayed.

The beacon signal display can be used to monitor the stability of the received signal at the client station radio.

About Tab

The about tab shows general information about the radio.

System Tab



On the system tab there are 4 additional sub-tabs: Network, Tools, Features and Database (if implemented).

On the System Tab page, the following are displayed in the System tab window.

REBOOT button. This button located to the right on the window is used to reboot the radio. When this process is initiated the firmware will be reloaded from the flash memory and all processes will re-initialized.

System Time shows the UTC time or the time for time zone the radio is located in.

Firmware Version displays the current firmware version on the GWS radio.

Serial Number which is required for warranty repairs and database query. The serial number is linked to a specific database token. A mismatch will cause a database query to fail.

MAC Address, provided to ensure no MAC address filtering issues.

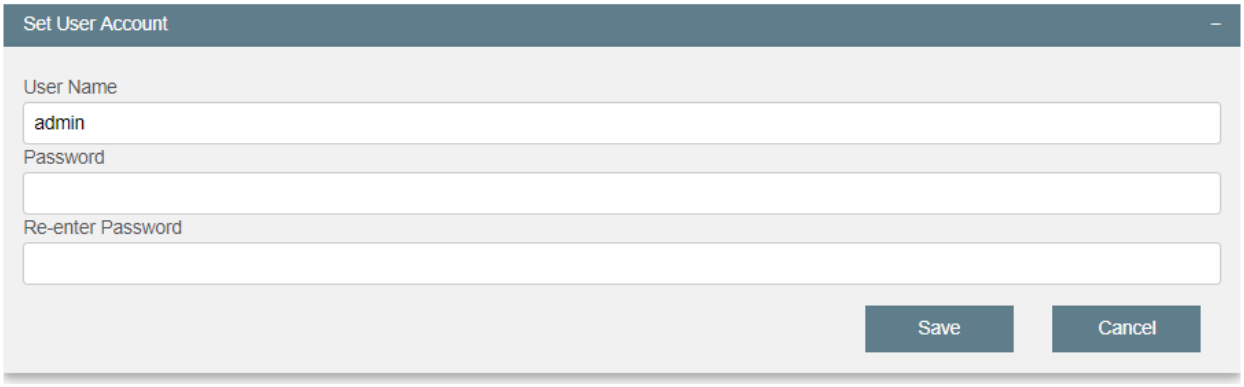
Location, described previously.

GWS Mode, should be CAR for a base station and EAR for client station. The loads must match the hardware.

Channel List, described previously.

Set User Account

Click on Set User Account and the window below appears:



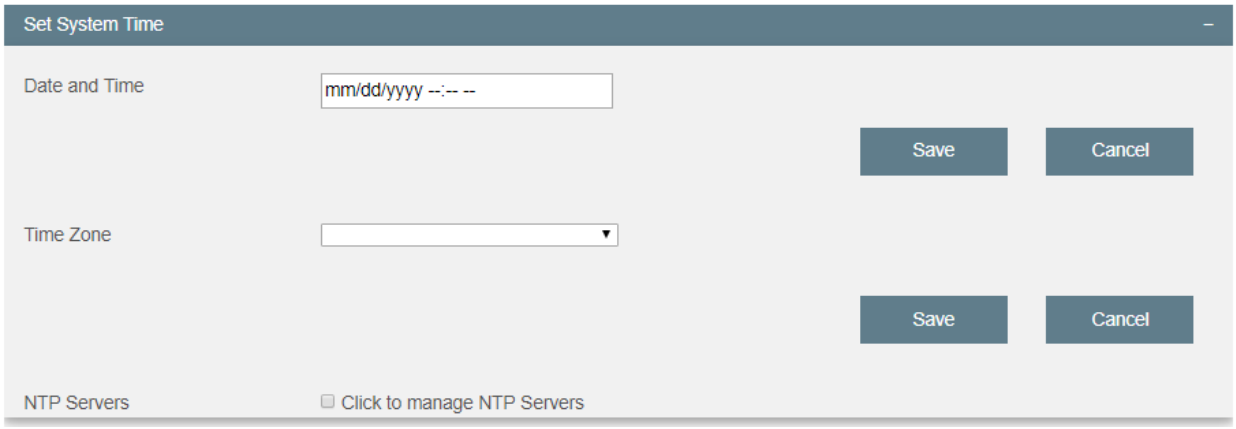
Enter a new username, password and password confirmation. Click on Save.

Click on the minus sign (top right) to close the window.

Set System Time

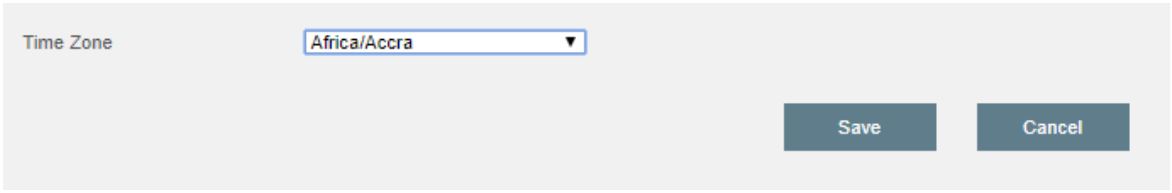
In order to complete a database query, the GWS radios need to set System Time.

Click on Set System Time and the window below appears:



Enter the date & time and save. Care with format.

Select the time zone from the pull-down menu.



The System Time on the monitor page should now display these values.

System time	Tue Jan 8 12:09:56 EST 2019

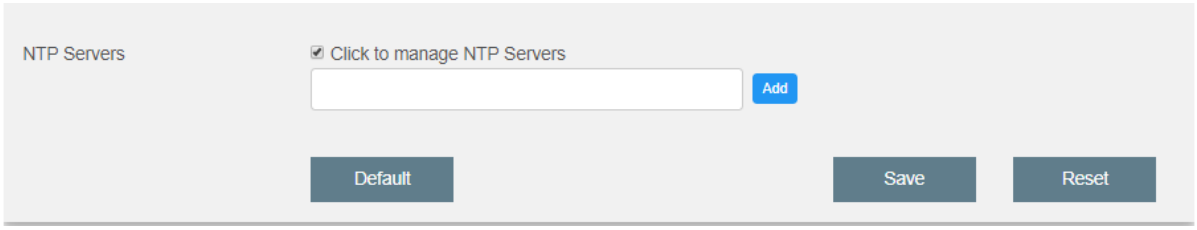
WARNING: If the System Time is set incorrectly then the "Channel List expired time" display window will be incorrect. This is because the Channel List expired time counts down from the absolute time (in minutes) between the current System Time and the time stamped last database query. Query time left is the relative time as a countdown timer to the next database query.

Channel list expired time	3177 minutes	Query time left	11 minutes

WARNING: The GWS radio does not have an internal battery. If the radio is power cycled it will lose the System Time setting.

To mitigate the loss of System Time during a power cycle or setting an erroneous System Time manually the GWS radio can use a public (WAN) or private (LAN) NTP server.

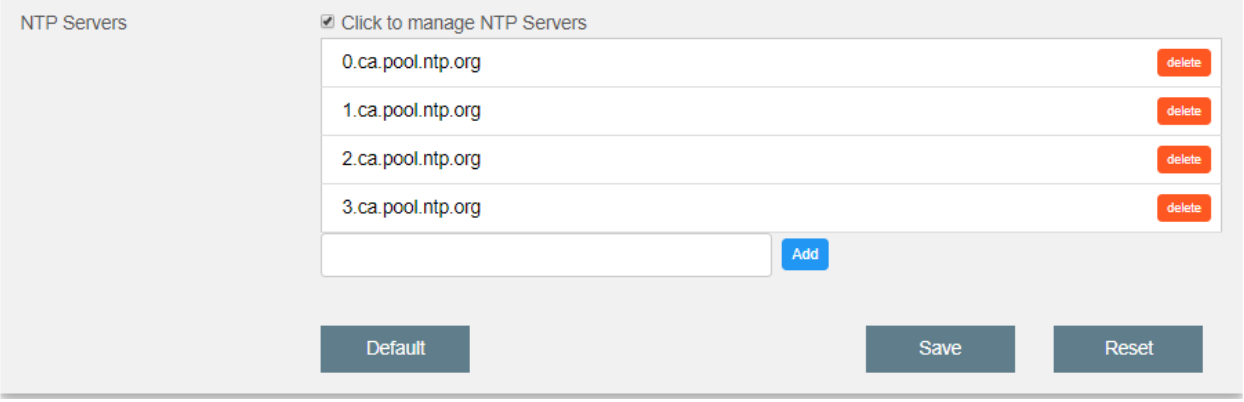
If either LAN/WAN has access to an NTP server, "Click to manage NTP servers" box and the window below appears:



The user may now enter an external or internal NTP server. Click on Save and the radio will now use this NTP server to get System Time. The user must ensure the GWS radio has the appropriate network access to a specific NTP server.

Install a Default External NTP Server

Click on Default to view and edit the Default NTP server list. Clicking on Default will load the following external (public) NTP Server list.



If required, click on the Add button and enter the web address of the NTP server. It will appear in the NTP server list.

NTP servers, either public or private, maybe deleted using the delete button. The radio will use the NTP servers in the list in order of the list to get System Time.

Once the list is correct, click on Save.

WARNING: If the radio does not have a valid System Time the database query may fail, and the radio will not operate. If the LAN / WAN does not allow access to the NTP server in the above list, the database query may fail.

TIP: Always try to use an NTP server for System Time.

Firmware Upgrade

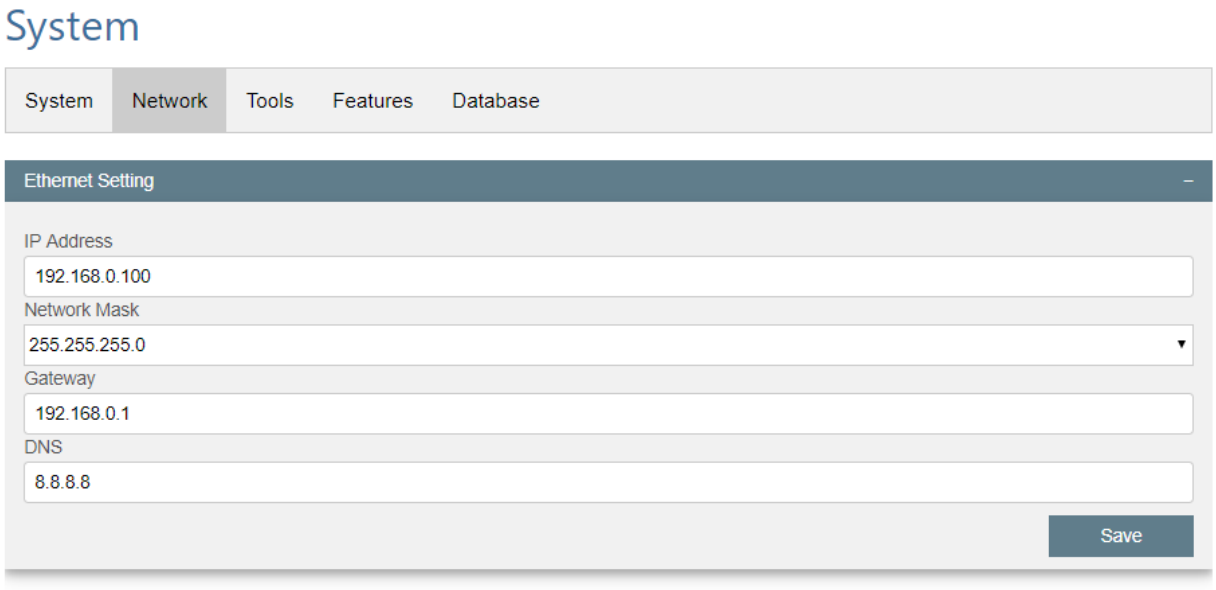
Click on the Firmware Upgrade tab and the following window appears:

When a firmware upgrade is required users will be provided with upgrade files and specific instructions.

WARNING: Do not attempt to upgrade without specific instructions and files from 6Harmonics.

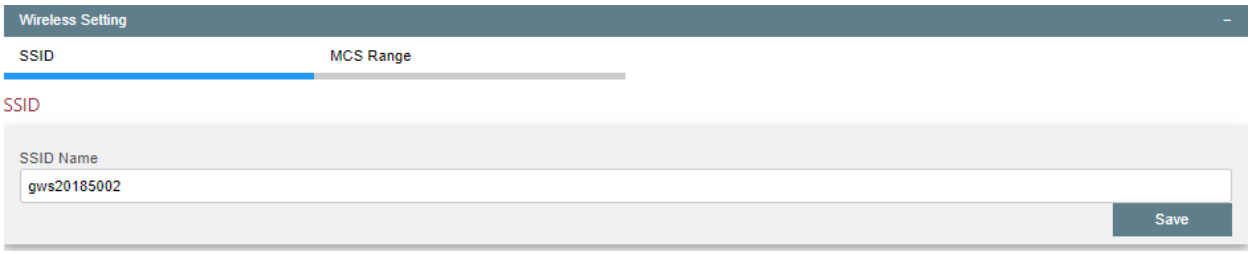
Network Tab

The **Ethernet Setting** window has been explained previously.



Wireless Settings

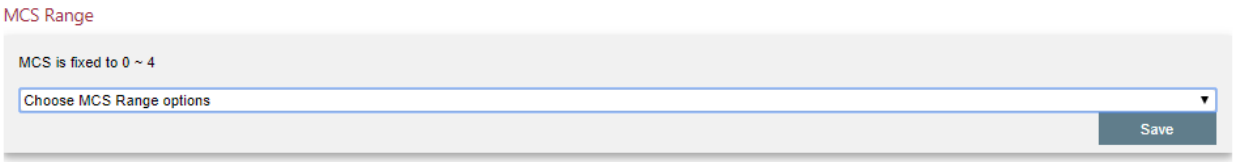
Click on Wireless Settings and the window below appears:



Input the SSID value and Save. Do not use spaces.

MCS Range

Click on MCS Range and the window below appears:

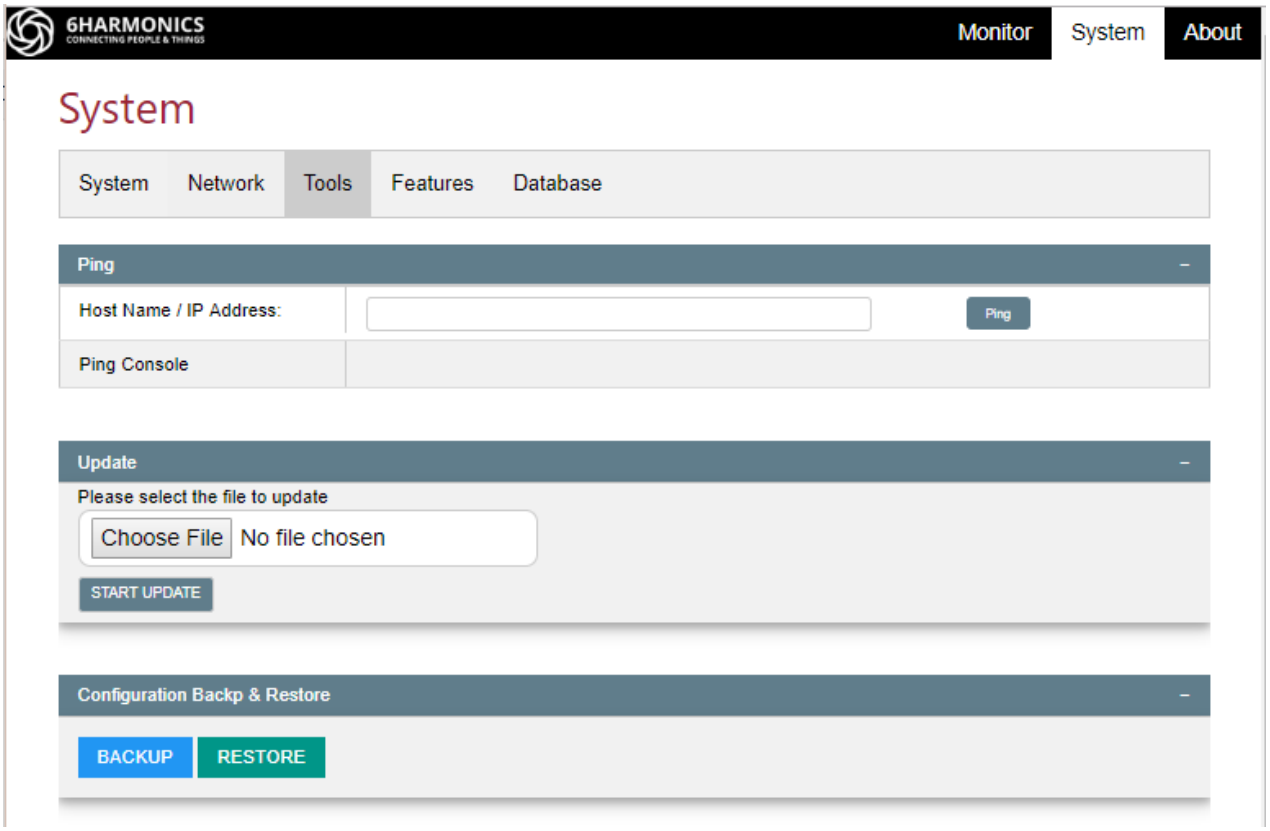


Use the pull-down menu to choose the MCS range and Save.

The purpose of this setting is to ensure link stability if the RF environment is unstable. If the RF environment widely fluctuates between being able to support say MCS 7 and MCS 3 because of intermittent interference or noise, it would make sense to set the MCS range to 0-4. This way the radio is not trying to stabilize the channel state algorithm to values it cannot reliably sustain.

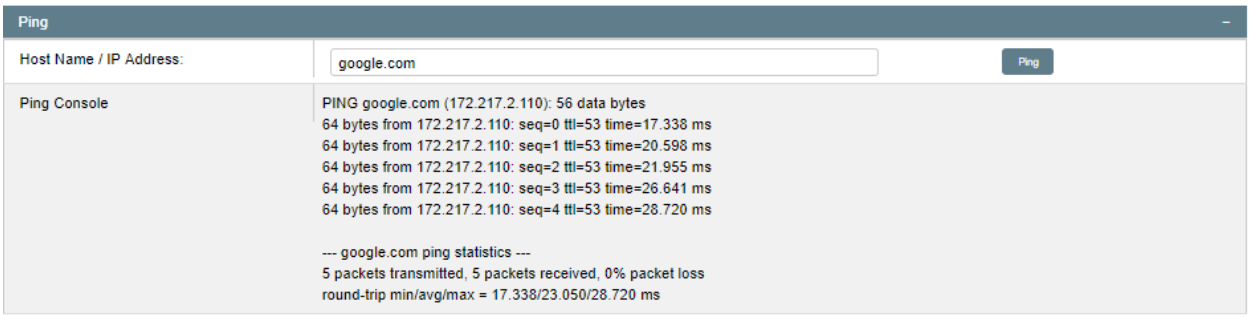
Tools Tab

The Tools tab consists of three windows, the Ping Tool, the Update tool and Configuration & Restore. Click on the respective bar to display.



Ping Tool

The purpose of the Ping Tool is to determine if any particular segments of the network are causing excessive latentcy or packet loss. This allows an operator to identify the source of problems. The ping tool can use a web address or an IP address.



Knowing the IP network configuration discussed previously we can try the following ping tests:

- Client to Google (as above)
- Client to base station
- Client to gateway
- Base station to Google
- Base station to gateway.

You may also be able, if network equipment allows, to ping Google from the gateway. All the ping tests should be additive and self-consistent. Repeat the test at least three times to obtain consistent results.

If any single ping test shows packet loss or excessive latentcy, investigate further.

TIP: Before installing a CPE do a ping test from the base station to the allocated IP address for that CPE. There should be no response. This quick and simple check avoids the risk of setting an IP address that causes an IP loop.

WARNING: When a base station has multiple clients and traffic is flowing the actual ping test from a base station to a client station, and vice versa, can vary from 2mseconds to as much as 20mseconds. This is because WiFi is an on-demand time-slot TDD based protocol

and traffic patterns determine access to the transport medium. If TDMA[37] is enabled, expect a change in latentcy. Similarly, ATF[38] will also impact the downlink latentcy.

Update

The Update window is used to patch the firmware. When a patch is applied, the firmware load will **NOT** change.

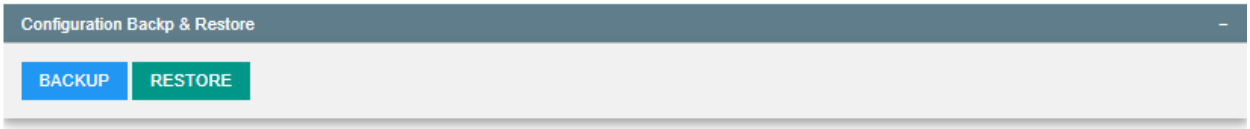
When an Update is required users will be provided with update files and specific instructions.

WARNING: Do not attempt to update without specific instructions and files from 6Harmonics.

Configuration & Restore

Click on the Configuration Backup & Restore bar to display the Configuration Backup & Restore window.

If the user has lost the IP configuration use the Djinni tool to regain access to the radio.



Backup:

Click on Backup to save the current configuration settings to memory.

Restore:

Click on Restore to install the configuration settings stored in memory.

[37] TDMA=time domain medium access, where stations have fixed time slots in a predefined sequence.
[38] ATF=airtime fairness, where a station cannot hold access to the medium to the detriment of other stations.

Features Tab

See Features section.

Database Tab

For operation in USA see Nominet Database Settings: FCC Operation.

For operation in UK see Nominet Database Settings: OFCOM Operation.

Testing Radio Database Connectivity Using Internet Connection Sharing (ICS)

Introduction

Users may experience problems getting the radios to turn on and / or create stable links due to network firewalls or other security settings preventing the radios completing a database query. Or users may experience residential gateways behind a client station radio having problems getting internet access.

The following is a simple procedure[39] that allows the database query process for a base station and client station radios to be validated independent of any external IP network.

We can also check that a PC connected to a client station radio, acting as a proxy[40] for a residential gateway, can get internet access.

The procedure requires:

- A laptop with an ethernet adapter and a WiFi adapter.
- A laptop that allows for internet connection sharing (ICS)
- A WiFi connection to the internet e.g. through a tethered hotspot.
- A GWS base station radio and a client station radio.

The GWS radios should have antennas attached and be sufficiently separated to avoid receiver saturation (say 100m outdoors).

In general terms the procedure requires:

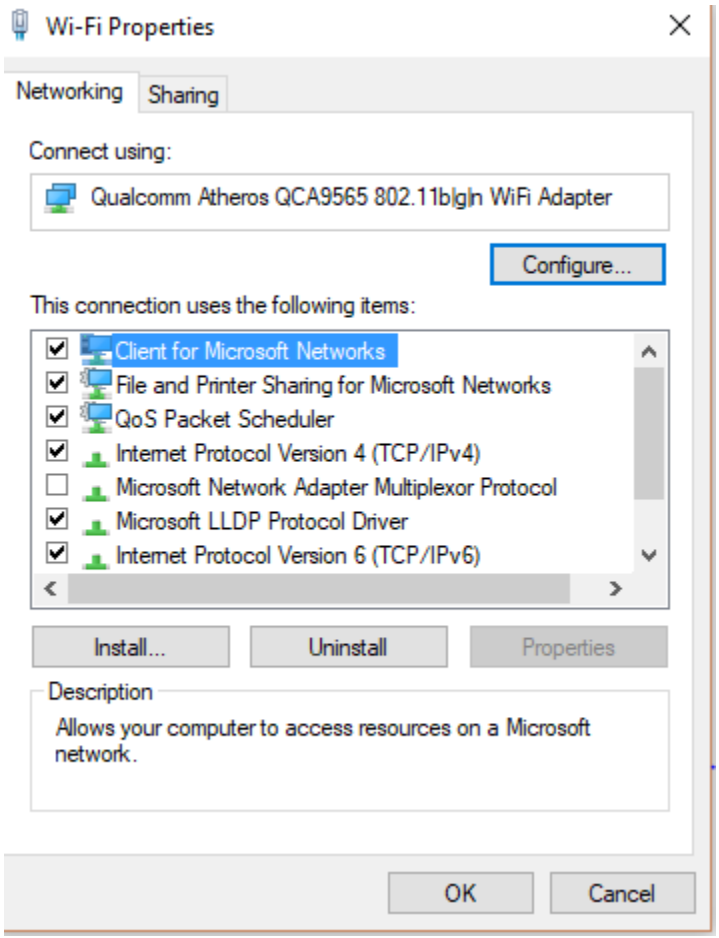
- Establishing a WiFi connection to the laptop
- Share the WiFi connection onto the ethernet adapter
- Set the IP address of the ethernet adapter
- Connect to the base station radio
- Ensure the base station radio is configured to access the internet through the ICS bridge
- Ensure the base station can complete a successful database query
- Configure a client station radio

[39] Assumes manually geolocated radios using an FCC database.
[40] Using the same IP configuration

- Ensure a client station radio can connect to the base station and successfully complete a database query-and then a stable link can be established.
- Ensure a laptop behind the client station radio can access the internet.

Set up ICS

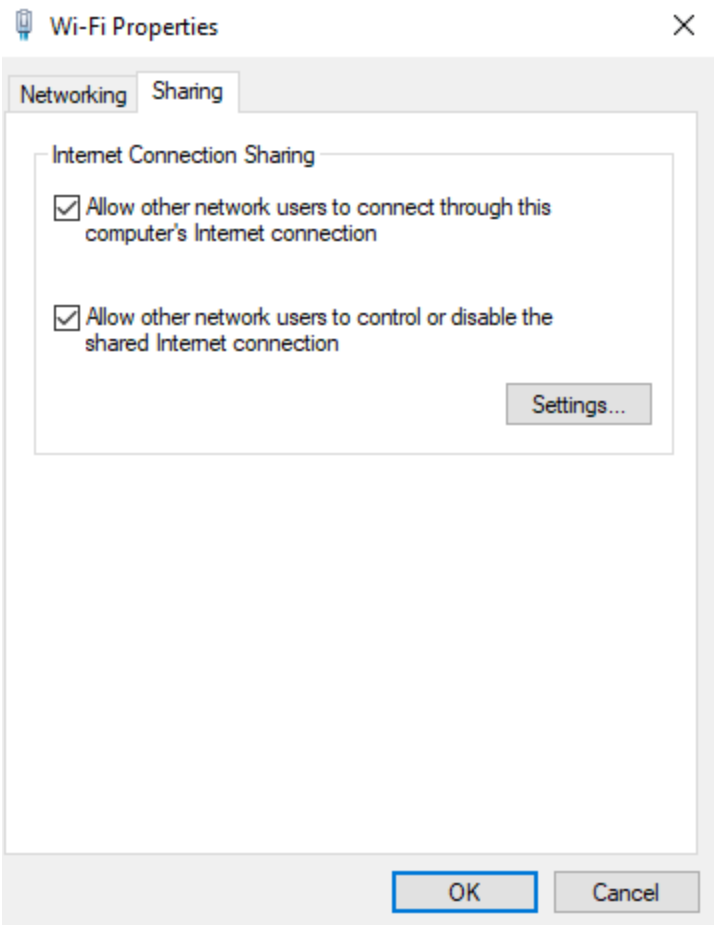
Check internet sharing enabled



If the sharing tab does not appear then you need to enable. Process varies by operating system.

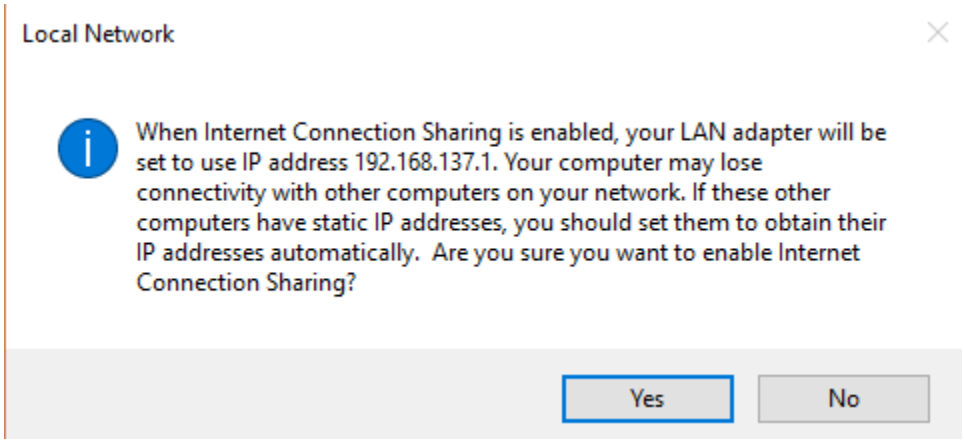
Use the links below to enable ICS:

- Windows 10
- Windows 7
- Windows Vista
- Windows XP



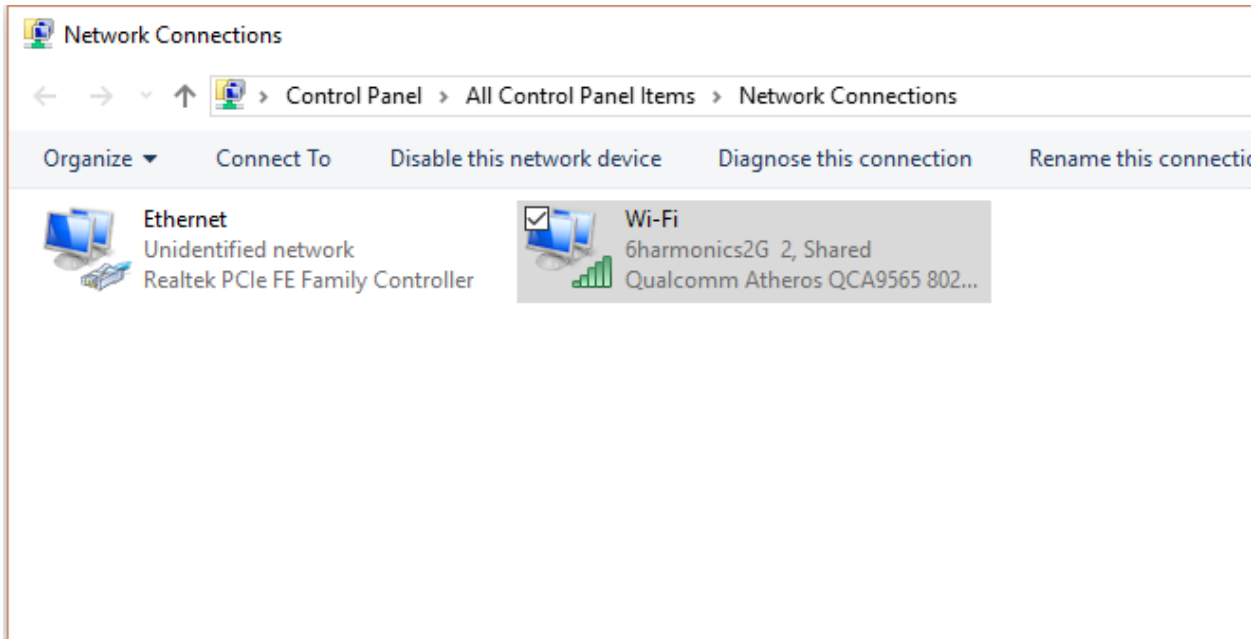
Turn on Internet Sharing (ICS) by clicking both boxes.

You will see this message:



This means the WiFi connection to the internet will be shared onto the LAN port which is set at 192.168.137.1

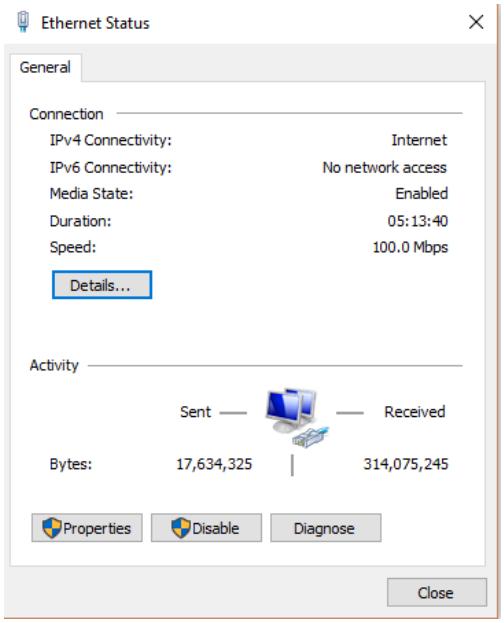
The adapter window will look like this:



We now need to check that all the network elements i.e. GWS radios on the ethernet port are all on the same subnet as the ethernet port on the laptop.

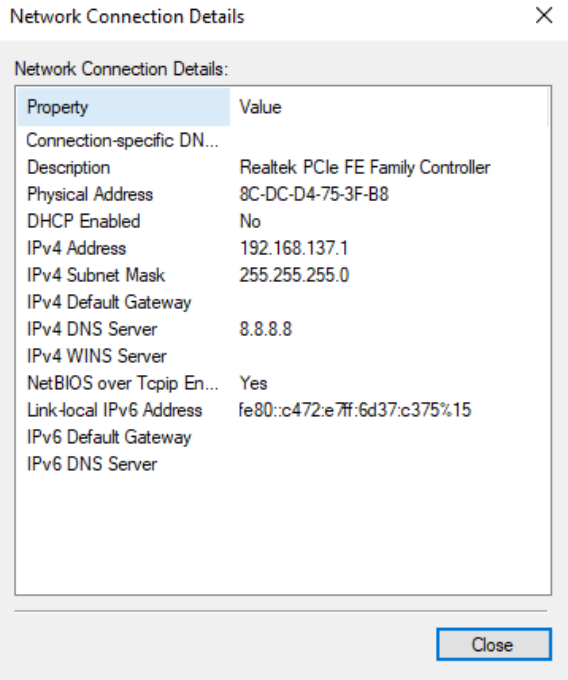
WARNING: The subnet of the DHCP server on the adapter[41] that is providing the internet access must be different than the subnet of the radios.

Right click on the ethernet adapter icon and click on status.



[41] In this example internet access comes from the WiFi adapter, but it could be a USB network adapter as a tethered connection to a phone.

Click on details:

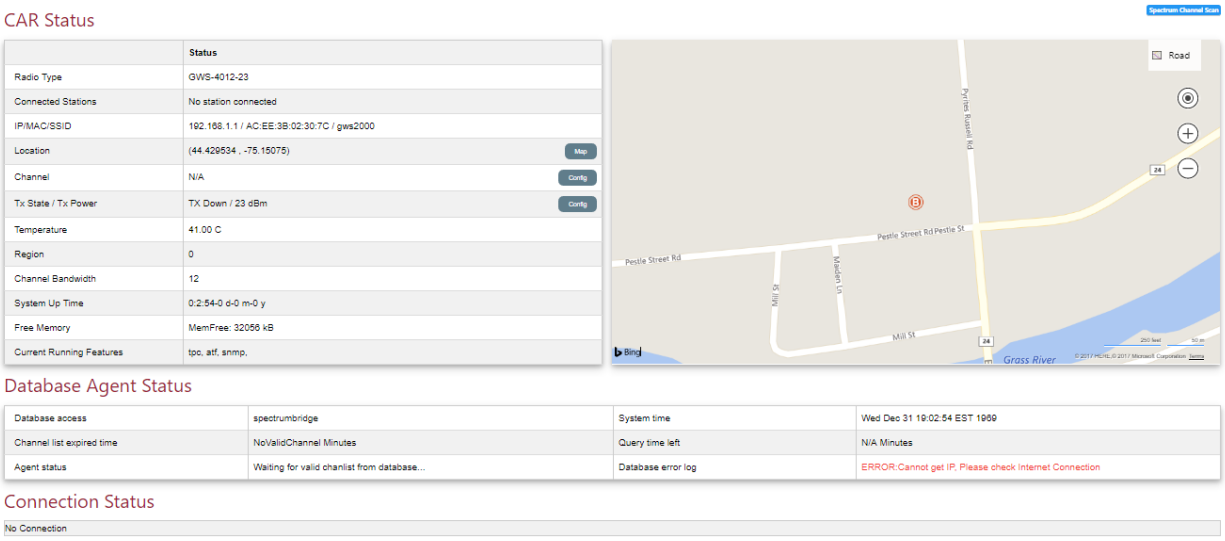


Open the ethernet adapter properties-and set to 192.168.1.99/ 255.255.255.0

Configuring the Base Station

- Connect the data port of the POE midspan to the ethernet port on the laptop.
- Connect the data plus power port of the midspan to the radio.
- Power up the midspan
- Open Chrome and open the radio GUI using the default IP address https://192.168.1.1[42]
- Login as normal

[42] Or use Djinni.



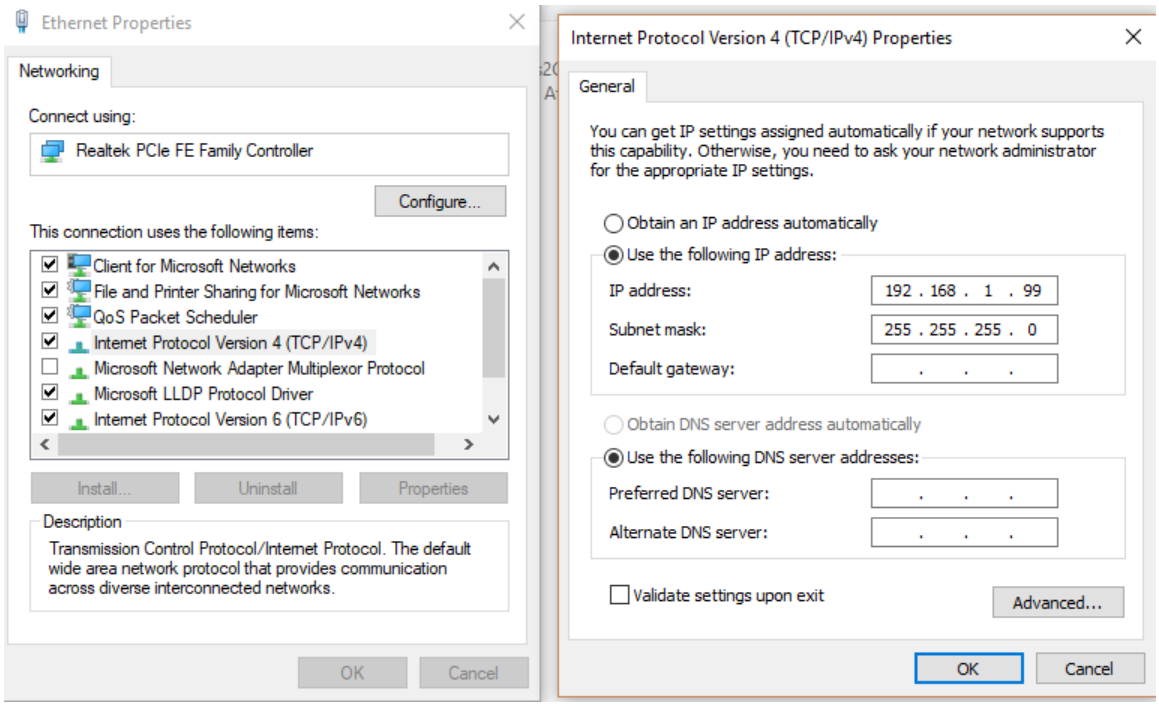
If the GUI comes up as above:

(a) The laptop has an internet connection via the WiFi connection (you know this because the map appears).

(b) The laptop has a connection to the radio via the ethernet port (you can login to the radio)

(c) The radio does not have a connection to the internet, most likely because the radio and the ethernet port have incorrect gateway/DNS or other IP network related settings.

To correct this problem, make sure the ethernet IP port on the laptop as follows:

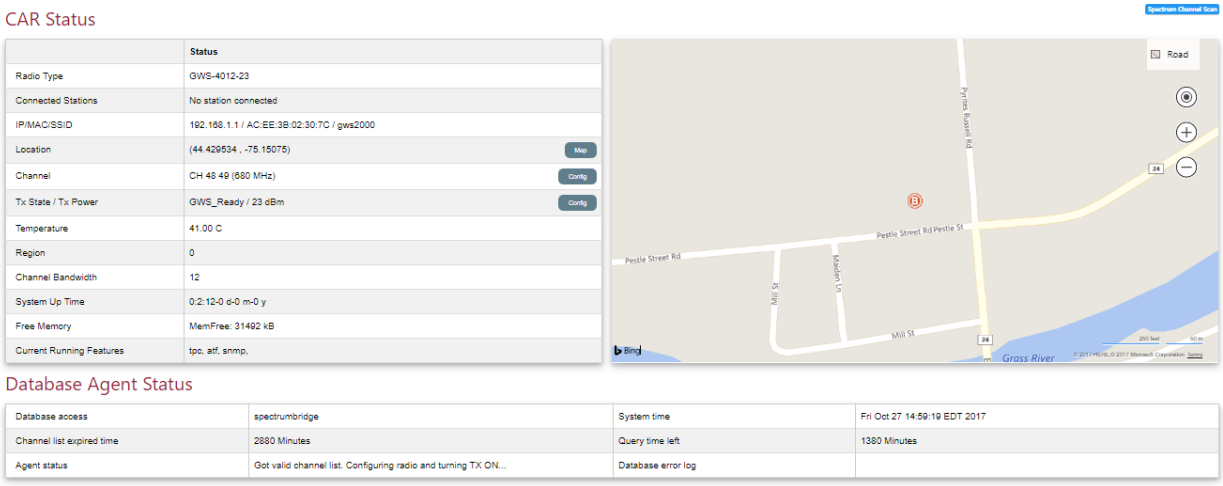


Now the laptop ethernet port is the gateway to the internet for the radio.

Set the radio IP parameters as follows:

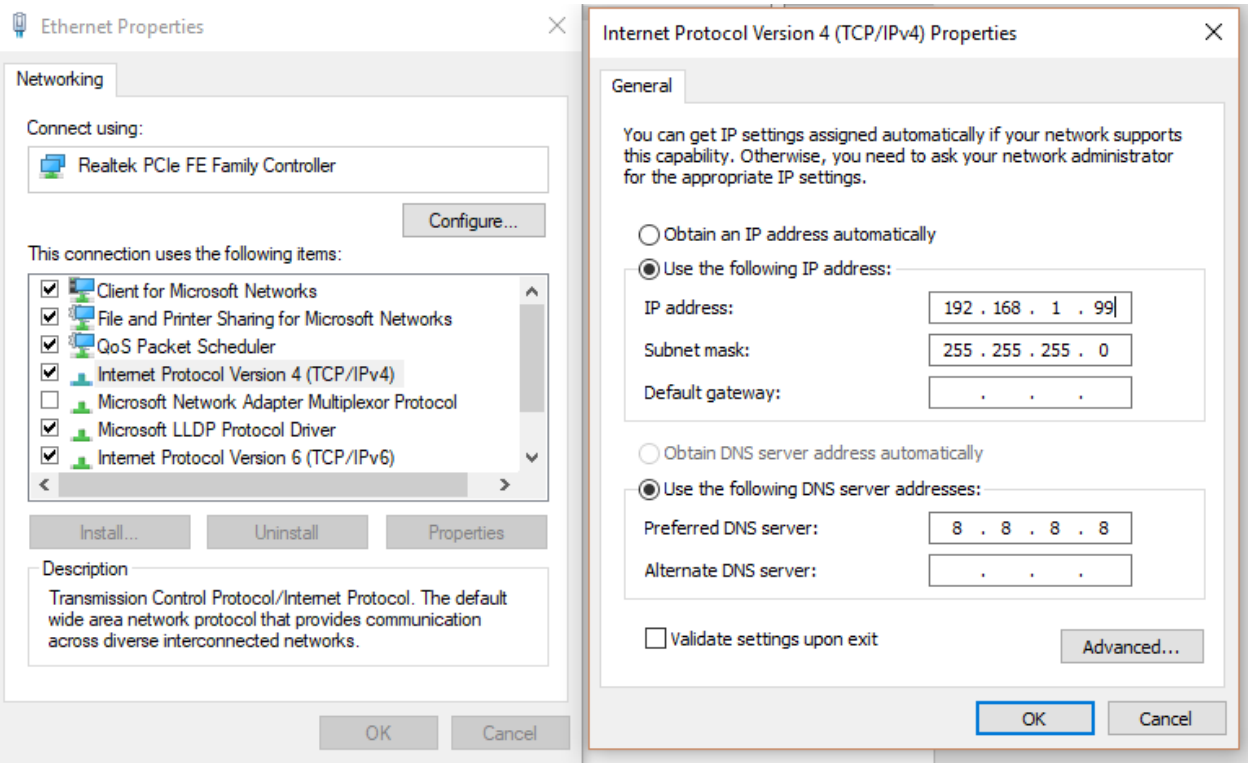
Don't forget to save and log back into the radio to avoid issues from the roll back feature!

Now the radio will be able to access the internet via the shared internet connection (I.e. ICS) and should be able to make a successful database enquiry and turn the radio on. At this point the monitor page that follows shows that the base station radio is working fine.



Use the LAN / WAN Diagnosis Tool on the Monitor Page to diagnose if there are any issues with database access.

TIP: Depending on what version of Windows is used you may have to make sharing available first. When sharing is available, also check that HTTPS is turned on as a service. The database uses HTTPS.



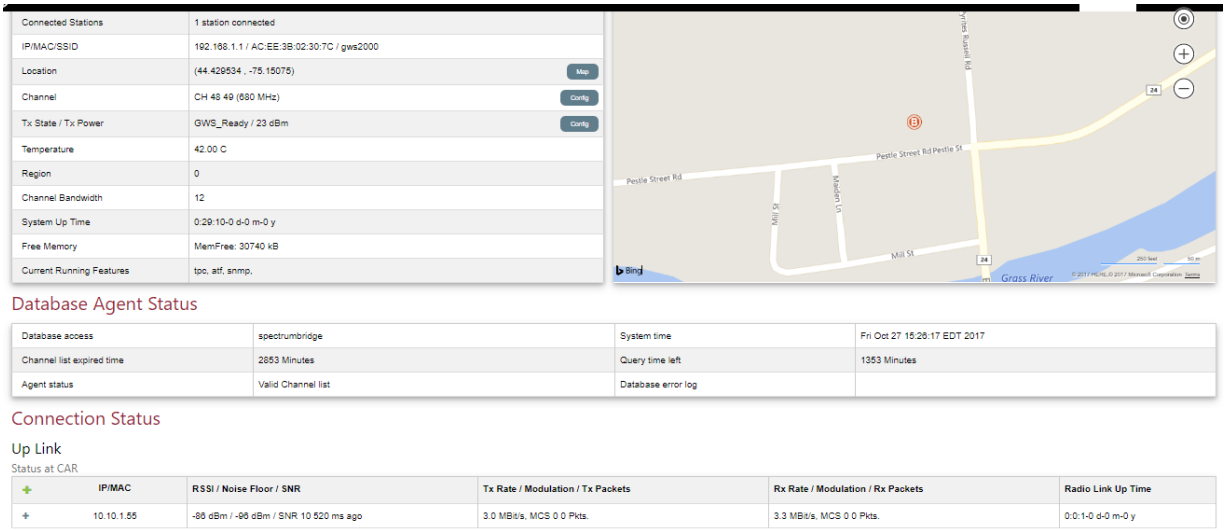
Connecting a Client Station to the Base Station

Configure the second laptop ethernet adapter to 192.168.1.150; subnet 255.255.255.0; gateway as per the ethernet adapter providing internet access (192.168.1.99).; DNS 8.8.8.8.

Configure the client station to 192.168.1.200; subnet 255.255.255.0 and gateway as per the ethernet adapter on the laptop (192.168.1.99). DNS 8.8.8.8.

If for some reason the CPE IP settings are not correct the CPE will scan and connect for about 20-50 seconds. This is because the CPE is unable to get an internet connection and therefore will not get a valid channel list and the CPE TX will not stay on. The CPE will continue to scan after 20-50 seconds[43]. A full scan takes about 5 minutes.

In the screen shot below the IP address is incompatible with internet access. (This assumes that the CPE and the BTS have compatible SSID).

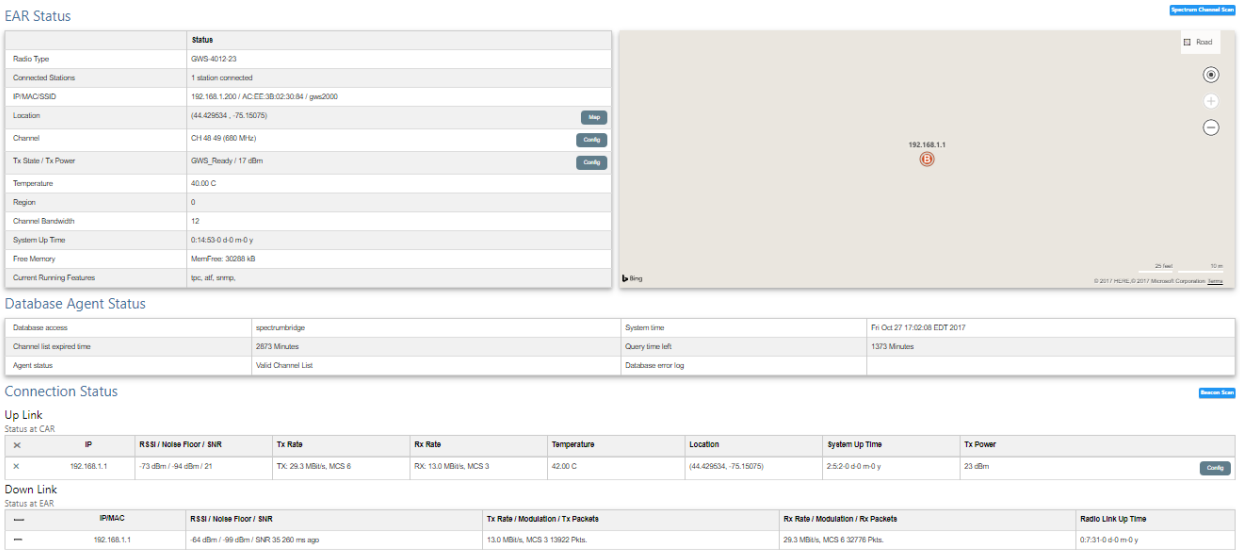


Here the PC is connected to the base station and consequently the laptop has internet access as the map is visible.

Below is the monitor status at the client station once the IP configuration has been set correctly.

[43] NB this behavior can also be observed if there is a channel availability mismatch between the Long/Lat co-ordinates of the CPE and the BTS. Check BTS channel is available at both CPE and BTS locations via online database.

CPE monitor page once CPE connected to BTS ***and*** CPE makes a successful database enquiry.



Now, the second PC is connected to the client station radio-and also has internet access since the map is visible.

Once this procedure has been completed the radios can be configured for the actual network they will be used on.

- Configure the base station first
- On the radio change the fixed IP, subnet, DNS & gateway, and save
- Connect the data port of the midspan to the real network
- Using the new IP configuration connect to the radio. (You will have to configure the ethernet adapter to be compatible with the real network).
- Restart the database agent and see if the radio is able to get a channel list and turn on the Tx.
- If the radio is able to get a channel list and turn on the Tx via the internet sharing BUT is not able to get a channel list when the radio is connected to the real network the issue is incompatible IP network settings between the radio and the network. Firewall settings can also be an issue.
- Similarly configure the CPE. It will scan and connect automatically (if the radio link is good).

TIP: If the CPE connects, *run the LAN diagnosis tool on the CPE immediately*. You have about 40seconds after the connection is made to check if the database query path for the CPE is correct. This is enough time to see if there is a problem or not.

Using a MiFi Hotspot to Configure a Client Radio with a Tablet

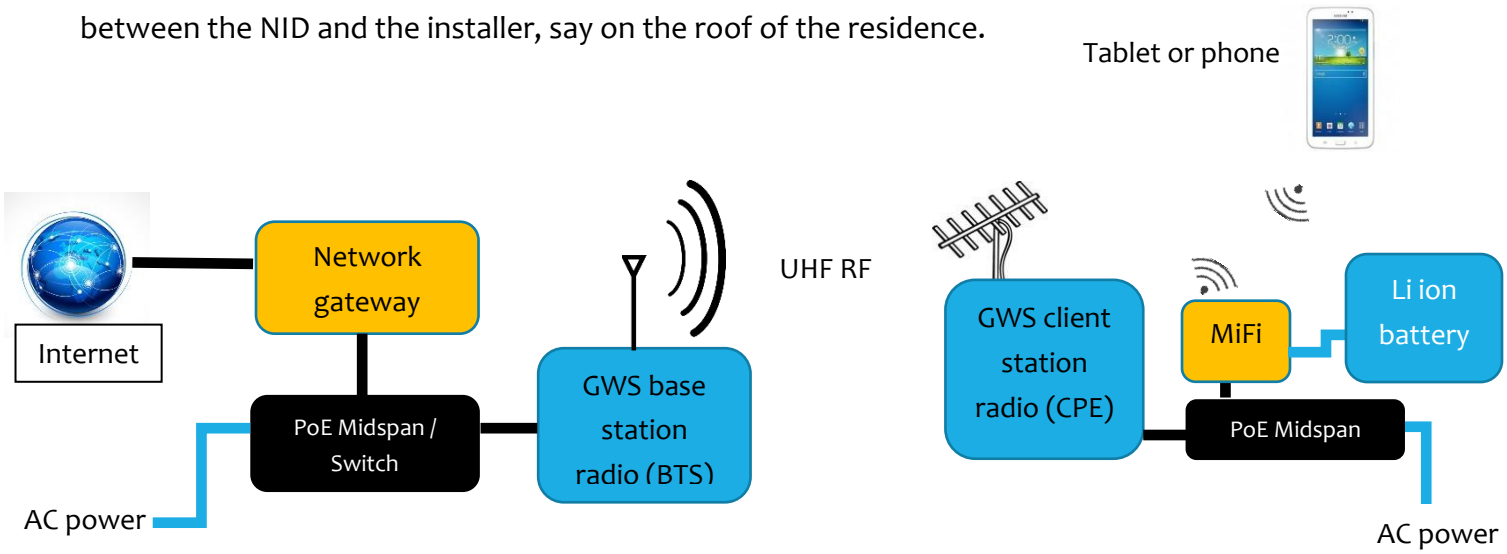
It is essential that installers are able to configure the client radio quickly and also align the client radio antenna to the strongest signal from the preferred base station. Because of the nature of the propagation of UHF signals the client station radio should be mounted as high as possible above ground level. This often requires the use of a ladder to install the radio-and in such a situation it is hard to see how the client radio connection is behaving. This situation can be addressed by adding a MiFi to the data port of the client station midspan during set up. The radio can then be accessed by the installer wirelessly via a tablet or phone that has access to the MiFi.

MiFi Unit

There are various MiFi units available. Typically, these are used to create a WiFi hotspot from a USB LTE stick. In addition, to the USB connector for an LTE stick the units have a RJ45 available which can be connected to the client station midspan data port to provide a WiFi hotspot, in the same way as a traditional WiFi router. Typically, these MiFi units are powered through a micro or mini USB connection, which can be connected to a Lithium battery pack.

These units can be used to create a battery powered WiFi hotspot which is backhauled via the GWS radios to the internet network gateway behind the TVWS radios.

Most MiFi units use 2.4GHz and 20MHz bandwidth so the range is sufficient for use outdoors between the NID and the installer, say on the roof of the residence.



Configuring the MiFi

Assume we will use the following internet settings:

Internet gateway is 192.168.0.1; Subnet is 255.255.255.0

Base station is 192.168.0.22; Subnet is 255.255.255.0

Client station is 192.168.0.100; Subnet is 255.255.255.0

We will allocate a fixed address to the ethernet port of the MiFi unit of 192.168.0.254.

We will set a limited range of DHCP addresses on the WiFi access point of the MiFi unit to be 192.168.0.250 to 253.

WARNING: This means allocating 192.168.0.250 to 254 as management IP addresses on the edge router behind the GWS base station radio and assuming 192.168.0.1 is the gateway address of the edge router.

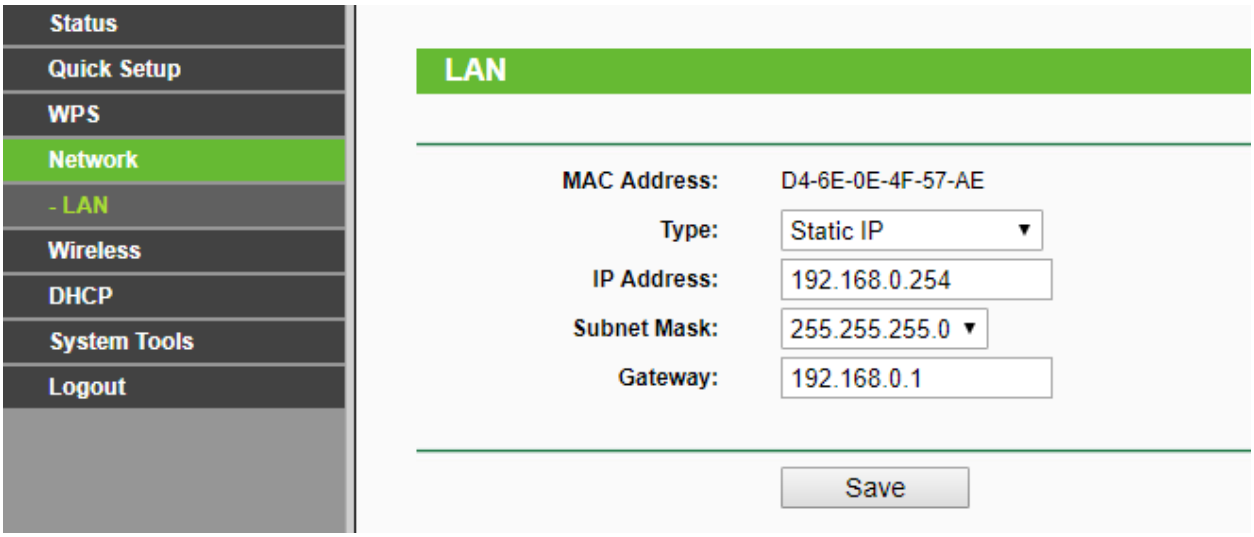
We will set the WiFi SSID to "6Harmonics Hub" and we will set the WiFi password to be 6harmonics.

A laptop, tablet of phone running Chrome is required.

LAN Configuration

Connect to the MiFi unit using the default settings provided with the unit.

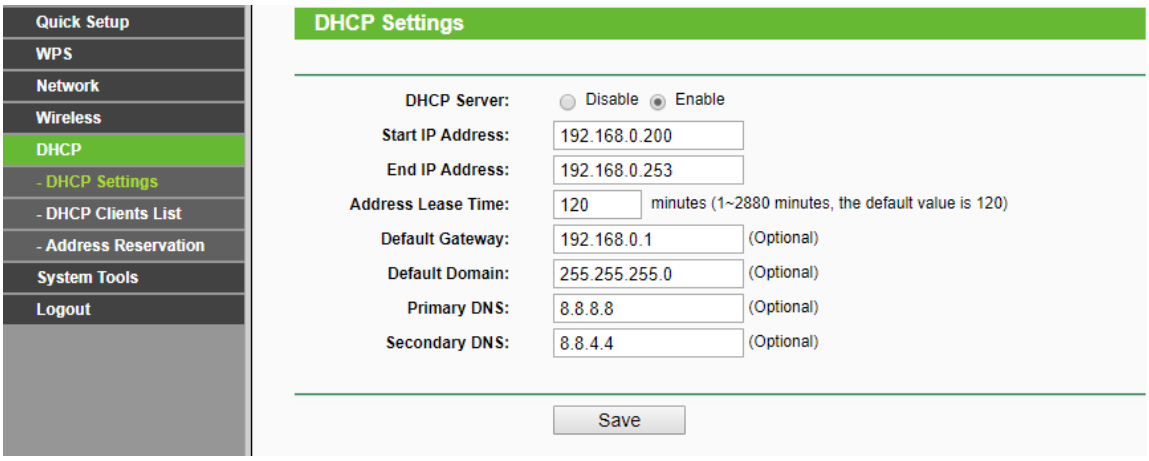
Set the ethernet first. In the unit GUI below, we set as follows:



The LAN port of the MiFi is now configured to be compatible with the data port of the POE midspan of the client radio, and more importantly the subnet of the GWS radios and the Edge Router gateway IP address.

WiFi Configuration

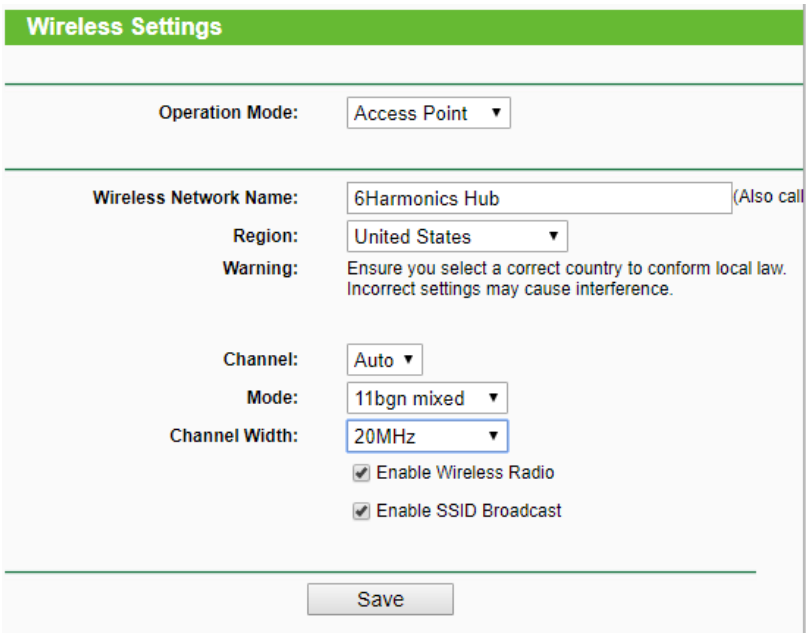
Remember the tablet, laptop or phone will connect to the WiFI access point of the MiFi unit. In order for the tablet to see the IP addresses of the CPE and the gateway it must be on the same subnet.



We enable DHCP & set a valid range for the IP addresses that will not cause an IP conflict (i.e. a range of addresses allocated to management).

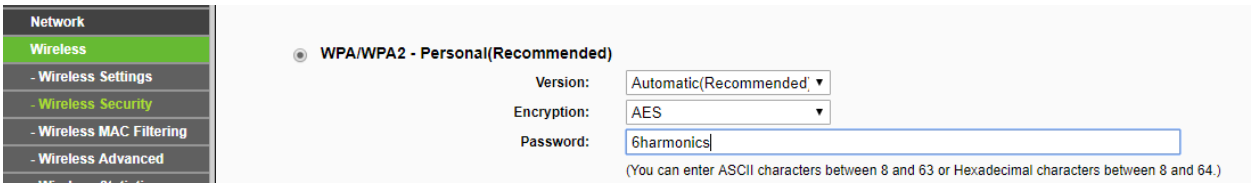
NOTE: The gateway for the DHCP WiFi access point of the MiFi unit is the edge router gateway IP address.

Set the SSID and other WiFi settings:



We use 20MHz to maximize the range of the WiFi signal from the MiFi to the tablet/phone.

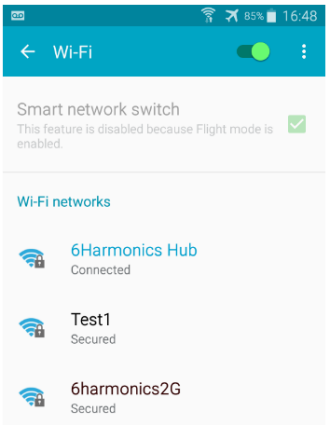
Set the WiFi password:



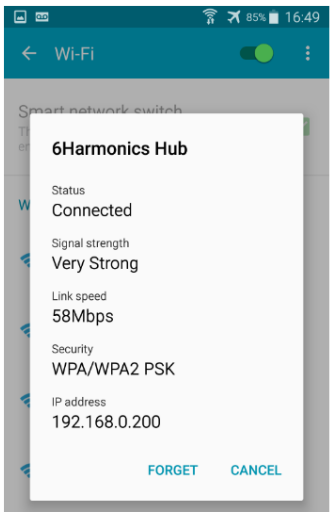
Connecting to the GWS Radio via the WiFi Access Point of the MiFi Unit

Connect the MiFi Unit LAN port to the data port of the midspan attached to the client station GWS radio using a Cat5e cable.

Connect a tablet or similar, to the WiFi of the MiFi unit using the SSID of "6Harmonics Hub", and the password of "6harmonics".

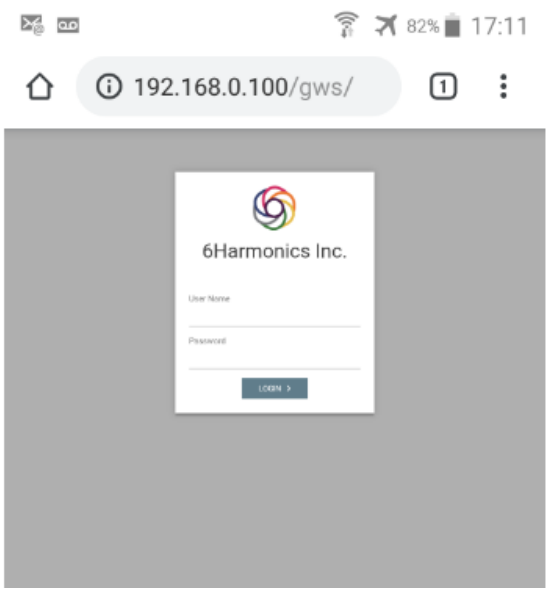


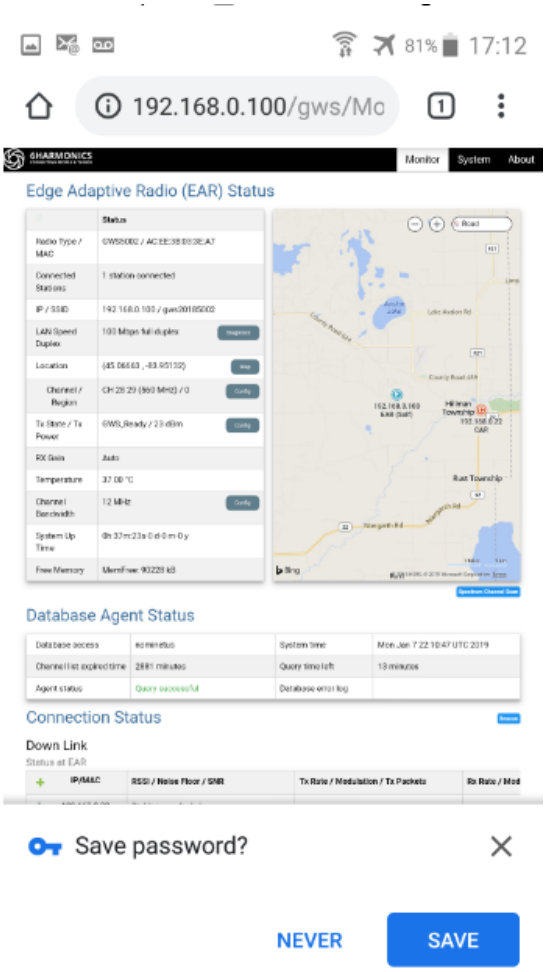
On Android devices a user can check the details of the connection of clicking the 6Harmonics Hub icon to reveal:



We can see that the tablet has pulled a DHCP address of 192.168.0.200, i.e. part of the previously pre-defined management IP pool.

On the tablet or phone open Chrome and login in to the client station GWS radio using 192.168.0.100. Enter the username and password & the main GUI for the client station radio will open:

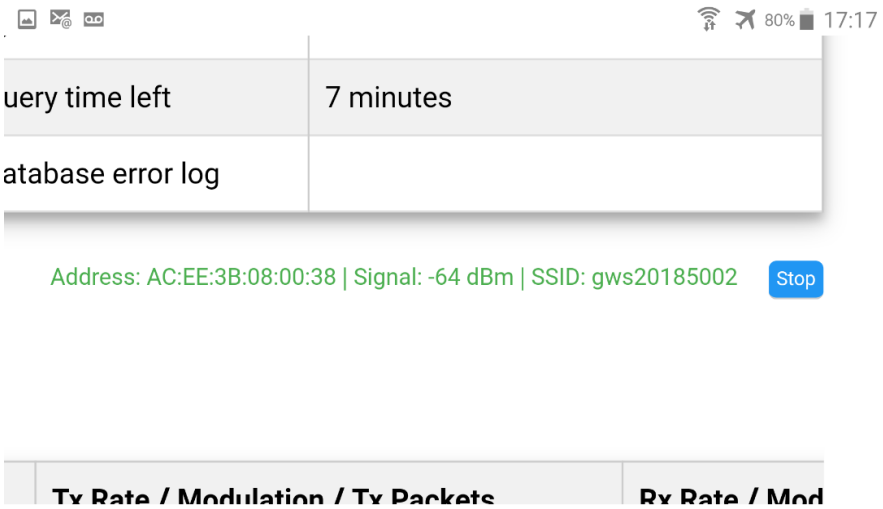




The password can be saved.

WARNING: In the example above the client GWS radio has connected to the base station. The tablet has then been able to obtain an IP address from the MiFi and also gain access to the internet. We know the tablet has access to the internet because the map appears. If the client station GWS has NOT connected to the base station the tablet will not have internet access. More importantly the MiFi unit will NOT have internet access either. In some cases when a tablet attempts to connect to a WiFi network that does NOT have an internet connection the tablet will reject the attempt to connect and will look for a WiFi network that does have internet access. This can be resolved by checking the settings on the tablet to ensure the tablet will connect to a WiFi network that does not have an internet connection. Laptops will always connect.

Zoom in to the beacon button on the GUI, click on the beacon button and the signal strength will be displayed.



The installer can now align the antenna to the strongest signal.

The installer can run speed tests or other network diagnositics available on the tablet.

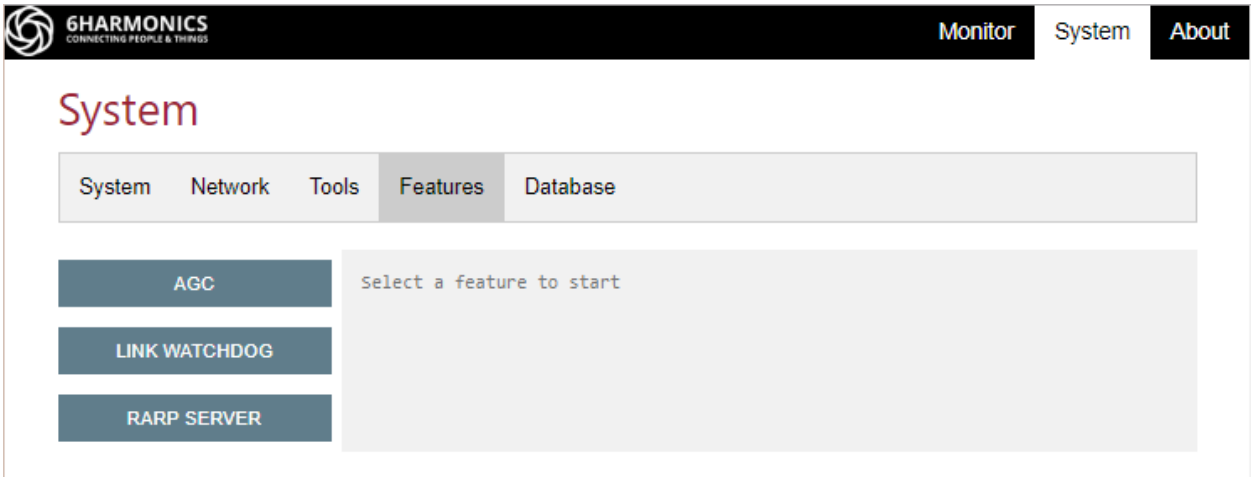
The installer can check all settings of the client station radio, for example the manaul input of Longitude & Latitude simply by sweeping/expanding the GUI on the tablet. Most phones / tablets have in built GPS and it is a simple matter to use the appropriate application on the phone / tablet to get the Longitude / Latitude values.

Summary:

- We configured a battery operated MiFi unit to act as a portable WiFi access point with backhaul over the GWS radio link.
- We used a tablet or phone to access the GWS radio over WiFi.
- A wired connection to a laptop is not required to access the client station radio, only a wireless connection to a tablet or phone is needed in the field.
- The set up can be used at any additional client station installation, so long as the client radio has a pre-configured IP address that is compatible with the rest of the network i.e. part of the management IP pool.
- Using a MiFi unit as above avoids some of the potential frustrations with ensuring the IP configuration of the laptop ethernet port is set correctly. Accessing the radio using a fixed range of management IP addresses using DHCP over Wifi guarantees avoidance of this problem. The reliance on a long fixed cable connection between the device and the POE used for configuration is also eliminated. Only a short Cat5e cable between the MiFi and the client radio POE is needed. A Li ion battery pack can easily continuously power a MiFi for a day or more.

Features

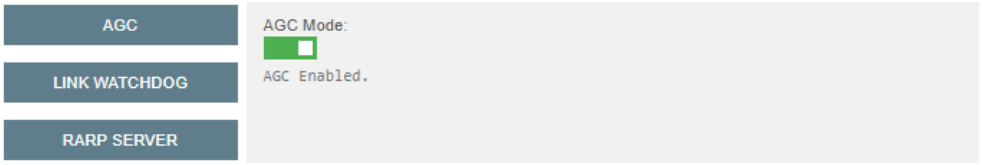
The features tab can be accessed from the System Tab.



If a feature is available, it will appear as above.

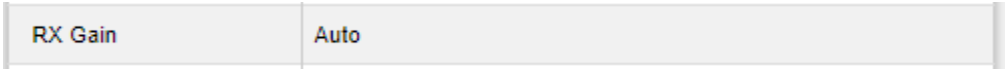
Automatic Gain Control (AGC)

Click on the button to access the AGC window.

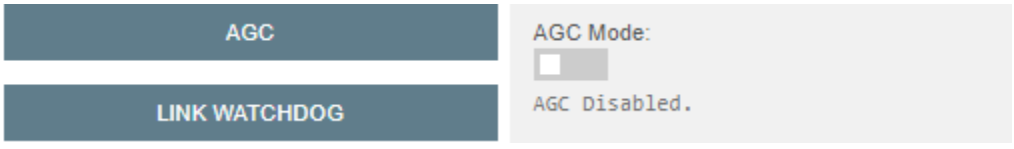


Click on the AGC Mode slider to toggle AGC between enabled / disabled.

If enabled check the Radio Status window on The Monitor Tab shows “Auto” in the RX Gain section.



For most deployments the GWS radio should have AGC enabled. However, under some circumstances, such as where there is significant noise and interference, to maintain link stability AGC should be disabled.



The RX gain may now be set manually using the pull down menu on the monitor tab. Don’t forget to Save!

The choice of manual RX gain is determined by the best SNR and MCS the radio link exhibits.

WARNING: Do not use RSSI or Noise as metrics to determine the optimum RX Gain. The optimum RX Gain is when the radio link has maximum throughput, so use SNR and MCS as the metrics to determine the manual RX Gain setting.

ATF
Reserved

Client RTS
Reserved

Security (PSK)
Reserved

TDMA
Reserved

SNMP
Reserved

Link Watchdog

Click on the Link Watchdog bar to display the Link Watchdog window:

The display shows the link watchdog version and status. The display should show **"2 5 50"**

```
----- linkwatchdog processes ---------------
linkwatchdog running on: 2 5 50
```

What does this feature do?

The GWS radios are based on a WiFi protocol which, as discussed previously, is a listen-before-talk (LBT) protocol. As many users will have experienced, a WiFi client station will rapidly reconnect to a WiFi access point (AP) if the link is broken, say the client moves away from the AP and then moves back towards the AP. Equally, noise or interference may break the WiFi link, and again the link will quickly re-establish itself once the SNR is sufficient. In these cases where the link is broken, the WiFi protocol will automatically start a process on the client station where it will try to reconnect back to the base station. Equally, processes run on the AP looking for clients that want to attach to the AP. Implicitly, the LBT protocol of WiFi is a robust protocol in the presence of noise, interference, signal multipath fading or unstable RF environments. It is ideal for unlicensed spectrum that is shared.

In most cases of GWS radio deployment the radio locations are fixed. The link can only (most likely) be broken intermittently by noise or interference. If the link is broken, the reconnect processes on the CPE and BTS radios will start. On the GWS radios, these processes are initiated by the Link Watchdog. Literally: the *watchdog of the link*.

Once the GWS radios reconnect, the link stabilization message appears in the Connection Status window, and after 2 mins the link statistics are displayed.

The default settings of the Link Watchdog for initiating reconnect processes are generally acceptable for most RF environments, even with significant intermittent noise and / or interference. In extreme cases, the settings on the Link Watchdog are too sensitive and the reconnection processes will be continuously triggered.

In these extreme cases, the Connection Status window on the Monitor tab will show “link stabilizing” continuously as the link is constantly broken, re-established and broken again. In terms of throughput, a residential router behind the client station radio will see a very unstable internet connection which appears fine for a few seconds and then is broken. In this case the Link Watchdog settings may need to be changed to reduce the sensitivity to triggering the reconnect processes. Contact 6Harmonics if you experience unstable links and you believe different Link Watchdog settings are required to improve link stability. Reducing the MCS range should also be considered.

Summary: The Link Watchdog enables rapid reconnect of the radio link if broken by noise or interference. If the link is exposed to very high levels of noise and interference and is unstable as indicated by continuous display of “link stabilizing”, the Link Watchdog settings may need adjustment.

QOS

Reserved

VLAN

Reserved

Troubleshooting

Troubleshooting suggestions to resolve common issues that may arise during setup and operation:

Symptoms	Possible Cause	Actions	Details
Unable to access the radio	POE cables or power cord are not properly connected	Check to see if POE LEDs are on. Check cable for continuity. Check AC power or DC power supply.	AC LED not on, AC power cord not plugged in
			POE Ethernet cable not powering GWS radio. Bad ethernet cable or connector.
		Check if PC ethernet LED is on and blinking. Check cable for continuity.	No datalink. Bad ethernet cable or connector.
	PC IP Address not on the same subnet	Use the Djinni tool	Reconfigure IP settings on PC and or radio
Cannot access radio unit with new IP after re-configure IP address	New IP may not have taken effect	Use Djinni, change IP setting and login to fully implement changes	Roll back implemented
		Use Chrome to access radio and set IP.	Non-standard browser?
	Intermittent access to radio from PC.	Use a PC with an RJ45	USB to ethernet emulator?
		Check settings such as public / private network on the PC do not cause conflict. Wait sufficient time for network authentication to complete.	Security setting on PC inhibits network authentication?
Cannot establish radio link	Are transmitter and receiver turned on?	Check database access and status.	Does the Radio Status window on the Monitor tab show TX ON or GWS_Ready?
	Are both BTS and CPE on the same RF settings?	Check the Radio Status window on Monitor tab?	Check bandwidth & channel number to see if they are same
	RSSI too strong	Lower T_X Power	Lower T_X power via GUI
	RSSI too weak	Increase T_X Power	Increase T_X Power via GUI

	Interference – the current channel has strong interference or noise	Change to different channel	Change to different channel **at both radios**.
Link performance poor	Link imbalanced, signal too weak or strong	Adjusting T_X power and / or RX gain	Increasing or lowering T_X power to adjust SNR and MCS within optimum range.
No connection even though radios indicate TX on, and link was previously fine.	Assuming link was previously operational likely a RF issue	Run the channel noise scan at both ends.	If you cannot see the TV signal markers then likely an issue with RF, check antenna alignment and RF cables.
Connection becomes unstable and Connection Status continuously shows "link stabilizing"	Interference and / or Noise	Review Link Watchdog settings. Reduce the MCS range.	If the Radio Link uptime does not last more than a few minutes likely unstable RF environment.
During a bench-test, field survey or install, radio operates then suddenly access is lost.	Radio has been hot-swapped multiple times i.e. powered up / down by inserting / removing the RJ45 on the Cat5e to the POE.	DO NOT HOT SWAP RADIOS. Radios use 4 pair POE. Contact 6Harmonics for repair.	Ethernet port and / or POE splitter on the radio has been damaged.
After a power outage or POE is exposed to significant surge the radio is not accessible.	Radio is in re-boot cycle.	If the radio does not reboot within 2 minutes remove power cord from POE, wait 10 seconds. Re-insert power cord. If the radio is a base station login to the POE switch, disable the power to the POE port, wait 10 seconds then re-enable the power to the POE port.	If the radio does not come back within 2 minutes after power cycling the POE power supply the surge has damaged the ethernet port. The ethernet port is tested to 10kV under EN 301.489-1. An additional NID surge suppressor is always recommended to reduce the likelihood of this event.
SNR is good but MCS is poor, throughput is poor.		Pass traffic and see if MCS changes	No packets are being transported and link has downclocked to a low MCS
		Check if PSK enabled	PSK consuming too much overhead.

		Change channel or contact 6Harmonics in case additional external filtering required.	Interference
The CPE scans onto the base station channel and connects for ~1 second and continues to scan		Check SSID and IP parameters on CPE to ensure correct with base station and edge router settings	CPE not validated on base station.
The CPE scans onto the base station channel and connects for ~40 second and continues to scan.		Check IP settings and if CPE has internet access, Use LAN Diagnosis tool during the 40 second window	CPE unable to complete a database query and get a valid channel list.
		LAN Diagnosis is a pass and CPE has a valid channel list, but CPE still continues to scan. Check BTS and CPE channel setting is available in both BTS and CPE channel list.	Geolocation error and / or channel availability mismatch between client and base station.
Long Ping times and packet loss		Check IP configuration	IP loop; IP and subnet combination not allowed[44].
Radio not operational after a power outage.		Replace radio and make sure a grounded ethernet surge suppressor is installed. Check AC power ground.	Power surge on restart has damaged ethernet port and /or POE splitter inside the radio.
Aggregate throughput of base station lower than expected		Check base stations cannot hear each other using the beacon scan tool	Base stations on the same channel will share the aggregate throughput if they can hear each other's beacon signal.
		Check the traffic statistics on the Edge Router behind the base station. Look for "bad actors" consuming too much airtime. Throttle throughput to the residential router IP address of bad actors in DOWNLINK only.	Too many clients on a base station to manage the traffic patterns. Do not throttle uplink traffic as this will consume too much airtime of the base station.
		Enable ATF	

[44] See http://www.subnet-calculator.com/

		Enable TDMA	

Other

Security

The 6Harmonics wireless network solution establishes wireless links between base stations and client stations as a Layer 2 link. As such security can be implemented at the application layer as an end-to-end security approach between the end user and the data source such as a banking website. This ensures that links can be made as secure as applications allow.

If there is no end-to-end security implemented the wireless link itself can be PSK encrypted at Layer 3 (IP packet) with 128AES.

Warranty

All equipment purchased from 6Harmonics is guaranteed for a period of one year (12months) from the date of shipment from their supplier on a replacement basis for the geographic region in which it was purchased. If a unit is re-installed in a geographic region outside the area for which it was originally purchased the warranty is void even if it is still within the original warranty period.

If any GWS radio units are installed that do not use antennas or PoE midspans approved 6Harmonics the warranty is void.

Any customers that purchase from a reseller or distributor should contact their reseller or distributor for a replacement first.

Customers that purchase from 6Harmonics should contact 6Harmonics for a replacement.

Before shipping back to either a reseller, distributor or 6Harmonics customers must obtain a return authorization (RAN) code from their supplier.

Extended warranties can be purchased. Please discuss with your supplier at time of ordering.

Terms and Conditions of Sale

GWS radios from 6Harmonics are subject to 6Harmonics standard terms and conditions of sale which can be found on the 6Harmonics web site **www.6harmonics.com** .

Database Tokens

Database tokens should be specified at time of ordering.

Service and Support

6Harmonics is committed to providing customer service before, during and after equipment sales.

For 30 days after equipment purchase 6Harmonics will provide unlimited online or phone support to help customers complete an installation.

After 30 days phone support is chargeable unless a service agreement is purchased as part of the equipment purchase.

Onsite engineering support is available from 6Harmonics for design, installation and ongoing maintenance. Onsite service is charged on a per diem basis. Travel is charged at cost. Travel time is charged at full rate. Please contact 6Harmonics for rates.

For deployments consisting of multiple base stations 6Harmonics recommends purchasing a service contract with the equipment purchase.

Training

6Harmonics is committed to providing training to resellers, distributors and installers.

Level 1 training is given on a regular basis at 6Harmonics main office on a first come, first served basis. There is no charge for Level 1 training. Attendees must cover their own travel and accommodation costs.

Level 1 training covers the content of this deployment guide with hands on configuring of all the different GWS series radios. Level 1 training will typically suffice for establishing a point-to point link.

Level 2 training is provided to professional installers and network management professionals who will install and maintain wireless networks using 6Harmonics equipment. Level 2 training is given at either the customer's site or at 6Harmonics main office on "as-needs" basis. Level 2 training can be in a shared or customized format depending on the customer's needs and is charged accordingly.

Level 2 training covers network design based on propagation models, installation, network optimization, and detailed software configuration. 6Harmonics recommends Level 2 training before deploying a multiple base station network.

Appendix

Regulatory

Key regulatory considerations for deployment are summarized in the following table:

Country / Regulatory Body	ITU Region	Allowed Frequency Range (MHz)	Antenna Height AGL Max (m)	EIRP Max per DTT channel (dBm)	Channel Plan	Database Provider(s)
UK / OFCOM[45]	1	470-790	30	36	1	Nominet
USA / FCC[46]	2	470-698	100	40	0	Nominet
Canada / ISED	2	470-698	30	40	0	TBD
Singapore / IDA[47]	3	478-738			0	TBD
New Zealand/RSM[48]	3	510-606			1	TBD
South Africa	1				1	TBD
Colombia	2				0	TBD
Trinidad & Tobago	2				0	TBD

[45] https://tvws-databases.ofcom.org.uk/

[46] https://www.fcc.gov/general/white-space-database-administrators-guide

[47] https://www.ida.gov.sg/Policies-and-Regulations/Industry-and-Licensees/Spectrum-Management/Spectrum-Planning/TV-White-Space

[48] http://www.rsm.govt.nz/projects-auctions/completed/television-white-space-licensing-rules/television-white-space-licensing-rules-consultation/television-white-space-devices-certification-and-licensing-rules.pdf

Database Parameters

TVWS Data Base Parameters by Database Provider & Regulatory Domain

Parameter	T_{update} *(Channel Validity on Radio)*	$T_{valididity}$ **(Channel Validity at database)**	N *(Weblisting of database URL Validity)*
OFCOM	15 minutes	1440 minutes	1440 minutes
Nominet Test Database (sandbox)	60 seconds	57 minutes	65 minutes
GWS radio capability	30 seconds	30 seconds	30 seconds

Please note $N>T_{validity}>T_{update}$

The way the database query processes work as follows:

The regulator provides a list of approved databases, as a list of URLs -this is the Database Weblisting[49]. Included in the string from the database weblisting is the time that this weblisting is valid, this variable is defined as "N".

Now the radio goes to the database to obtain a valid channel list for a given location[50]. This list of operational parameters is valid for $T_{validity}$.

The radio must then update the database[51] every T_{update} with the operational parameters it actually using to ensure they are allowed with respect to the operational parameters in the database.

[49] If a database were to lose certification the regulator would remove it from the Database Weblisting within N

[50] If, for example, a channel were to be removed from the database the change would be implemented within $T_{validity}$.

[51] If a change in the channel list operational parameters occurs, then the radio will update within T_{update}. In other words, the longest a radio can operate with operational parameters that are not valid in the database is T_{update}.

Regulatory Notice USA

See FCC Regulatory Notice.

Regulatory Notice Canada

Declaration of RF Exposure Compliance for Exemption from Routine Evaluation Limits

ATTESTATION: I attest that the radiocommunication apparatus meets the exemption from the routine evaluation limits in Section 2.5 of this standard; that the Technical Brief was prepared and the information contained therein is correct; that the device evaluation was performed or supervised by me; that applicable measurement methods and evaluation methodologies have been followed; and that the device meets the SAR and/or RF field strength limits of RSS-102.

Signature: _____ Date: _____

NAME: Dr Michael Davies

TITLE: VP, Business Development

COMPANY: 6Harmonics Inc

PRODUCT MARKETING NAME (PMN): GWS 5000 Series

HARDWARE VERSION IDENTIFICATION NO. (HVIN): 20750-GWs-5002

FIRMWARE VERSION IDENTIFICATION NO. (FVIN): TBD

HOST MARKETING NAME (HMN): NA

IC CERTIFICATION NUMBER: TBD

Technical Brief RF Exposure Limits

ISED requires the maximum permissible exposure at 20cm separation distance to the user / bystander to be declared following RSS-102[52]. Since the distance between the user / bystander in normal operation exceeds 20cm then as per Section 2.5.2 Exemption Limits for Routine Evaluation – RF Exposure Evaluation

"RF exposure evaluation is required if the separation distance between the user and/or bystander and the device's radiating element is greater than 20 cm; except when the device operates as follows:"

"at or above 300 MHz and below 6 GHz and the source-based, time-averaged maximum e.i.r.p. of the device is equal to or less than 1.31×10^{-2} f0.6834 W (adjusted for tune-up tolerance), where f is in MHz"

Assume the highest frequency is 698MHz then $698^{(0.6834)}$=87.8

Therefore: $1.31 \times 10^{-2} \times 87.8$=1.15W is the RF exposure limit at 20cm separation distance from the antenna or 30.6dBm.

Free space loss over 20cm is 15.34dB at 698MHz.

Maximum EIRP from the antenna is 42dBm, so at 20cm separation distance, the maximum EIRP is 42-15.34dBm=26.66dBm or 463mW.

The maximum allowed exposure is 1.15W or 30.6dBm.

Compliance margin is 30.6-26.66=3.94dB or 59.7% {(1150-463)/1150 expressed as a percentage}.

[52] https://www.ic.gc.ca/eic/site/smt-gst.nsf/vwapj/rss-102-issue5.pdf/$file/rss-102-issue5.pdf

Regulatory Notice UK

Manufacturers Declaration

These radios are provided with a separate EU Declaration of Conformity (DoC) which states that these radios are imported, sold or distributed in the EU subject to meeting the requisite EN standards.

Base Station

Unique identification of the product:

GWS-5002

Software load BTS

Name and address of the manufacturer:

6Harmonics Inc.

Suite 10

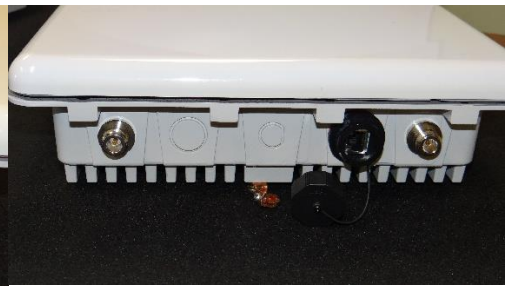
21 Concourse Gate

Ottawa

K2E 7S4

This declaration of conformity is issued under the sole responsibility of the manufacturer, 6Harmonics Inc.

Object of the declaration



The object of the declaration described above is in conformity with the relevant European Community harmonization legislation:

- Electromagnetic Compatibility Directive (2014/30/EU)
- Radio Equipment Directive 2014/53/EU
- Restriction of Hazardous Substances in Electrical and Electronic Equipment (RoHS)
- General Product Safety Directive 2001/95/EC

References to the relevant standards used (or references to the specifications in relation to which conformity is declared):

- EN 301 598 V1.1.1
- EN 301 598 V2.1.1
- EN 301.489-1

Notified Body

Notified body:	Nemko (1622)
Performed:	EN 301 598 V2.1.1 (2018-1)
Issued certificate number:	192101 20th June 2019

Client Station

Unique identification of the product:

GWS-5002

Software load CPE

Name and address of the manufacturer:

6Harmonics Inc.

Suite 10

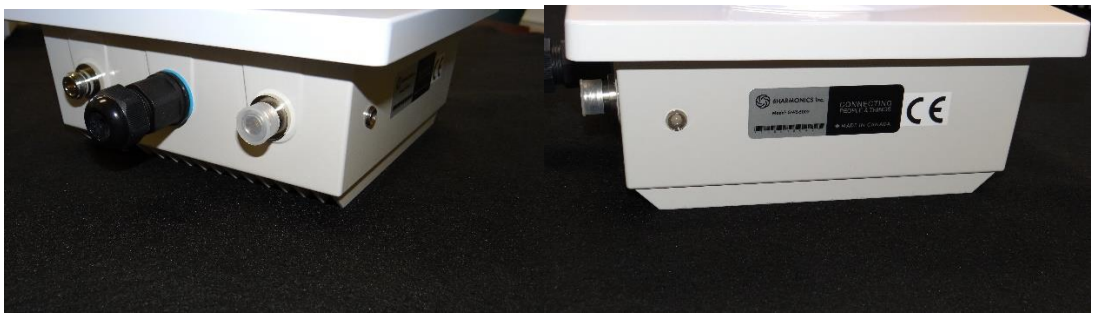
21 Concourse Gate

Ottawa

K2E 7S4

This declaration of conformity is issued under the sole responsibility of the manufacturer, 6Harmonics Inc.

Object of the declaration



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- EN 301 598 V1.1.1
- EN 301 598 V2.1.1
- EN 301.489-1

Notified Body

Notified body:	Nemko 1622
Performed:	EN 301 598 V2.1.1 (2018-1)
Issued certificate number:	192101 20th June 2019

Relationship between EN 301.598 and the essential requirements of Directive 2014/53/EU

U=unconditionally applicable; C=conditionally applicable.

Harmonized Standard ETSI EN 301.598					
Requirement				Requirement Conditionality	
No	Description	Status	Reference / Clause Number	U/C	Condition
1	Nominal Channel Bandwidth	24MHz	4.2.3	U	
2	Total Nominal Channel Bandwidth	470-774MHz	4.2.3	U	
3	RF Power	28dBm/8MHz (Class 1)	4.2.4	U	
4	RF Power Spectral Density	<11dBm/100kHz	4.2.4	U	
5	Transmitter Unwanted Emissions	Class 1 Pass	4.2.5	U	
6	Transmitter Reverse Intermodulation	Pass	4.2.6	U	
7	TVWSDB Identification	Pass	4.2.7.2	C	Master only
8	Data exchange and compliance with parameters	Pass	4.2.7.3	C	
9	Master TVWSD update	Pass	4.2.7.4	U	
10	Slave TVWSD update	Pass	4.2.7.5	C	
11	Receiver blocking	Pass	4.2.8	U	
12	Receiver spurious emissions	Pass	4.2.9	U	
13	Geo-location capability	Pass	4.2.10	U	
14	Software, Firmware and User Access Restrictions	Pass	4.2.11	U	
15	Security Requirements	Pass	4.2.12	C	

Product Information and Operational Parameters

Master

Parameter	Description
Antenna Location	Longitude and Latitude are displayed on the Monitor page in real time with a 1Hz refresh rate.
Antenna Location Uncertainty	Better than 50m with a 95% confidence level. Unless the GPS returns an uncertainty better than these values the radios will display "No GPS Fix"
Device Type	Type A or Type B: Dedicated External antenna, single spatial stream with receive diversity OR MIMO.
Device Category	Master
Unique Device Identifier: Manufacturer Identifier	MAC address displayed on the Monitor page, e.g. AC:EE:3B:03:3E:BA
	First three fields of the MAC address are unique to 6Harmonics i.e. ***AC:EE:3B***:XX:XX:XX
Unique Device Identifier: Model Identifier	Displayed on the System Tab in the Firmware version window e.g. GWS-5002, and also on the enclosure body.
Unique Device Identifier: Serial number	Displayed on the System Tab in the Serial number window e.g. GWS-5002, and also on the enclosure body.
Technology Identifier	Displayed on the About Tab as a weblink to 6Harmonics Inc website
Device Emission Class	Software definable from 1 to 3 with automatic EIRP limit adjustment based on database channel availability.
Spectral mask Improvement	Assumes 0dB
Reverse Intermodulation attenuation improvement	NA
Operating Frequency Range	470MHz to 774MHz
Multiple DTT transmission	The device can support transmission in up to 3 contiguous channels
Nominal channel bandwidth	24MHz
Maximum channel bandwidth	24MHz
DTT channel range (8MHz)	Channel 21 to Channel 58 inclusive
Maximum PSD/100kHz	11dBm
Maximum EIRP	Conducted power plus antenna gain over 24MHz: 40.2dBm (database specifies limit)
Modulation	OFDM
Modulation Schemes	BPSK to 64QAM with 5/6 FEC
Antenna Connection	Female N type, 50 Ohm impedance
Antenna Gain Maximum	12dBi
Transmit Mode	CSMA, TDMA for Medium Access Control (Listen-Before Talk)
Horizontal Location Capability	Yes. Geolocation update every 3 seconds to meet Type B requirement
Vertical Location Capability	No
Access Restrictions	No user access to firmware that controls database exchange or RF operational limits, manufacturer access only.
Temperature Range	Normal: +20C Min: -40C Max: +50C
Power Supply	4 pair POE; 48-56V DC
Security Requirements	Authentication Key to access database server using TLS handshake
Regulatory Domains	UK (OFCOM)

Slave

Parameter	Description
Antenna Location	Longitude and Latitude are displayed on the Monitor page in real time with a 1Hz refresh rate from the GNSS. Location on Monitor page has 60 second update.
Antenna Location Uncertainty	Better than 50m with a 95% confidence level. Unless the GPS returns an uncertainty better than these values the radios will display "No GPS Fix"
Device Type	Type A or Type B: Dedicated External antenna, single spatial stream with receive diversity.
Device Category	Slave
Unique Device Identifier: Manufacturer Identifier	MAC address displayed on the Monitor page, e.g. AC:EE:3B:03:3E:BA
	First three fields of the MAC address are unique to 6Harmonics i.e. ***AC:EE:3B***:XX:XX:XX
Unique Device Identifier: Model Identifier	Displayed on the System Tab in the Firmware version window e.g. GWS-5002, and also on the enclosure body.
Unique Device Identifier: Serial number	Displayed on the System Tab in the Serial number window e.g. GWS-5002, and also on the enclosure body.
Technology Identifier	Displayed on the About Tab as a weblink to 6Harmonics Inc website
Device Emission Class	Software definable from 1 to 5 with automatic EIRP limit adjustment based on database channel availability.
Spectral mask Improvement	Assumes 0dB
Reverse Intermodulation attenuation improvement	NA
Operating Frequency Range	470MHz to 774MHz
Multiple DTT transmission	The device can support transmission in up to 3 contiguous channels
Nominal channel bandwidth	24MHz
Maximum channel bandwidth	24MHz
DTT channel range (8MHz)	Channel 21 to Channel 58 inclusive
Maximum PSD/100kHz	11dBm
Maximum EIRP	Conducted power plus antenna gain over 24MHz: 40.2 dBm (database specifies limit)
Modulation	OFDM
Modulation Schemes	BPSK to 64QAM with 5/6 FEC
Antenna Connection	Female N type, 50 Ohm impedance
Antenna Gain Maximum	12dBi
Transmit Mode	CSMA, TDMA for Medium Access Control (Listen-Before Talk)
Horizontal Location Capability	Yes. Geolocation update every 3 seconds to meet Type B requirement
Vertical Location Capability	No
Access Restrictions	No user access to firmware that controls database exchange or RF operational limits, manufacturer access only.
Temperature Range	Normal: +20C Min: -40C Max: +50C
Power Supply	4 pair POE; 48-56V DC
Security Requirements	Authentication Key to access database server using TLS handshake
Regulatory Domains	UK (OFCOM)

Channel Plan

In most countries, TV channels use either a 6MHz or an 8MHz channel. The channels have a lower edge frequency, centre frequency and upper edge frequency. Even though the actual TV broadcast technology may change by country the TV channel number and associated lower edge frequency, centre frequency and upper edge frequency are defined as follows:

Channel Plan o

Each channel is 6MHz. Countries/regions using this channel plan include:
Americas (most countries), South Korea, Taiwan and the Philippines
Japan uses the same channel plan, but the channel numbers are 1 lower than in those countries; for example, channel 13 in Japan is on the same frequency as channel 14 in North and South America[53].

Channel	Lower edge (MHz)	Centre Frequency (MHz)	Upper edge (MHz)
14	470	473	476
15	476	479	482
16	482	485	488
17	488	491	494
18	494	497	500
19	500	503	506
20	506	509	512
21	512	515	518
22	518	521	524
23	524	527	530
24	530	533	536
25	536	539	542

[53] On 14 September 2009, Chile announced its decision to adopt the Japanese standard ISDB-T with MPEG-4 for digital terrestrial television, joining Argentina and Peru. ISDB-T (Integrated Services Digital Broadcasting-Terrestrial) in Japan use UHF 470 MHz-770 MHz, bandwidth of 300 MHz, allocate 50 channels, namely ch.13-ch.62, each channel is 6 MHz width (actually 5.572 MHz effective bandwidth and 430 kHz guard band between channels).

Channel	Lower edge (MHz)	Centre Frequency (MHz)	Upper edge (MHz)
26	542	545	548
27	548	551	554
28	554	557	560
29	560	563	566
30	566	569	572
31	572	575	578
32	578	581	584
33	584	587	590
34	590	593	596
35	596	599	602
36	602	605	608
37	608	611	614
38	614	617	620
39	620	623	626
40	626	629	632
41	632	635	638
42	638	641	644
43	644	647	650
44	650	653	656
45	656	659	662
46	662	665	668
47	668	671	674
48	674	677	680

Channel	Lower edge (MHz)	Centre Frequency (MHz)	Upper edge (MHz)
49	680	683	686
50	686	689	692
51	692	695	698
52	698	701	704
53	704	707	710
54	710	713	716
55	716	719	722
56	722	725	728
57	728	731	734
58	734	737	740
59	740	743	746
60	746	749	752
61	752	755	758
62	758	761	764
63	764	767	770
64	770	773	776

Channel Plan 1

Each channel is 8MHz. Countries/regions using this channel plan include:

United Kingdom, Ireland, Hong Kong, Macau, Falkland Islands and Southern Africa

Western Europe, Greenland, most countries in Asia and Africa, and most of Oceania

France, Eastern Europe, Former Soviet Union, French overseas territories and former French colonies in Africa.

NB Australia only uses 520MHz (Channel 28) and up.

Channel	Lower edge (MHz)	Centre Frequency (MHz)	Upper edge (MHz)
21	470	474	478
22	478	482	486
23	486	490	494
24	494	498	502
25	502	506	510
26	510	514	518
27	518	522	526
28	526	530	534
29	534	538	542
30	542	546	550
31	550	554	558
32	558	562	566
33	566	570	572
34	574	578	582
35	582	586	590
36	590	594	598
37	598	602	606

Channel	Lower edge (MHz)	Centre Frequency (MHz)	Upper edge (MHz)
38	606	610	614
39	614	618	622
40	622	626	630
41	630	634	638
42	638	642	646
43	646	650	654
44	654	658	662
45	662	666	670
46	670	674	678
47	678	682	686
48	686	690	694
49	694	698	702
50	702	706	710
51	710	714	718
52	718	722	726
53	726	730	734
54	734	738	742
55	742	746	750
56	750	754	758
57	758	762	766
58	766	770	774
59	774	778	782
60	782	786	790

Antennas

6Harmonics provides a variety of UHF antennas to cover all typical deployment scenarios. When performing propagation modelling only performance values of 6Harmonics qualified antennas should be used. Not all antennas meet regulatory compliance with all GWS radio units in all regions. All antennas are 50 Ohm.

Gain	Type	Manufacturer / Part Number	Regulatory Approval
9dBi	LPDA Dual polarized	KP Antennas PN: KP-TWDPLP9	ETSI: max EIRP defined by database
9dBi	LPDA 470-630MHz Dual polarized	Wireless Instruments PN: WiLPDA M0406-65-9X	ETSI: max EIRP defined by database
9dBi	LPDA 600-780MHz Dual Polarized	Wireless Instruments PN: WiLPDA M0608-65-9X	ETSI: max EIRP defined by database
8dBi	LPDA Single polarization	6Harmonics PN: GWS-SL14174A	ETSI: max EIRP defined by database
11dBi	LPDA Single polarization	6Harmonics PN: GWS-SL14175A	ETSI: max EIRP defined by database
2dBi	Omni Vertical polarization	6Harmonics PN: GWS-SL13319A	ETSI: max EIRP defined by database
6dBi	Omni Vertical polarization	6Harmonics PN: GWS-SL13304B	ETSI: max EIRP defined by database
12dBi	Panel Single polarization	6Harmonics PN: GWS-SL12948B	ETSI: max EIRP defined by database
6dBi	Panel Single polarization	6Harmonics PN: GWS-SL12948A	ETSI: max EIRP defined by database
11dBi	Panel Dual polarized	MTI PN: MT006D11VH	ETSI: max EIRP defined by database
12dBi	Panel 470-630MHz Dual polarized	Wireless Instruments PN: SA M0406-65-12	ETSI: max EIRP defined by database
12dBi	Panel 600-780MHz Dual polarized	Wireless Instruments PN: SA M0608-65-12	ETSI: max EIRP defined by database
13dBi	Panel Dual polarized	MTI PN: MT006S13VH	ETSI: max EIRP defined by database
8dBi	Panel Dual polarized	Wireless Instruments PN: WiBOX PA M0407-8X	ETSI: max EIRP defined by database
12dBi	Panel Dual Polarized	KP Antennas PN: KP-TWDP65S-12	ETSI: max EIRP defined by database
12dBi	Panel Single Polarized	KP Antennas PN: KP-TWVP65S-12	ETSI: max EIRP defined by database
9dBi	Panel Dual polarized	KP Antennas PN: KP-TWDPFP9	ETSI: max EIRP defined by database
8dBi	Panel Dual polarized	Lanbowan PN: ANT0407D8Z-DP	ETSI: max EIRP defined by database
7.5dBi	Panel Dual polarized	MTI PN: MT006D07VH	ETSI: max EIRP defined by database

Many custom vertical or dual polarized options can be made available for deployment specific needs, such mobility. Please contact 6Harmonics for further details. Antennas for deployment in USA must be declared as approved components and used on an "equivalent or less" basis[54] . Any antennas not supplied by 6Harmonics must be approved for use by 6Harmonics to maintain radio warranty. Correctly grounded lightning surge suppressors are required on the base station RF port.

[54] FCC 15.204.(c).(4) Any antenna that is of the same type and of equal or less directional gain as an antenna that is authorized with the intentional radiator may be marketed with, and used with, that intentional radiator. No retesting of this system configuration is required. The marketing or use of a system configuration that employs an antenna of a different type, or that operates at a higher gain, than the antenna authorized with the intentional radiator is not permitted unless the procedures specified in §2.1043 of this chapter are followed.

Glossary of Terms

MCS

MCS refers to the Modulation Coding Scheme.

RSSI

Received signal strength indicator

WinpCap

WinPcap is the industry-standard tool for link-layer network access in Windows environments. It allows applications to capture and transmit network packets bypassing the protocol stack, and has additional useful features, including kernel-level packet filtering, a network statistics engine and support for remote packet capture. WinPcap consists of a driver, that extends the operating system to provide low-level network access, and a library that is used to easily access the low-level network layers. This library also contains the Windows version of the well-known libpcap Unix API. Thanks to its set of features, WinPcap is the packet capture and filtering engine of many open source and commercial network tools, including protocol analyzers, network monitors, network intrusion detection systems, sniffers, traffic generators and network testers. Some of these networking tools, like Wireshark, Nmap, Snort, ntop are known and used throughout the networking community.

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