SOTA LoRa APRS Tracker

Setup and User guide

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This document describes how to build and configure the LoRa APRS Tracker which is available from the Summits On The Air (SOTA) online shop. It is available as either in kit form or as a fully built and configured tracker. The former is available for those in the hobby who like do things for themselves, and the latter for those who just want to get on an start using this new techology - especially as part of a SOTA activation.

The SOTA LoRa APRS tracker and accessories are currently available from the link below or you can scan the QR opposite with your phone.

https://sota-shop.co.uk/dp/SOTA APRS tracker

Summits on the Air (SOTA), what is it ?

Summits on the Air (SOTA) is an award scheme for licensed radio amateurs, that encourages portable operation in hilly and mountainous areas. SOTA has been carefully designed to make participation possible for all Radio Amateurs and Shortwave Listeners – it is not just for the mountaineers amongst us! There are awards for activators (those who ascend to the summits) and chasers (those who either operate from home, a local hilltop or are even Activators on other summits). SOTA is fully operational in nearly a hundred countries across the world. Each country has its own Association which defines the recognised SOTA summits within that Association. Each summit earns the activators and chasers a score which is related to the height of the summit. Certificates are available for various scores, leading to the prestigious "Mountain Goat" and "Shack Sloth" trophies. An Honour Roll for Activators and Chasers is maintained at the SOTA online database.

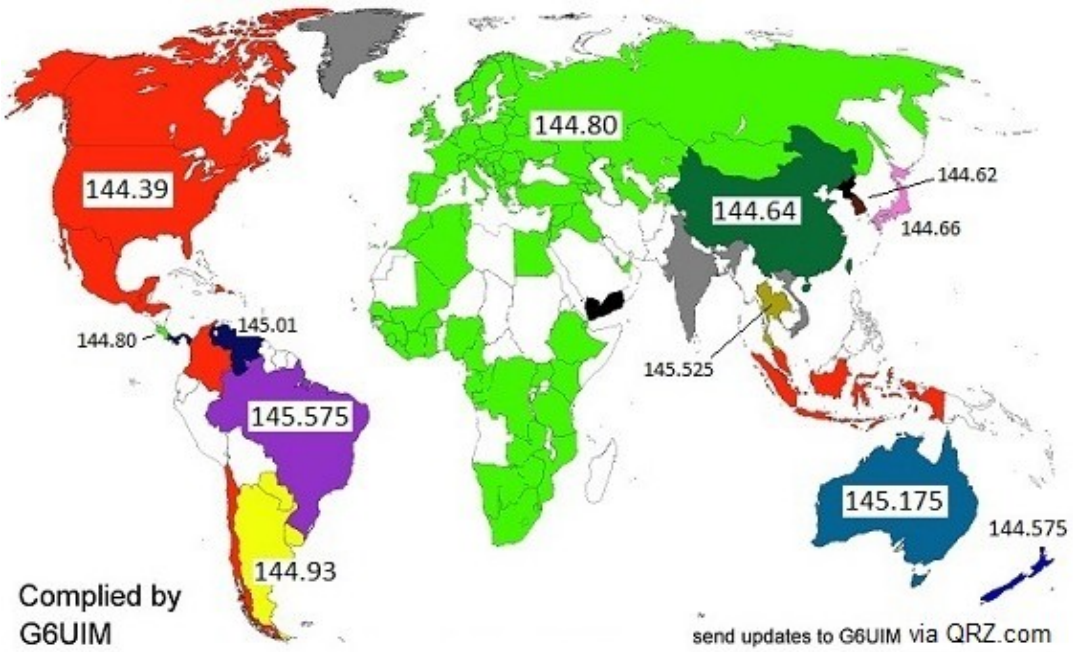
For more information on SOTA see the link or scan the QR code

https://www.sota.org.uk

Automatic Packet Reporting System (APRS), what is that ?

The Automatic Packet Reporting System (APRS) is an amateur radio based mechanism for real-time communications, which allows small packets of data to be sent and received over RF. More recently APRS now also allows APRS data packets to be routed from RF through the Internet and then back to RF through devices call iGates. It was invented in the 1990’s by Bob Bruninga, callsign WB4AP (now sadly SK). It is based on a tweaked version of the ITU-T X25 protocol called AX25, which amongst other things, adds an amateur radio callsign and a 4 bit SSID to the existing X25 protocol. The addition of a amateur radio callsign allows the X25 protocol to be used to send small packets of data to and from APRS equipment belonging to licensed Radio Amateurs; and the SSID allows the APRS system to differentiate between different APRS equipment belonging to a single Radio Amateur. Until very recently, APRS was predominately used around with world on

2m using Audio Frequency-Shift Keying (AFSK). Below is a map compiled by G6UIM which shows what frequency are allocated for AFSK APRS on 2m, and where.



LoRA APRS, how is that different to AFSK APRS?

AFSK based APRS, as used on 2m, uses two frequencies in the audio spectrum, 1200Hz and 2400Hz to represent binary data at a speed of 1200 bits per second (or as only one bit is sent at a time, 1200 baud). For example, the letter “A” in ASCII (a standard for representing alpha numeric character in computers from the 1960s, but sill used today) is 65 in decimal (base 10), 41 (written as 0x41 or 8’h41) in hexadecimal (base 16), and 01000001 in binary (base 2). To send the letter “A“ using AFSK, a device call a MoDeM (Modulator/Demodulator) takes the binary version of a alpha numeric charachter (for example 01000001 for “A”), processes it from left to right, sending an audio tone of 1200Hz if it encounters a 1 and an audio tone of 2400Hz if it encounters a 0. The audio tone is then FM modulated to the carrier frequency of 144.8MHz (EU), 144.39MHz (US) and then transmitted. Depending on how long each tone is transmitted for, dictates the bit rate. At the baud/bit rate of 1200 bit/s means each tone is transmitted for a period of just under 1mS (883uS to be precise). This is deliberate to ensure that the receiver can distinguish between a tone at 1200Hz and a tone 2400Hz, especially if the Signal to Noise Ratio (SNR) of the received signal is poor.

Until quite recently, APRS really only used AFSK on 2m. However, a new low power, long range proprietary technology called LoRa (**Lo**ng **Ra**nge) was introduced in the last few years by the French (now US) company Semtech. As the name suggests it is designed for Long Range communications but using Low Power. To achieve this, LoRA uses a digital modulation technique called Spread Spectrum (SS) and a variant of SS called Chirp Spread Spectrum (CSS). If this all sounds to good to be true, it’s because it is. There is no free lunch with digital communications, and SS is no different. To achieve long range, low power communications, SS modulation techniques deliberately spreads a low bandwidth baseband signal over a much larger modulated bandwidth. This sounds nuts, right? As Radio Amateurs we are taught that bandwidth is a precious resources and that we must be careful to use it wisely and with consideration for other users. However Spread Spectrum, which was designed for military communications, and was actually invented by a Holywood actress called Hedy Lamarr back in the 1940’s, has a very different approach to spectrum usage. Up at high frequencies (e.g. beyond UHF and mmWave) there is lots of bandwidth available (especially to the military) and so when operating at these high frequencies, the prevention of

interference, either deliberate (i.e. jamming) or due to external factors is far more important than the conservation of bandwidth.

At this point I don't want to go into more details about SS and CSS, because it's quite complicated. To understand how LoRa works it's sufficient to know that when a transmitting station deliberately spreads a baseband signal over a much larger modulated bandwidth, when a receiving station then does the reverse (called despreading) the wanted signal is de-spread back to baseband, but the opposite happens to any interference/noise that is picked up in the communications channel. The action of despreading the wanted signal has the effect of spreading any interference or noise over a much larger bandwidth, reducing it and so increasing the Signal to Noise Ration (SNR) of the recovered signal. Thus with CSS (and with other SS techniques) we get something called processing gain; which is basically the ratio of the baseband signal to the spread signal. In LoRA this is called the Spreading Factor or SF. The higher the SF, the higher the processing gain, but lower the overall data rate. For something with a low data rate such as APRS, but which needs to be Long Range and Low Power, LoRa is thus a great fit.

SOTA LoRa APRS Tracker Case

To help Radio Amateurs get started with LoRA and APRS, SOTA have designed a rugged outdoor case for a neat little LoRA Single board computer module (SBC) called the "Heltec LoRa Wireless Tracker". This board is actually a LoRA development PCB designed by Chinese company Heltec Automation which consists of a ESP32-S3FN8 microprocessor, Semtech SX1262 LoRa modem, 0.96" OLED display, WiFi, Bluetooth and UC6580 dual-frequency multi-constellationon GNSS SoC which supports GPS, GLONASS, BDS, Galileo, NAVIC and QZSS. For more information about the "Heltec Wireless Tracker" board please checkout the following URL, or scan the QR code embedded in the above picture with your phone.

https://heltec.org/project/wireless-tracker/

You can either buy the Heltec Wireless Tracker board for yourself and purchase the tracker case from the SOTA shop, or you can buy a fully assembled tracker which includes the Heltec Wireless Tracker board from the SOTA shop:

https://sota-shop.co.uk/dp/SOTA APRS tracker

If you decide to source the Heltec Wireless Tracker board for yourself, then please remember to buy it from a reputable source, preferably from Heltec's shop on Ali-express or Amazon. You must also remember to buy the "EU433" version and not the "EU868" version (which is for Meshtastic).

The SOTA LoRa APRS Tracker case consists of a 3D printed main body and a separate front panel which neatly snap tightly together. The main body of the case houses a 3.7v 2000mAh LiPo battery, a external SMA connector (for connecting the external antenna), an On/Off switch and a small PCB which connects the On/Off switch between the battery JST XH (2.54mm) connector and the 1.25mm JST connector on the rear of the Heltec Wireless Tracker board. The front panel houses the Heltec Wireless Tracker board and allows the two buttons to be accessible when the two parts are snapped together (i.e the case is closed). On the rear of the Heltec Wireless Tracker board there is a 1.25mm JST female connector and two IPEX U.FL connectors labelled GNSS and LoRA. When

snapping together the front panel and the main body it is important to remember to connect up the power to the Heltec Wireless Tracker board using the supplied JST 1.25mm cable and to connector up the external SMA antenna port – plugging it into the “LoRa” IPEX connector not the “GNSS” connector.

Assembling the SOTA APRS Tracker

As detailed above, the SOTA LoRa APRS tracker case comes in two sections; a main body and a front panel. The Heltec Wireless Tracker board snaps in the front panel; the battery, SMA to IPEX cable, Switch and power cables reside in the main body. If you purchased a complete tracker (case and Heltec board) from the SOTA shop, everything will shipped pre-assembled. However, if you purchased just the case from the SOTA shop and sourced the Heltec Wireless Tracker board from elsewhere, you should assemble the various parts as recommended below.

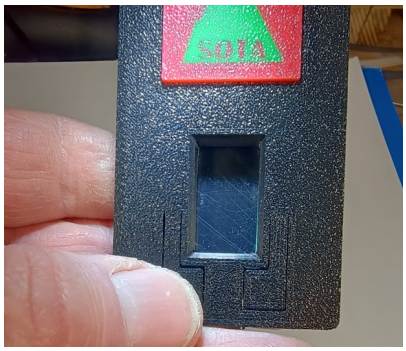
On the rear of the front panel you will observe two parallel rails with grooves in them. The front panel has been designed so that the 1.6mm thick PCB of the Heltec Wireless Tracker board will snap tightly into the two grooves in these rails.

At the top of the grooves is a end-stop which ensures the board sits correctly and lines up properly with the OLED display window, the thin GNSS antenna window and with the two switches at the bottom of the Heltec Wireless Tracker PCB.

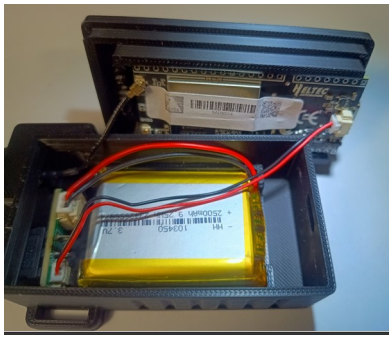
To fit the Heltec Wireless Tracker board it is recommended that the front panel is first placed face down on a flat surface. Next insert one side of the Heltec Wireless board into one of the slots in the front panel. It is recommended that the side of the board which houses the WiFi antenna (which is just a coil of copper wire) is pushed into the right-hand slot (the right-hand slot being the one where the switches are at the bottom and the GNSS antenna at the top) as shown below. This is to prevent the Wi-Fi antenna from being accidentally sheared off if you are tad too vigorous in the next step. With the PCB now in the right-hand slot, make sure the PCB is pushed up against the end-stops so that the switches are aligned correct as shown below.

With everything align correctly (especially the switches) place one thumb on one end of the PCB that is not in it’s slot (i.e. the left-hand side) and another thumb on the other end and gently push. It should only require a minimal amount of force.

If all is well you should hear a satisfying click as the left-hand side of the board snaps into the left-hand groove. With the Heltec Wireless Tracker board seated firmly in the SOTA LoRa APRS tracker front panel, the next step is to check that the board is aligned correctly with the two switches on the front panel. To do this, turn the front panel over and press the two switch tabs. They should make a satisfying click if the switches on the Heltec Wireless Tracker board are aligned correctly with the case tabs. If the tabs on the front panel are bent or the Heltec Wireless Tracker board is protruding too far out of the front panel (i.e. it is not hard up against the end-stops because the switches are snagging), use two pairs of tweezers to gently lift the tabs and then with a thumb push the Heltec Wireless Tracker board back into place. Don't lift the switch tabs too much as they will snap off.

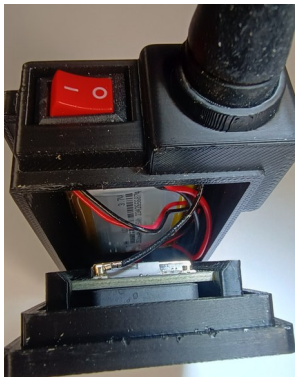


The final stage is to connect the Heltec Wireless Tracker board JST 1.25mm female connector and LoRA IPEX connector to the cables in the main body. You will observe that the SMA to IPEX pigtail is rather short; this is deliberate to stop it getting snagged up when the two halves of the case are snapped together. It is recommended that the SMA to IPEX pigtail is connected up first by lying the front panel (now holding the Heltec Wirless Tracker board) on it's side next to the main body as shown. Lift the SMA to IPEX cable up out of the main body and snap it into the IPEX connector maked LoRA on the Heltec Wireless Tracker board as shown. Next plug in the JST 1.25mm pigtail into the JST socket at the bottom of the Heltec Wireless Tracker board.



The final stage is to snap the main body and front panel together without snagging any of the pigtails so that the front panel aligns neatly with the main body of the tracker case. The best way of doing this is to push the bottom of the front panel into the bottom of the main body, while carefully ensuring that the protruding USB-C connector (on the Heltec Wireless Tracker board) gets pushed carefully into the USB-C sized hole in the bottom of the tracker case main body.

With the USB-C connector firmly seated in the USB-C sized hold at the bottom of the main body, next turn your attention to the top of the front panel and main body. As shown check that none of the pigtails or cables are likely to get caught between the side rails of the front panel and the bottom of the case; and then with your thumb and forefinger push the front panel into the main body. Use a pair of tweezers to move any cables out of the way if there is a chance they will snag.



If all is well, then both parts should snap together very tightly. If the case body and the front panel are a little tight coming together, cup your hands

together with the bottom of the tracker sitting in your cupped hands, and then use both thumbs to pull down on the top of the front panel while at the same time pushing. That usually does the trick if things are a big tight.

If the front panel and main body do not snap together tightly, then it is probably because one of the pigtails or power cables has got snagged between the battery and the Heltec Wireless Tracker board. Open up the case a few mm and using a pair of tweezers or long nose pliers, try moving the cables around until they no longer snag.

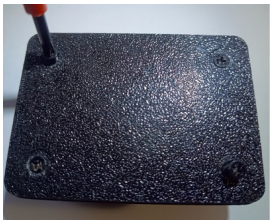
The final thing to do is now assemble the antenna (either the one supplied with the Heltec Wireless Tracker board, or the flexible antenna available in the accessory pack) and then switch on your SOTA LoRa APRS tracker, and make sure it boots up. If the OLED display doesn't show anything, it's probably because one of the power connectors is loose.

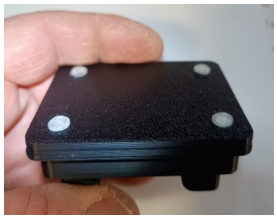
Assembling the SOTA LoRa APRS Tracker Accessory pack

The SOTA LoRa APRS Tracker accessory pack is an optional extra that can be purchased at the time of checkout from the SOTA shop. The accessory pack includes a wrist band, belt clip, flexible 3dBi EU433 antenna, a USB type C charging/docking station and a USB type C cable.

Some parts of the accessory pack come as self-assembly. The two parts which need assembling are the rear belt clip (which needs screwing on to the main body of the case) and the USB charging/docking station. To attach the rear belt clip to the main body use the two M2.5 screws in the accessory pack. There are two M2.5 threaded holes on the rear of the main base body.

The USB charging/docking station consists of three main parts that need to be assembled. They are the body of main charging/docking station, a USB type C 90° adaptor, a bottom plate, four screws and four self-adhesive feet. To assemble the USB charging/docking station turn the main charging/docking station body upside down, and holding it in the palm of your hand insert the USB type C 90° adapter through the hole. Next place the docking station on a flat surface (still upside down) and then place the bottom plate over the bottom of the charging/dock station body. Then using the four self tapping screws supplied, secure the bottom plate in place. Finally, cover the four self-tapping screw heads with the self-adhesive feet supplied.

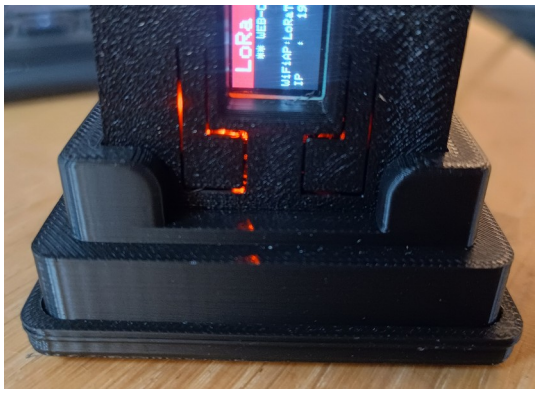




To being charging your SOTA LoRa APRS tracker, plug one end of the USB cable the USB type A end) into a PC or a USB wall charger, and then push the USB type C end into the USB type C 90° adapter inside the charging docking station. Next place your SOTA LoRa APRS Tracker into the USB charging/docking station. On the rear you will see there is a small recess into which the end of the belt clip will sit. This is to prevent the SOTA LoRa APRS tracker from becoming unseated when charging. To remove the SOTA LoRa APRS tracker from the

USB charging/docking station, simply push the top of the belt clip (so the bottom of the belt clip comes out of the recess) and then lift out.

A point to note here is that the switch on the SOTA LoRa APRS tracker is, just a switch. It sits between the 2000mAh 3.7V LiPo battery and the Heltec Wireless Tracker board (JST 1.25mm) battery connector – simply so that the battery can be isolated when not in use. When the SOTA LoRa APRS tracker is seated in the USB charging/docking station, and is on-charge, it is important to remember that the switch needs to be turned ON so that the LiPo charger IC on the Heltec Wireless Tracker board (i.e. TP4054) is physically connect to the battery. Even though the Heltec Wireless Tracker board will boot up when it is being powered via USB (when seated in the USB docking/charging station), if the switch is not turned ON, the battery will not charge. You will know when the TP4054 is charging the battery as the bright orange LED on the Heltec Wireless Tracker board will shine through the gabs in the left-hand button on the front case. When charging is complete the orange LED will go off. It will also not be illuminated if you do not have the switch turned ON.



Finally, you will no doubt observer that the percentage battery charger level (reported on the OLED display) is somewhat misleading during USB charging. When charging from USB, the A/D on the ESP32 which measures the battery voltage level, is actually measuring the charge voltage of the TP4054 during the constant current and constant voltage phases of charging.

If you would like to power down the ESP32 and OLED display on a SOTA LoRa APRS Tracker during charging, simply press the left hand button three times – so it displays the “CONFIG” menu.

Next ensure that the right arrow symbol “>” is next to the “Turn Tracker Off” option. If it is not, short press the left-hand button once to move it. Keep doing this until the “>” symbol is next to “Turn Tracker Off”. Next long press (around 2 seconds) the left-hand button so that “starting DEEP SLEEP” is displayed on the OLED. Shortly after this the ESP32 on the Heltec Wireless Tracker board will go into a deep sleep mode. It will also turn of the OLED (and presumably the SX1262 LoRa modem) but the LiPo charger IC (TP4054) will continue to charge the 2000mAh 3.7v LiPo battery.

Again it will only charge if the switch is turned ON.

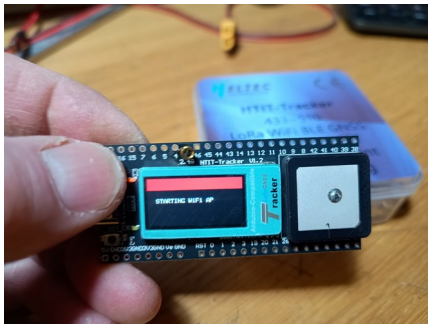
Specifying your callsign at the SOTA shop checkout

The software installed on the SOTA LoRa APRS tracker allows up to three different callsigns/SSID combinations to be configured. When purchasing the SOTA LoRA APRS tracker if the

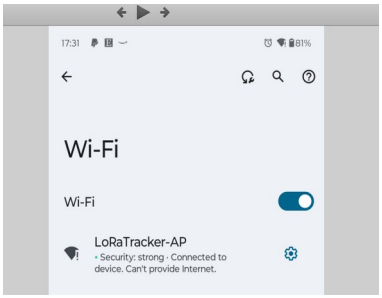
"configuration" option was selected during checkout, the tracker will be configured with the callsign you requested – it will be repeated three times. The default SSID will be 7 unless you request something different in the "comment" field on the store tracker configuration option page. You can also use the "comment" field to also request other callsigns and SSIDs, which for U.K operators should be use if you wish to have a regional callsign identifier include (i.e. E,W,M,I,D,J,U). For example, you could specify M0JKS-7, MW0JKS-8 or MM0JKS-9 if you wanted. Remember you can only have three. You can then use the buttons on the front of the tracker to switch callsigns, which in the UK is useful when switching between operating in England, Scotland, Wales, Northern Ireland, Jersey, Guernsey and the IoM. See "**Changing SOTA LoRa APRS Configuration using the buttons"** below on how to do this.

Tweaking the SOTA LoRa APRS Configuration using the web interface

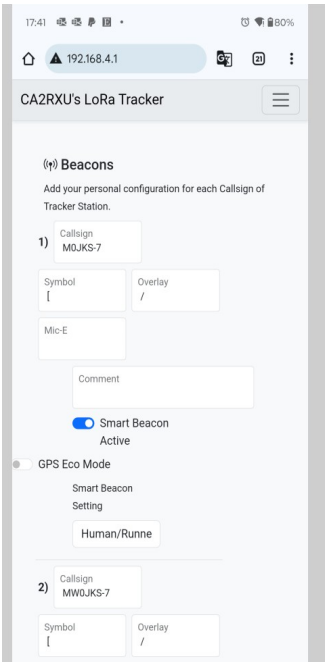
If at any time you wish to change the callsigns or SSID in your SOTA LoRa APRS tracker, then the easiest option is to force the tracker into web configuration mode, and then connect to it from your phone web browser. To do this press the left-hand button on the tracker three times in succession, so that the display switches to display "CONFIG" mode. Next short press the left-hand button so that the ">" character moves down next to "Config WiFi AP", then long press the left-hand button (about 2 seconds) and you should see the display say "STARTING WIFI AP".



At this point the SOTA LoRa APRS tracker should reboot itself and come back up in Web configuration mode.Your SOTA LoRA APRS tracker is now in a mode where you can connect to it using WiFi on your phone, and then browse to a special configuration website. To do this, on your phone connect to the WiFi AP called "LoRaTracker-AP".



It has no encryption enabled, so simply select it and then navigate to your favourite web browser on your phone and enter "192.168.4.1". My (Android) phone gets a tad confused at this point, as it realises it cannot access the internet via the "LoRATracker-AP" so automatically switches to a WiFi AP it knows is connected to the internet (i.e. my GPON 802.11N router).



If all goes correctly, you should be presented with a web page on IP address 192.168.4.1. You will then be able to change the callsigns you want to use and any other options you see fit. Once you are happy with the configuration options you have changed, click on the three parallel parts at the top right-hand corner (next to "CA2RXU's LoRa Tracker") and you should be presented with a big green "Save" button like so:

Click on the green "Save" button, the SOTA LoRa APRS tracker will reboot and should now display the updated callsigns; or whatever else you changed. As I note below, do not be tempted to change the frequencies in the "lora" section. These frequencies are enumerated in

Richardo's software and fiddling with them will mess up the menu mechanism for switching between frequencies.

Changing SOTA LoRa APRS Frequency using the buttons

When purchasing a SOTA APRS tracker from the SOTA shop, if the "configuration" option was selected during checkout, it will be configured with the callsign and SSID you requested. The default will be CALLSIGN-7 where "CALLSIGN" is the callsign you entered. You also have the option to specify a different SSID other than 7 (in the range 0-15).

The software version installed on a full SOTA tracker is now version 2025.02.13, but this may change with future versions. This version of the software allows up to three different callsign and SSID options, and three different VCO frequencies.

```
"lora": [
    {
        "frequency": 433775000,
        "spreadingFactor": 12,
        "signalBandwidth": 125000,
        "codingRate4": 5,
        "power": 20
    },
    {
        "frequency": 434855000,
        "spreadingFactor": 9,
        "signalBandwidth": 125000,
        "codingRate4": 7,
        "power": 20
    },
    {
        "frequency": 439912500,
        "spreadingFactor": 12,
        "signalBandwidth": 125000,
        "codingRate4": 5,
        "power": 20
    }
],
```

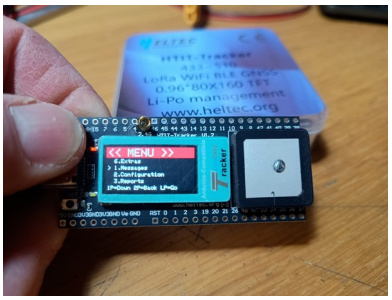
There are currently three LoRa frequencies that APRS operates on around the world, they are 433.775MHz (EU), 434.855MHz (Poland) and 439.9125MHz (UK). If you look at the configuration file in data/tracker_config.json you will see these specified like so:

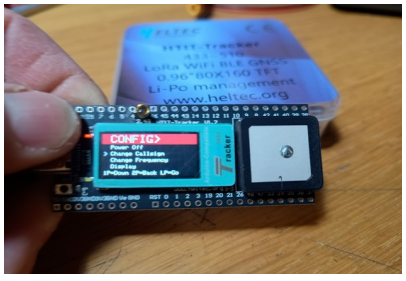
I do not recommend fiddling with these unless you fancy diving into the code. The order is important, as the code enumerates the positions so the first in the list is the EU frequency, the second is the frequency in Poland and the third is the frequency in the UK.

If you are really interested to know why this is, have a look in the code and you will see the following:

```
String loraCountryFreq;
switch (loraIndex) {
    case 0: loraCountryFreq = "EU/WORLD"; break;
    case 1: loraCountryFreq = "POLAND"; break;
    case 2: loraCountryFreq = "UK"; break;
}
```

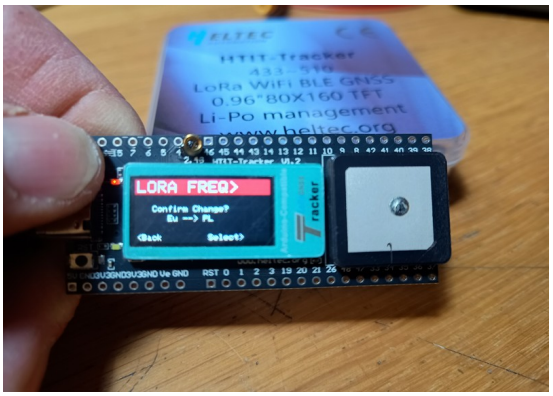
If you wish to change the current frequency of operation, for example you are a UK operator and wish to use you SOTA LoRa APRS tracker in the EU, simply use the two buttons on the Heltec Wireless Tracker board to change frequency. Press the left hand-button twice and you should be presented with the "MENU". Next give the left-hand button a short press so that the ">" character moves down so it is next to "2. Configuration". Now press the left-hand button for a long time (about two seconds) to switch to the menu to the "CONFIG" page. Now give the left-hand button a short press so that the ">" moves down so it is next to "Change Frequency" and then press the left-hand button for a long time (again about 2 seconds) so that the menu switches to new page called "LORA FREQ>" page.

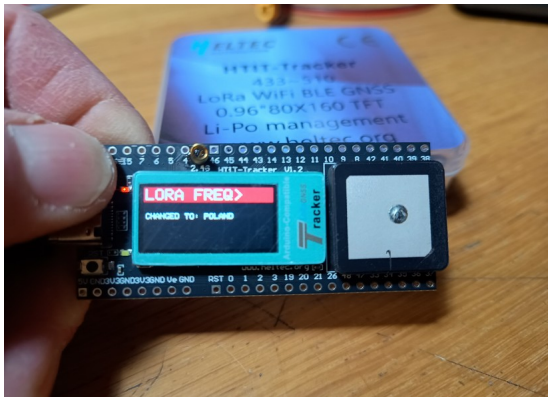




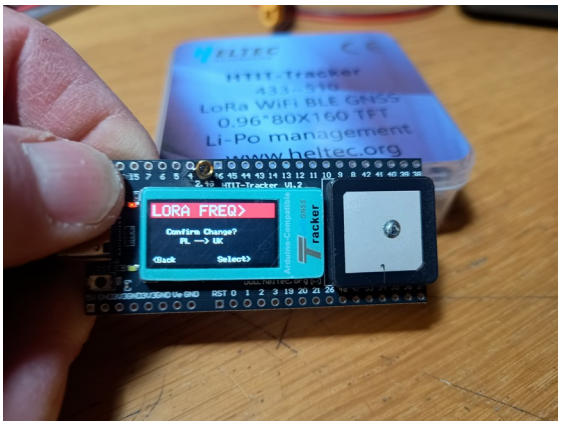
As mentioned above the frequencies are encoded in the code so that the first entry in the config file is the EU frequency (433.775MHz), the second is the Frequency in Poland (434.855MHz) and the third is the frequency in the UK

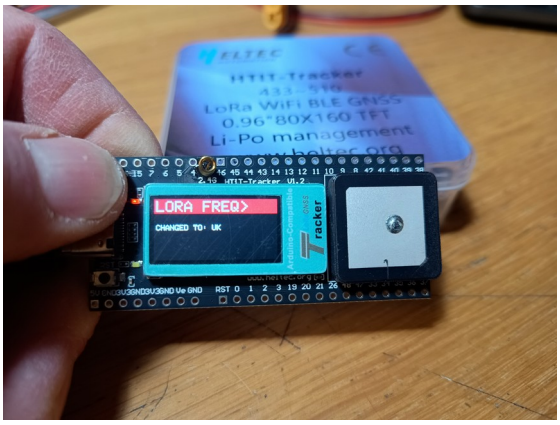
(439.9125MHz). The change frequency menu allows you to switch between frequencies in the following order EU → PL → UK → EU, in a loop. For example, if the current frequency is that of the EU (433.775MHz), then to switch to the UK frequency is it necessary to switch to frequency in Poland first:





You will then need to repeat the same operation to switch from the frequency in Poland to the frequency in the UK (i.e. PL → UK) as shown below





As mentioned above, there are only three enumerated frequencies in the code at this time (February 2025) and this may change.

Switching between call-signs using the buttons

If your SOTA LoRa APRS tracker is configured with multiple callsign/SSID combinations (either you did it yourself, or asked for it to be configured that way when your purchased it from the SOTA shop), then at some stage it may be necessary to actually switch between them. For example, you might be doing an SOTA activation along the border of two countries and at some stage will need to switch between different callsigns. This is particualary true in the U.K when activating on the border of England and Wales.

The simplest way to switch callsigns is to long press (2 seconds or more) the left-hand button until the next callsign in the list is displayed. Long press to select, and after a few seconds your SOTA LoRa APRS tracker will be using the new call-sign. Repeat once more to access the last callsign in your list.

Best 73 Dave M0JKS.