AIRWAYS

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Build Your Own ADS-B Aircraft Tracking System

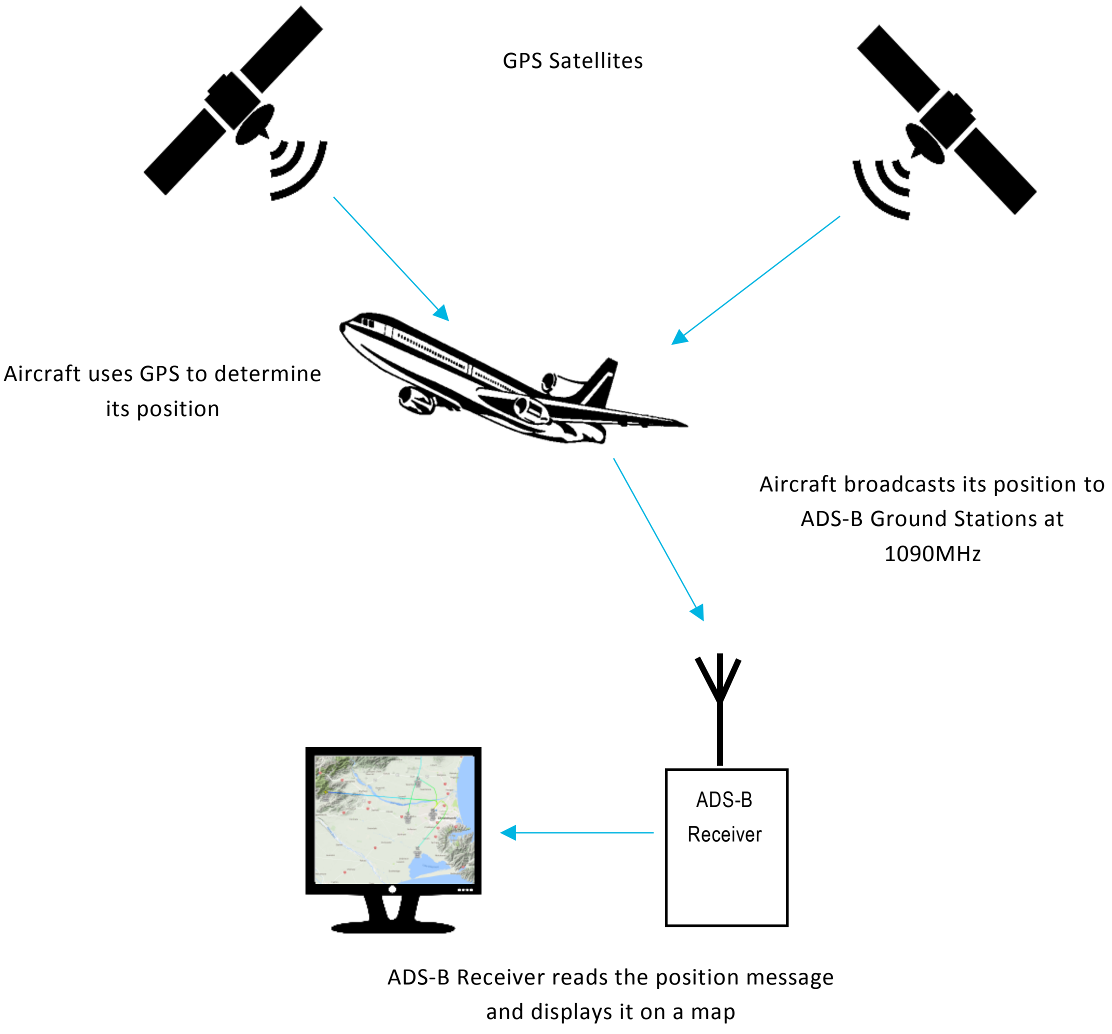
CONTENTS

1 BUILD YOUR OWN ADS-B AIRCRAFT TRACKING SYSTEM

1.1 Background

Most commercial aircraft constantly broadcast their position from an on-board device called a transponder. This transmission is called Automatic Dependant Surveillance – Broadcast (ADS-B).

ADS-B is a replacement, or supplement, to radar based surveillance of aircraft. ADS-B is a major change in surveillance philosophy – instead of using ground based radar to interrogate aircraft and determine their azimuth and range from the ground radar, each aircraft will use GPS satellites to find its own position and then automatically report it to ground stations.



The aircraft's broadcast report contains much more information than just its location. The aircraft broadcasts the following information at regular intervals:

- "Airborne Position" every 0.4 to 0.6 seconds.
- "Surface Position" (if on the ground) every 4.8 to 5.2 seconds.
- "Identification" (call sign, flight number) every 4.8 to 5.2 seconds.
- "Airborne Velocity" every 0.4 to 0.6 seconds.
- "Aircraft Status" (In-flight or on the ground) maximum 2 per second

Because the aircraft broadcasts these reports, anyone with the appropriate hardware (receiver and antenna) can listen to this message. In addition, given the right software, the messages can be decoded and the information can be shown on a map, similar to an Air Traffic Control radar screen.

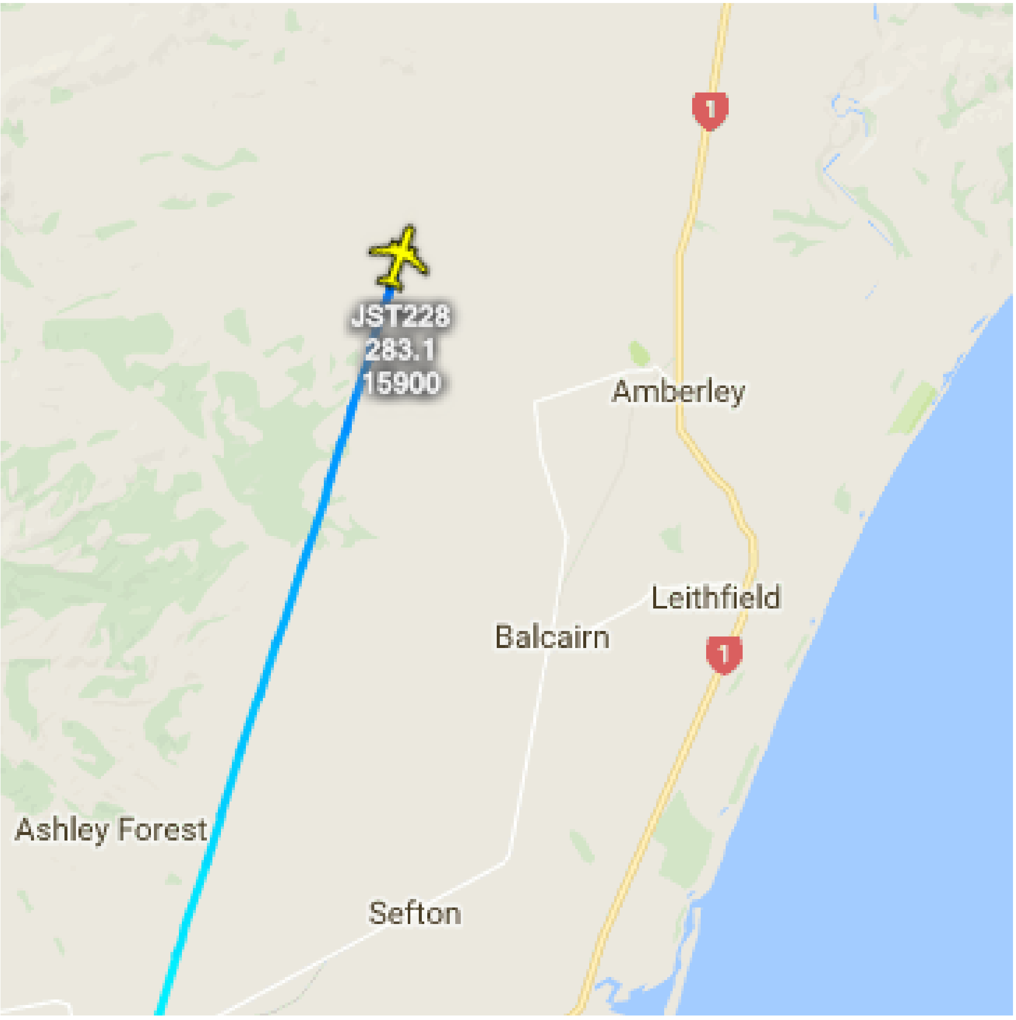


Figure 1 – JST228 travelling at 283.1 knots, 15900ft. Over Amberley, Canterbury

2 THE ADS-B RECEIVER

In the past, receivers tuned to the aviation specific frequency used (1090MHz) were very expensive, and only available to the aviation community. This is because all of the radio frequency parts were finely tuned for tracking aircraft.

Modern radios are much more flexible. These rely on software to define what frequencies and modes the radio runs; and are called Software Defined Radios (SDR).

2.1 Software Defined Radios

In a Software-defined radio (SDR) the tuned hardware components of a traditional radio have been replaced by software on a computer or embedded system.

An SDR system, often, consists of a computer equipped with an analogue-to-digital converter (sound card), preceded by some form of radio front end. The computer processor, rather than the radio hardware (electronic circuits), handles the radio signal processing. This design produces a radio that can receive all types of different radio protocols based solely on the software used.

Because almost all of the processing is completed in software, these radios can be very small. SDR devices are commonplace in cell phones and computers, and are the core component in the ultra-cheap USB TV tuners you can buy everywhere.

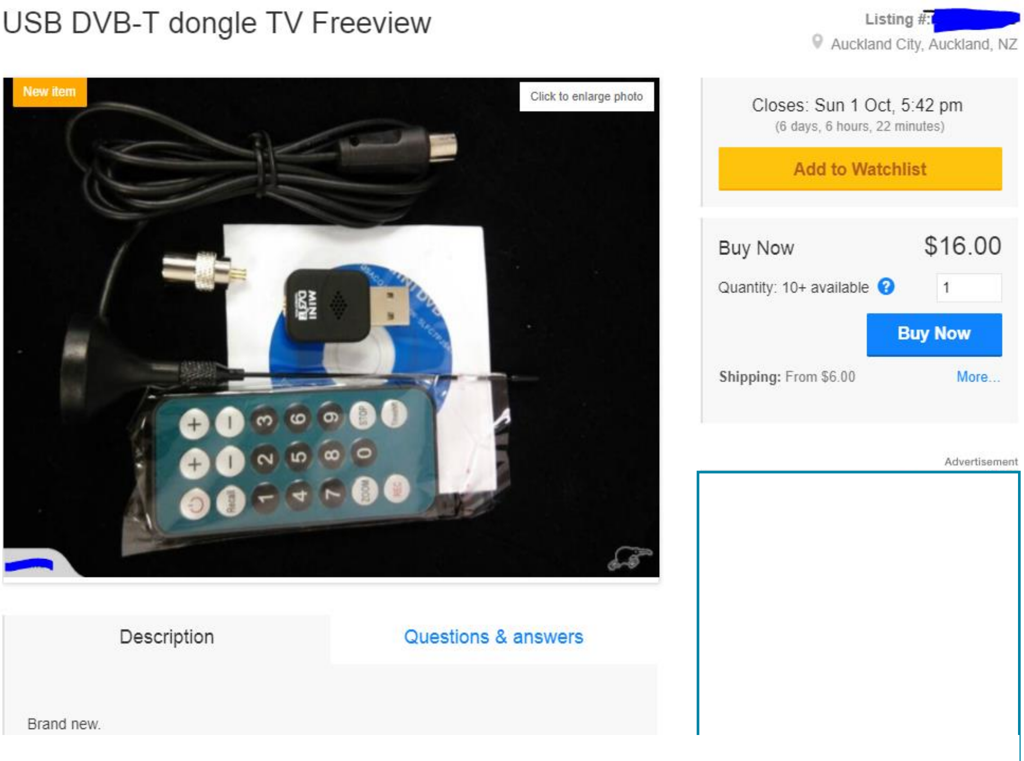


Figure 2 - NZ$16 for a USB SDR from Trademe

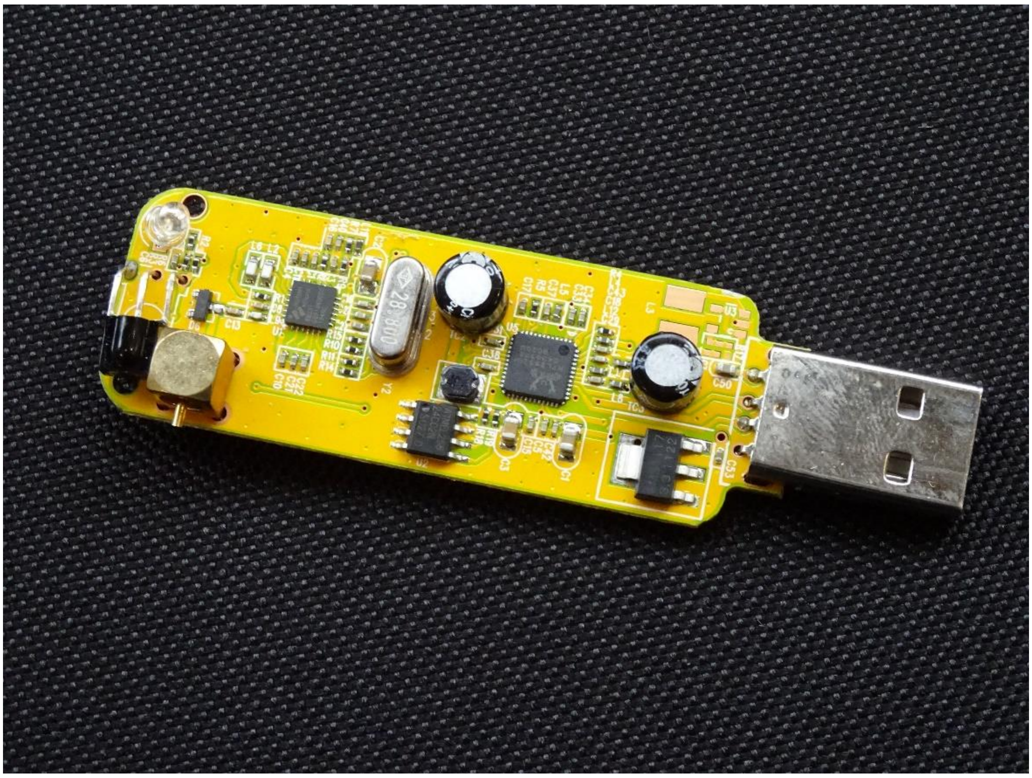


Figure 3 - The inside detail of a USB SDR

These USB TV Tuners operate on the Digital Video Broadcast – Terrestrial (DVB-T) band and allow any laptop, desktop or Raspberry Pi to be used as a TV. With ample processing speed, and large storage (HDD), many people turn their desktop PC's into Personal Video Recorders (PVR), downloading free-to-air program guides, to record their favourite shows.

However, like the early pioneering radio engineers, many hobbyists saw these cheap SDRs as an opportunity to experiment with other radio systems without having to spend a fortune on expensive hardware.

The first applications for these SDRs was to turn them into multipurpose receivers for FM and AM radio broadcasts. Soon after that, they turned their attention to receiving aircraft transmissions.

However, not all USB Tuners are created equal. In NZ, TV (DVB-T) frequencies range from 510MHz-606MHz. Hobbyists have discovered that USB tuners containing the R820T or R820T2 chipset worked the best in the 1090MHz frequency range. At this frequency, the USB receiver is required to work at double its originally intended frequency.

Therefore, the first step is finding a suitable SDR. These are readily available from E-bay or Amazon. There are even USB SDRs specifically build for ADS-B applications. These have special filters designed to allow only the 1090MHz frequency band through. Of course you cannot use them for anything else other than tracking aircraft.

2.2 ADS-B Decoders

The first piece of software needed to run an SDR-based ADS-B receiver is the ADS-B decoding software.

With this software you can tune the SDR to the correct receiving frequency (1090MHz) and decode the received aircraft broadcasts into messages that can be processed by a mapping application.

Each aircraft message is not very long. It has only 112 bits (112µs) to convey the information needed. Each message is converted from binary format to hexadecimal format for ease of display. The program then outputs this data to a display application for human use.

2.3 Distribution and Display Applications

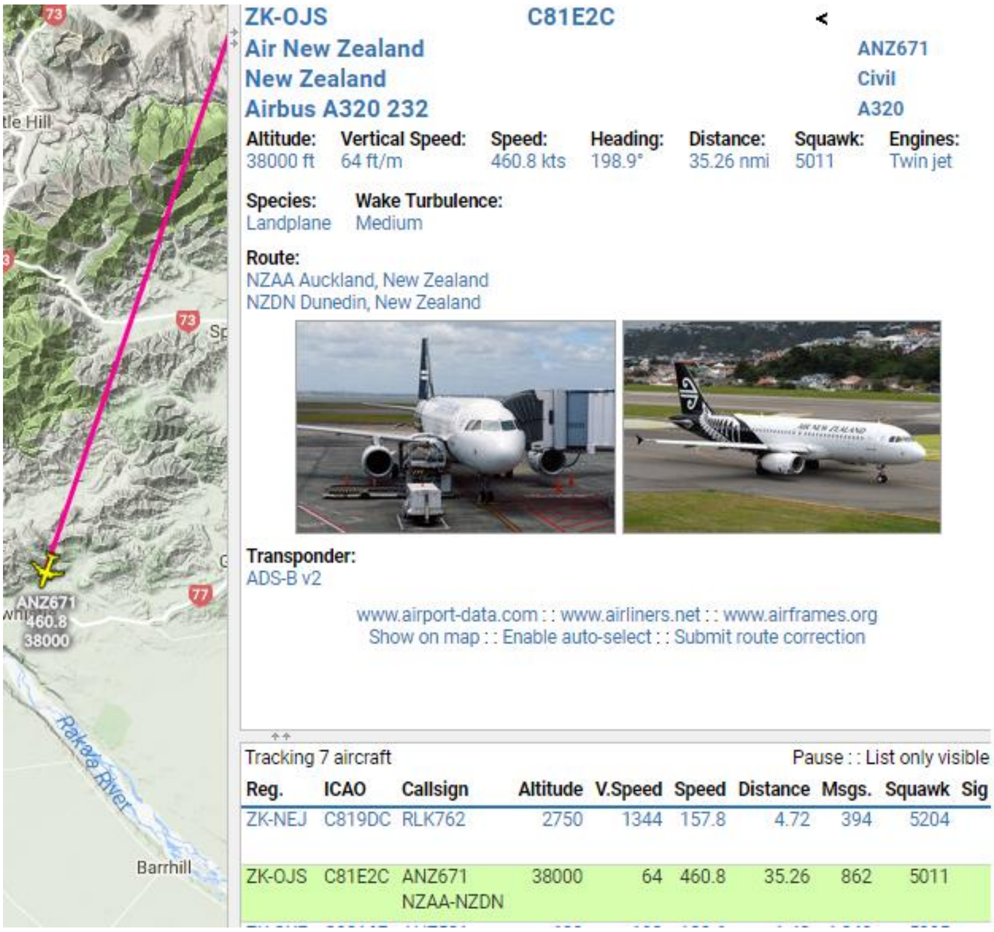
Once we have a data stream of decoded Aircraft messages, we need to be able to display them on a map, or distribute them to a website such as FlightRadar24, or FlightAware.

These websites gather ADS-B data from thousands of home ADS-B receivers around the world to form a worldwide picture of, real-time, aircraft movements.

Most software of this type, typically, overlays the ADS-B data from our receiver onto a Google map. This means that an active internet connection is needed, even if you are not sharing the data outside of your home.

The advantage of having the application internet connected is that the program can access additional information on the Aircraft from online databases. This can include pictures of the Aircraft, flight route, aircraft owners/operators, aircraft registration etc.

This can be achieved because each aircraft has a unique code identifying it. This is often called its ICAO code. ICAO is the International Civil Aviation Organisation, and it holds a register of the unique code for every ASD-B equipped aircraft in the world



In the display window shown above, you can see the details for Air New Zealand ANZ671 flying from Auckland to Dunedin.

The ADS-B data gives us the aircraft's actual location on the map, as well as its callsign/flight ID (ANZ671), its Airspeed (460.8kts) and its altitude (38000ft). Other data such as vertical speed, heading (magnetic bearing) and ICAO Code are also displayed in the data boxes.

Using the ICAO code, the software queries an online database to return a picture of the actual aircraft, along with Registration (ZK-OJS) and its flight details based on its callsign/Flight ID.

Other information is calculated by the software. For example, distance from the receiver is calculated because we have entered the location of the receiver into the configuration files.

Some other information (such as Squawk Code - 5011) is also available because the aircraft is also responding to Airways' Mode S Radar operating on the same frequency nearby.

3 WHAT TO BUY, BUILD AND DOWNLOAD

The components needed to build the ADS-B receiver system are relatively cheap. The biggest cost is the processor needed to do all the work. If you are happy to use a computer you already own, then the other components cost less than $30 USD; and the software is free to download.

3.1 The USB Software Defined Radio (SDR)

As mentioned before, the USB SDR needs to be based upon the R820T or R820T2 chipset. The R820T2 is the latest version. These can be easily obtained from E-Bay or Amazon. Simply Google for “R820T2”.

Most of these come with a basic antenna, and even come with a remote control if you want to use it for TV broadcasts. If you are going to utilise the SDR for experiments other than ADS-B, then these are the types to use.

There may be other expenses associated with these radios, as they often use a special (mcx) antenna connector. If you are going to experiment with other antennas, then you may need to purchase adapters for the kit.

The USB SDR we use in Airways has been modified to perform its best at 1090 MHz, and cannot be used for anything else.

It was purchased at [RTL-SDR.COM](RTL-SDR.COM) and included the optimised SDR and a special antenna kit. The price at the time of writing was US$25.95

This kit uses an SMA antenna connector. These are more common, and are often used for Wi-Fi routers. If you are going to use anything other than the included antenna, then you will need to buy, or build, an adapter such as the SMA (Female) to BNC adapter shown below.

3.2 The Computer

If you have access to a standard Windows computer with Administrator rights and Internet access, then you should be able to install and run all the necessary drivers and software required to enable the ADS-B Aircraft Tracker.

The software, when running, does not interfere with the day-to-day use of the PC. You will hardly know its running. However, you will tie up a USB port with the SDR and, if you are using a laptop, then you will be limited to a single location if you want to use a permanent antenna.

For more advanced users, there is a cheaper option than tying up an expensive PC for aircraft tracking.

The software runs on the powerful, yet inexpensive, Raspberry Pi 3. Complete Raspberry Pi 3 kits cost approximately NZ$120, and can be used for many more things than just tracking Aircraft.

Of course, the Raspberry Pi runs on Linux, so a knowledge of this operating system is recommended.

3.3 The Software

All of the software is free to download. In the early days this software was scattered around the internet like breadcrumbs. Part of the challenge of engineering this system was finding the correct software. These days, the software has been included in various locations and installer packages.

Windows

For Windows systems, the easiest way to install all the drivers, software and databases needed is to download the RTL1090 IMU (Installer and Maintenance Utility). It can be found here. Zadig; as referred to below, is the Windows program needed to install the SDR drivers.

This internet based utility helps you with setting up a complete RTL1090 installation with almost no manual intervention. It automatically downloads the relevant files as rtlsdr.dll, zadig.exe and helps to configure zadig with a built in tutorial. Just place and start the utility in the RTL1090 target folder (do not use a "C:/program" folder to avoid administrator problems).

The other pieces of software required are the display/mapping software.

One is called Virtual Radar Server and the other is DatabaseWriterPluginSetup. They are available from virtualradarserver.co.uk

Linux

The easiest way to install an ADS-B system on a Raspberry Pi is to download the PiAware Raspbian Linux Distribution.

This is a completely setup Linux system which you can use to boot up a Raspberry Pi with the FlightAware software and SDR drivers already installed. This will allow you to feed your ADS-B data into the FlightAware network. The instructions are included at the FlightAware website.

If you really want to get your hands dirty, then there are plenty of instructions available on the internet for manually installing the software on a Raspberry Pi.

3.4 The Antenna

The R820T2 Receivers come with basic antennas that will perform well for testing purposes. If you really want to explore the full potential of an ADS-B receiver then a well-designed antenna is essential. A well-sited, tuned antenna connected to our $30 ADS-B receiver can track aircraft up to 240NM (440km) away.

There are many ADS-B antennas available for sale on the internet; however, we have included a design for a home-made ADS-B antenna in this guide.

For a few dollars of co-axial cable, some heat shrink tubing and a radio frequency connector, you will be able to build an antenna that is able to track aircraft across the South Island. For a few extra dollars and some scrap PVC conduit, you can make the antenna waterproof so you can mount it outside.

Positioning the antenna is also important. Ideally, you will need a high point with 360 degrees view of the horizon. The radio waves from the aircraft travel in a line of sight. They will not pass through buildings or mountains. So, unless your antenna site is on top of a hill, then you will have a few blind spots in your coverage. The rule of thumb is; the higher-the better.

Putting an electrically conductive stick high on a building has other implications. You may need a mast; which has health and safety implications if you are climbing. Then there is lightning. If your antenna is struck by lightning, then there is the potential to cause damage to anything, or anyone, connected to it.

4 INSTALLING RTL1090 AND VIRTUAL RADAR SERVER

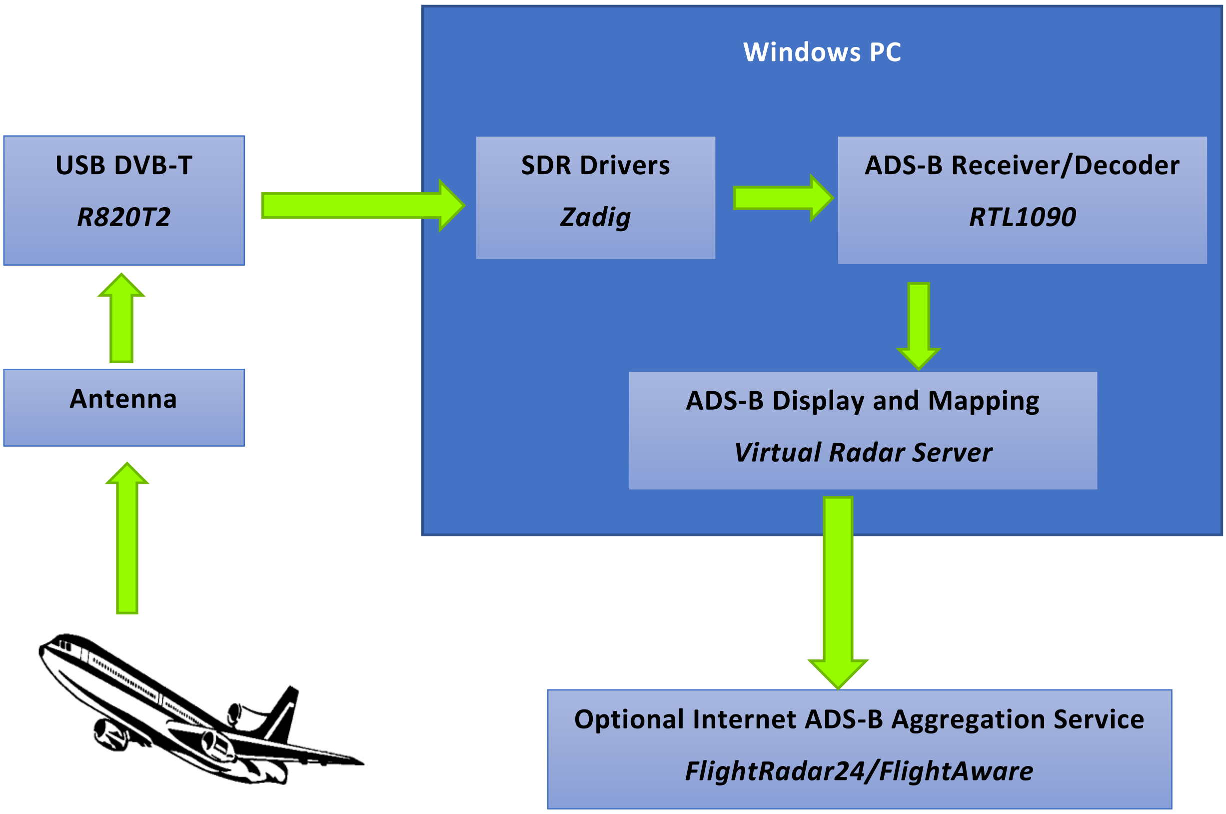
4.1 The Setup

We are going to set up our ADS-B system on a Windows PC.

Let's see how it goes together.

If we plugged the USB DVB-T receiver into our PC, the Windows operating system would search the internet for a set of driver files to allow it to operate correctly.

Because we are not intending to use the DVB-T receiver to watch TV, we need to download a new driver to unlock the SDRs full potential. The application that loads these drivers is called Zadig.



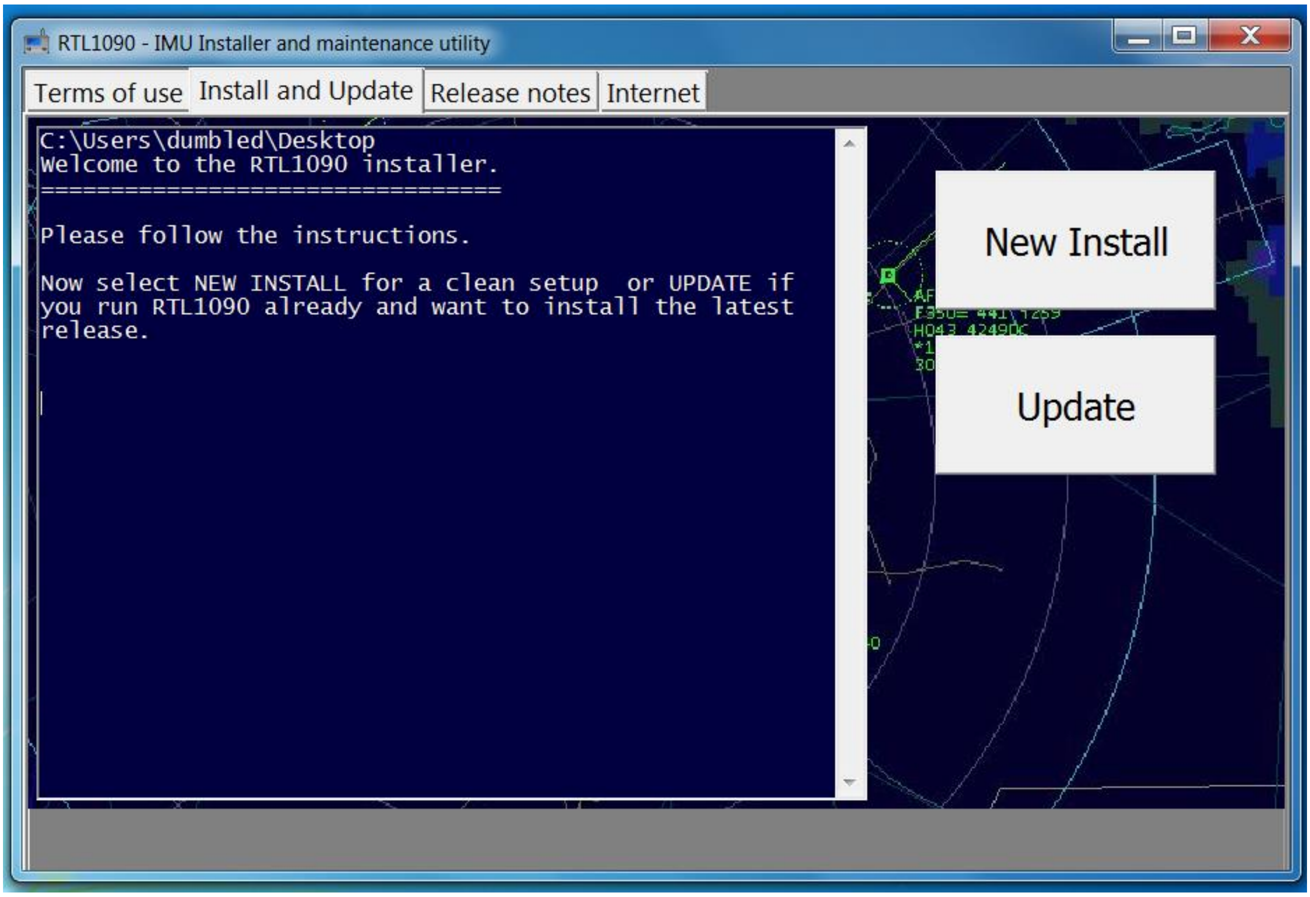
After installing the drivers, the ADS-B Receiver/Decoder can be installed. This program is called RTL1090. It tunes the unlocked SDR to 1090MHz and decodes any ADS-B messages received from nearby aircraft.

Once the Receiver/Decoder is installed, the display application can be loaded. In this case we are using Virtual Radar Server. This program has a nice Google Maps display and many advanced options for serving decoded ADS-B data to other sources.

4.2 RTL1090 IMU

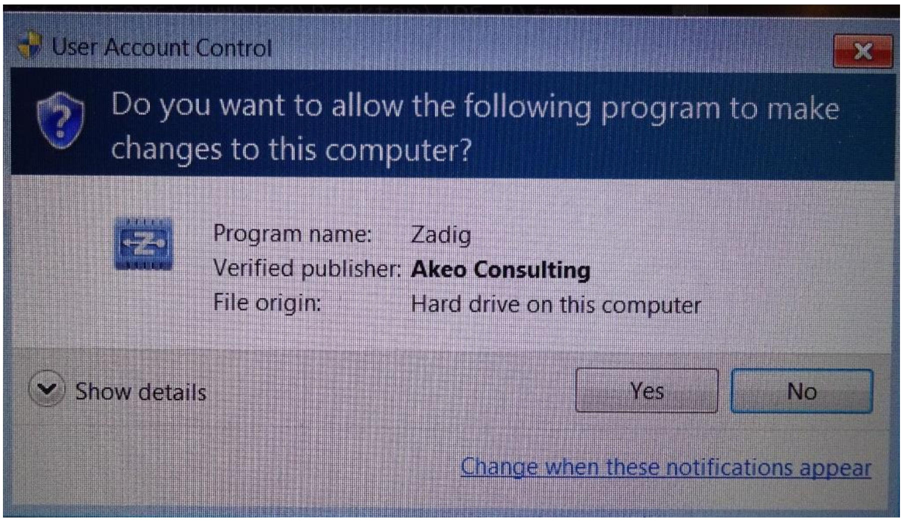
These instructions were made with a PC running Windows 7. There may be variations in procedures with other versions of Windows.

- The first thing to do is to create a folder called ADS-B on your desktop.
- Copy the following files from the supplied USB stick to the ADS-B folder:
  - rtl1090imu.exe
  - VirtualRadarSetup.exe; and
  - DatabaseWriterPluginSetup.exe
- Run the rtl1090imu application.
- Once you have read and accepted the Terms and Conditions, click the New Install button

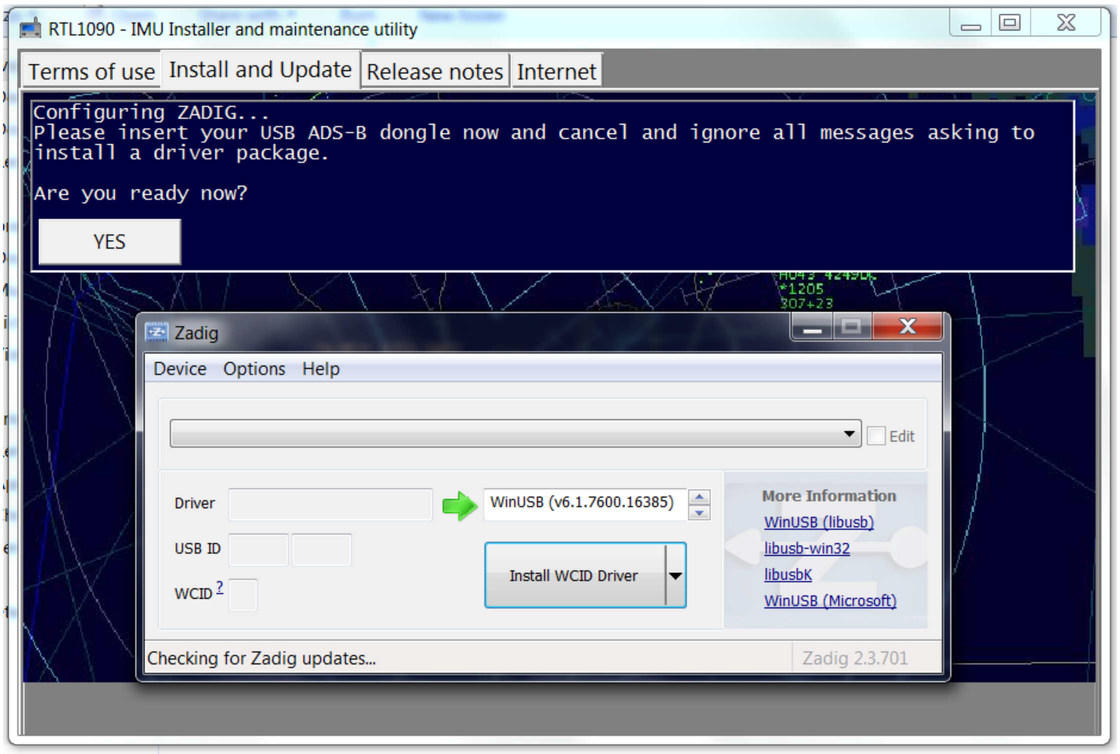


- Confirm your Windows version. Windows 10 is also supported, but not listed.
- Confirm your application folder. This should be the ADS-B folder you created earlier.

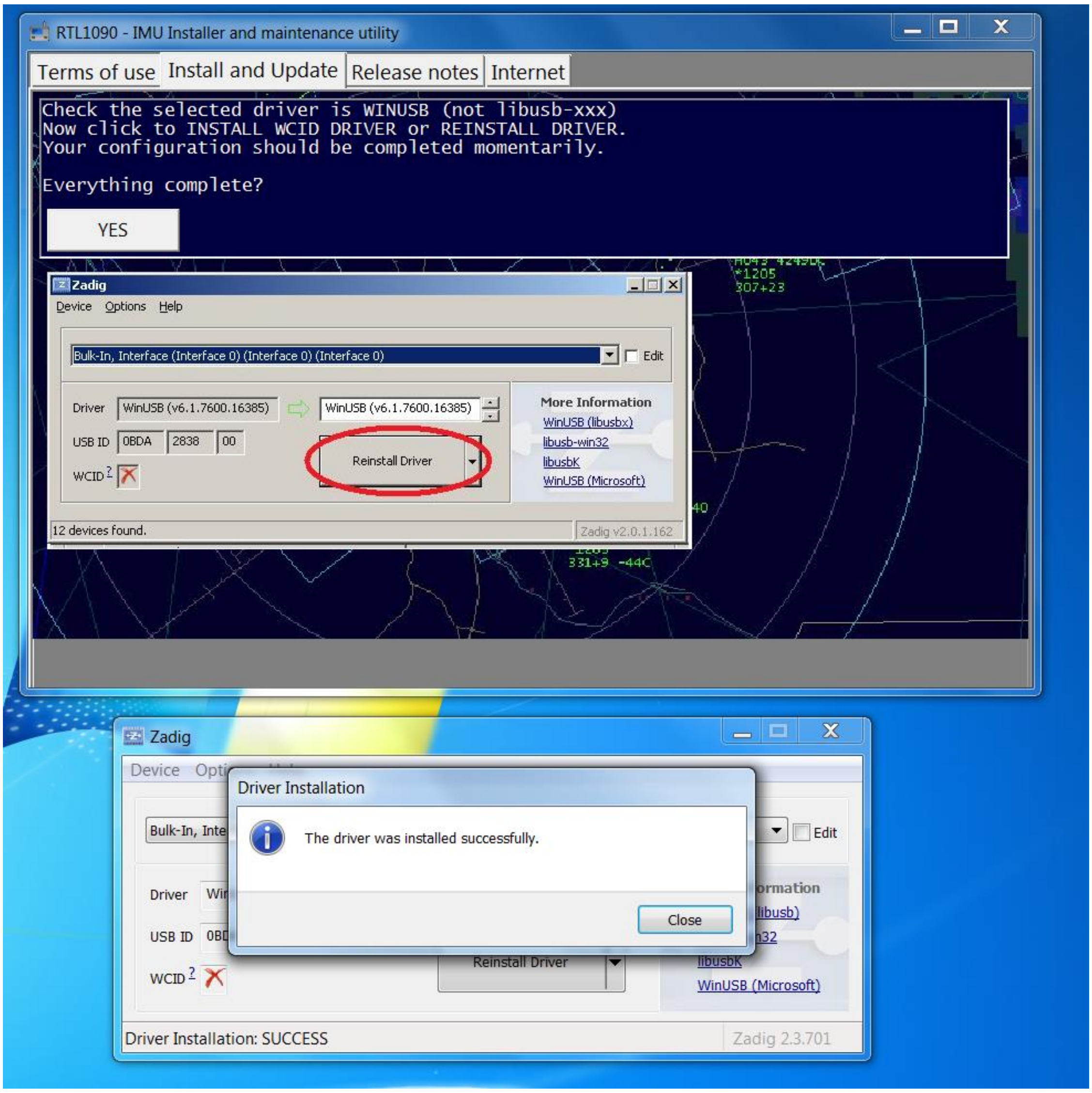
- The IMU will download the correct versions of the software needed; including the Zadig driver application.
- Accept any messages asking for permission to make changes



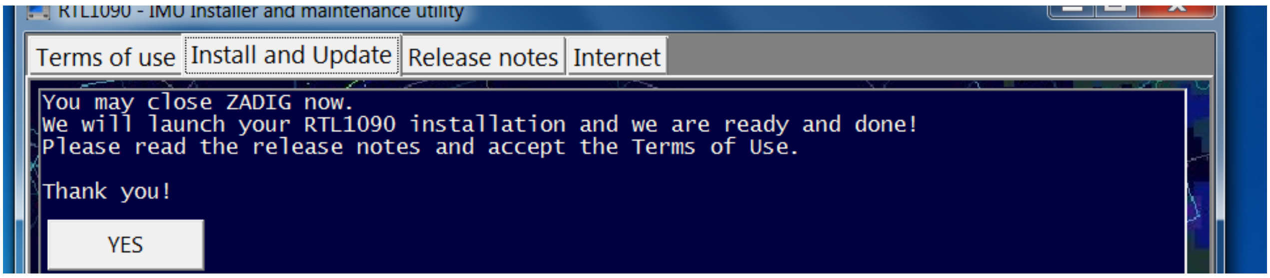
- Follow the instructions in the IMU window. Ignore messages to install a driver package. If it installs before you get a chance to stop it, don't worry. It should fix itself in the following steps.



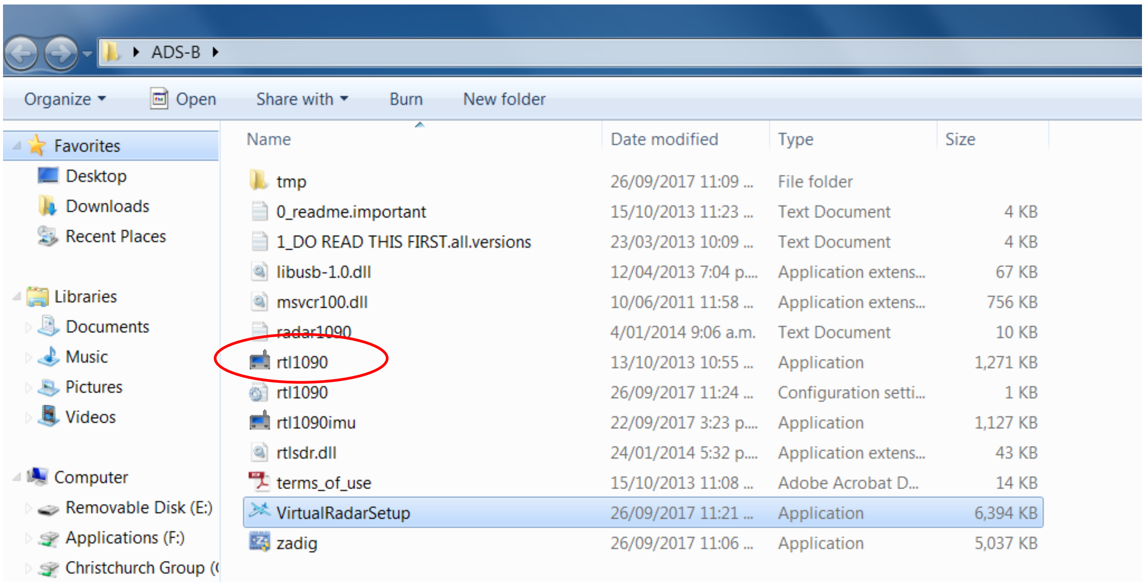
- Follow the steps in the IMU. This will lead you through the process of installing the drivers for the SDR.



- Once the driver has been installed successfully, the IMU will prompt you to exit the application.

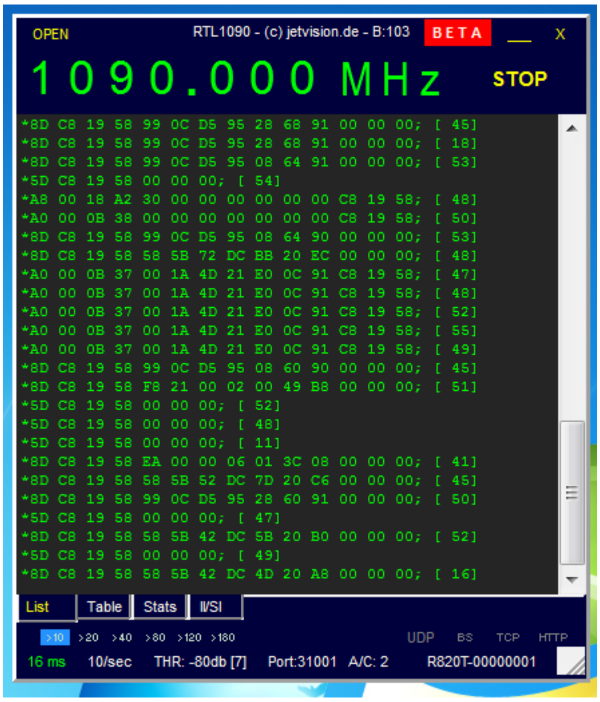


- Now you can connect your antenna to the USB SDR and start RTL1090. Set it up near a window where you have a good view of the open sky. Second story windows are best.
- Open the ADS-B folder on the desktop.
- Double click the RTL1090 Icon



- The RTL1090 application will start up.

- Click “Start” and, after a few seconds, if there are aircraft within range, the ADS-B codes from aircraft will start rolling up the screen.



- Click on the Table tab and you will see a list of Aircraft being tracked. Below, I can see:
    - RLK193 at 16600ft,
    - Travelling 270 knots,
    - Descending at 11ft/second
    - On a course of 232 degrees magnetic.

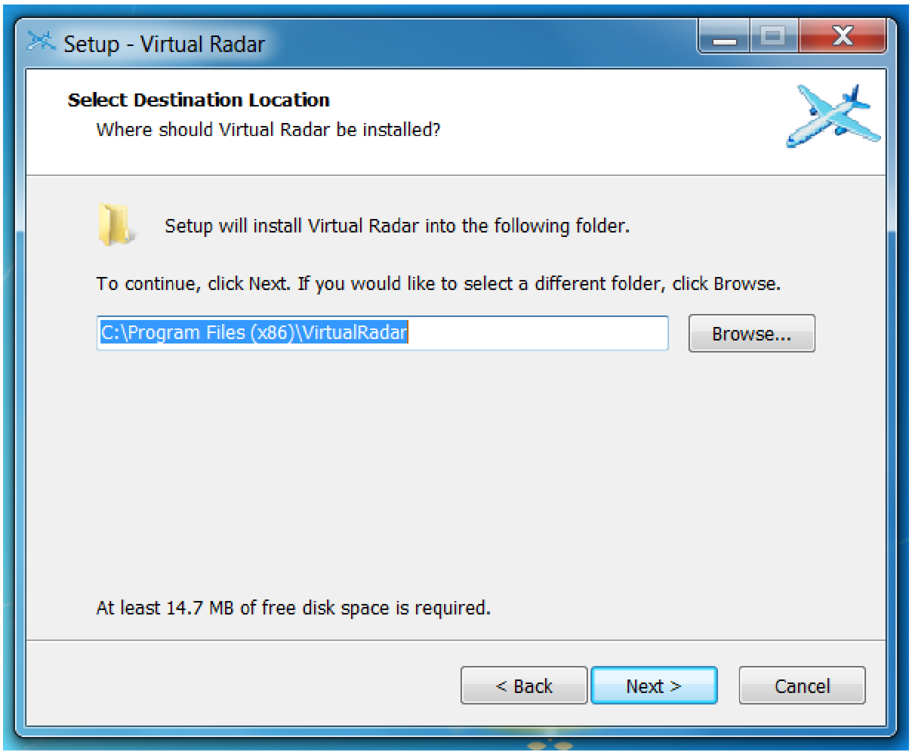
- It is a bit like reading the Matrix; and it’s not particular user friendly. There are no maps for situational awareness. That comes in the next part.

4.3 Virtual Radar Server

These instructions are based upon a blog by Sonic Goose (Rob Jones)[1].

Installation of VRS is reasonably simple.

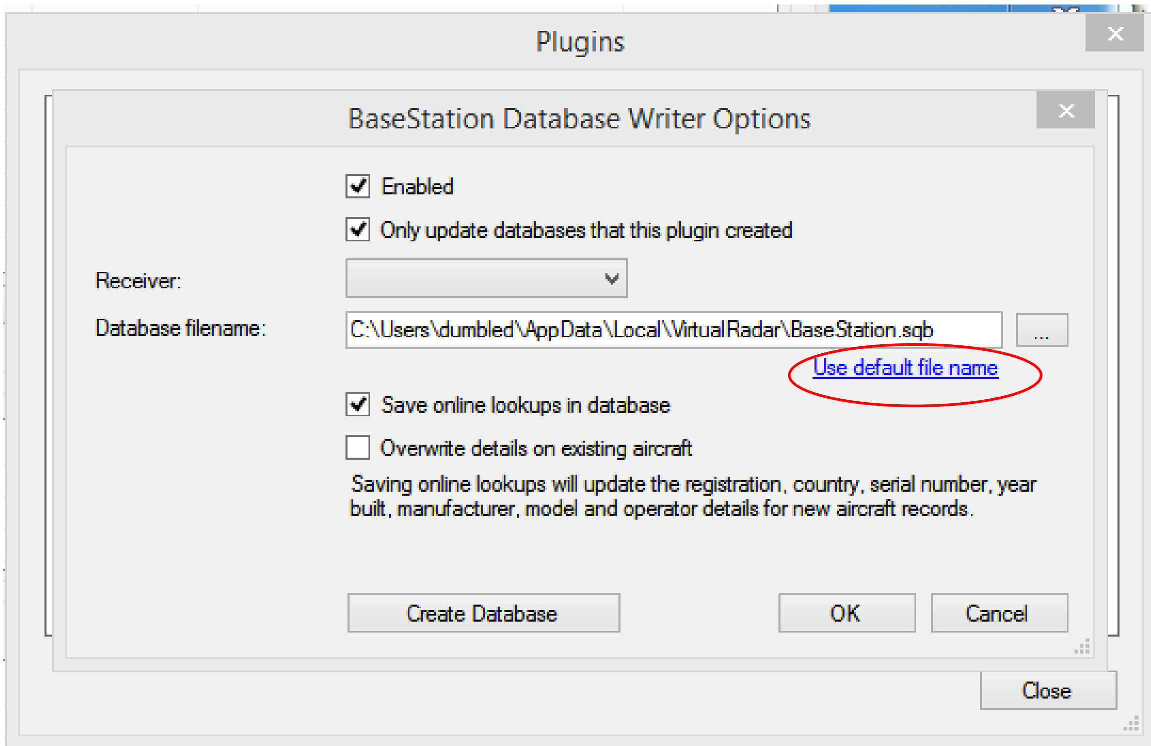
- Inside the ADS-B folder you created on the desktop are two files.
  - VirtualRadarServer.exe
  - DataBaseWriterSetup.exe
- Download and run VirtualRadarSetup.exe.
  - Accept the installation location it suggests. You can select another location if you want.



  - Accept the options presented to you by the installer. Unless you are sure about your organisation's IT security rules, do not tick the Firewall checkbox. You can always change this later if you need.

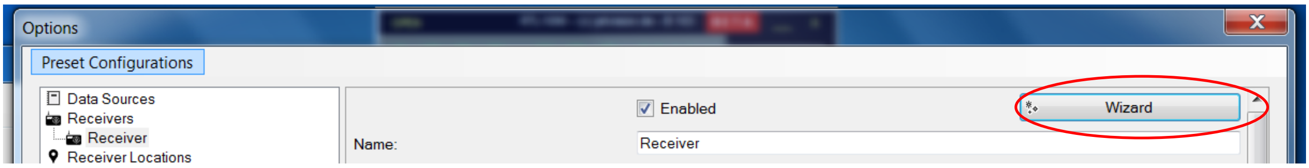
[1] Used with permission obtained 27 Sep 2017. Credit Rob Jones (www.sonicgoose.com)

- Download and install DatabaseWriterPluginSetup.exe. This is a plug-in for VRS that creates and populates a database of aircraft and flights for use in the virtual radar display.
    - Accept the installation location it suggests. You can select another location if you want.
    - Accept the options presented to you by the installer.
- Run Virtual Radar Server (it should be in the Windows list of programs).
- Click Tools, Plugins. A window opens showing the Database Writer.
- Click Options.
    - In the field for Database filename, click the “Use default file name” link. This will populate the field with the location for the Database.

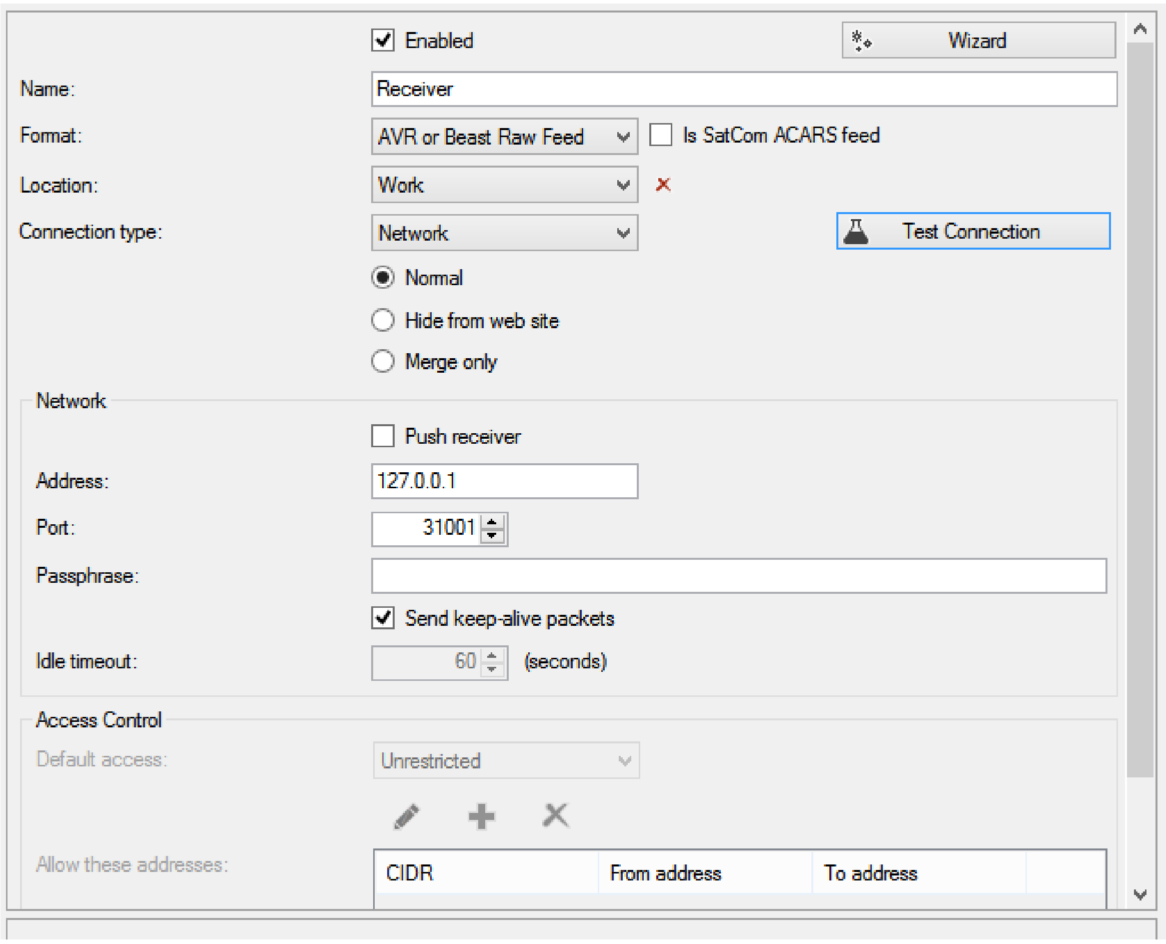


- Click Create Database.
    - Check the box beside Enabled to activate the plug-in, then click OK to close the window.
    - Click Close to close the Plugins window.
- Select Tools > Options.
- Navigate to Receivers >Receiver

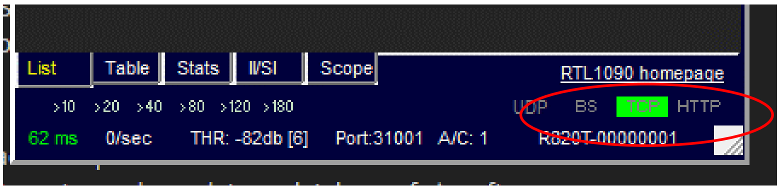
- Click the Wizard button at the top right of the window. This will launch a setup tool to allow you to configure VRS to talk to RTL1090.



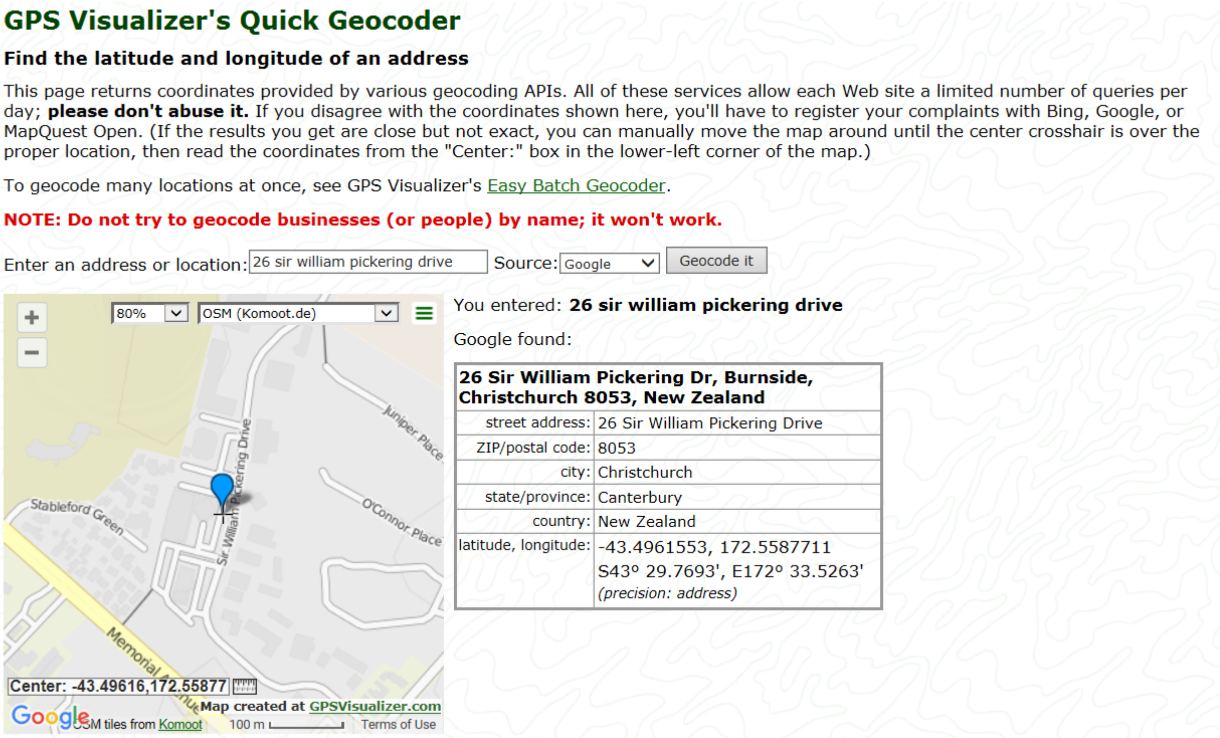
- Select “A software defined radio”. Click next.
- Select “RTL1090”. Click Next.
    - Note there are many other options for future experiments.
- Select “Yes”. Click Next
- Click “Finish” to modify the receiver details.
- Check the receiver details. They should read as follows



- If RTL1090 is running, stop and start it.
  - If VRS is setup correctly, then the Green TCP light on the RTL1090 window will light. This indicates a network connection has been made.



- On the left side of the VRS Options window, click Receiver Locations
- Set Receiver location to the latitude and longitude of your location.
  - If you don't know your location in lat and long format, you can find it at http://www.gpsvisualizer.com/geocode
  - Simply enter your street address, city, and country, select Google, then click Geocode It.
  - You will get Lat and Long numbers in the format xx.xxxxxx. Use these numbers in VRS. (Note, because we are south of the equator, your Lat will start with a –)



GPS Visualizer's Quick Geocoder

Find the latitude and longitude of an address

This page returns coordinates provided by various geocoding APIs. All of these services allow each Web site a limited number of queries per day; **please don't abuse it.** If you disagree with the coordinates shown here, you'll have to register your complaints with Bing, Google, or MapQuest Open. (If the results you get are close but not exact, you can manually move the map around until the center crosshair is over the proper location, then read the coordinates from the "Center:" box in the lower-left corner of the map.)

To geocode many locations at once, see GPS Visualizer's Easy Batch Geocoder.

NOTE: Do not try to geocode businesses (or people) by name; it won't work.

Enter an address or location: 26 sir william pickering drive Source: Google Geocode it

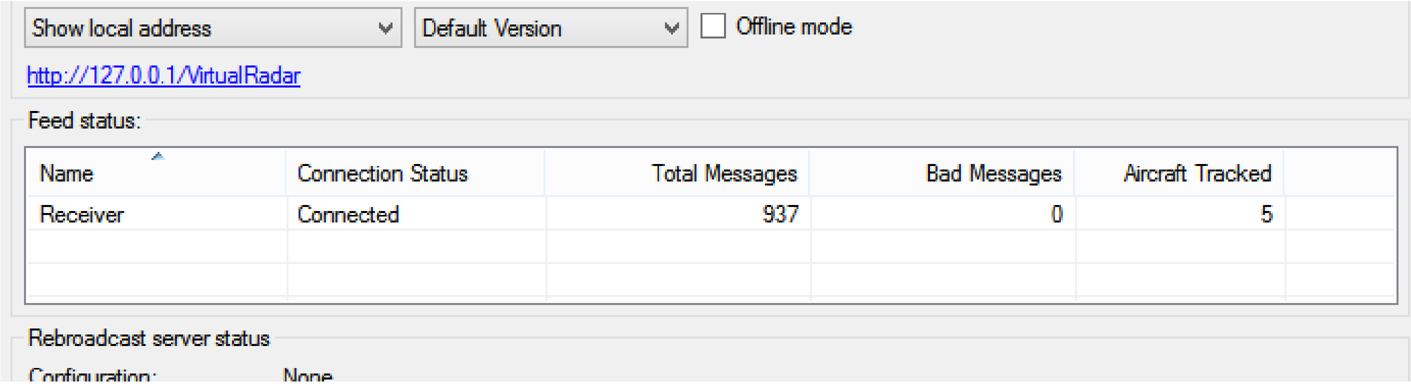
You entered: **26 sir william pickering drive**

Google found:

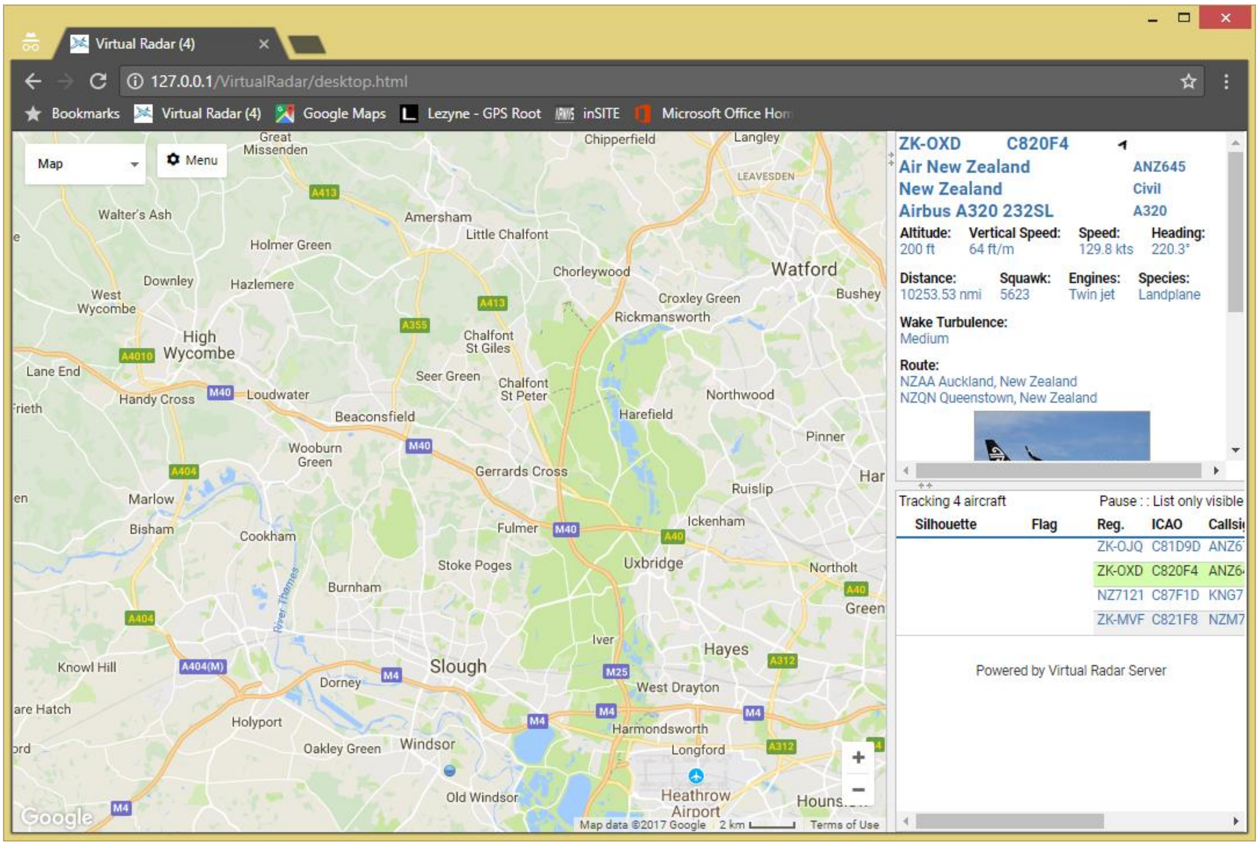
26 Sir William Pickering Dr, Burnside, Christchurch 8053, New Zealand	
street address:	26 Sir William Pickering Drive
ZIP/postal code:	8053
city:	Christchurch
state/province:	Canterbury
country:	New Zealand
latitude, longitude:	-43.4961553, 172.5587711 S43° 29.7693', E172° 33.5263' *(precision: address)*

- Give this location a name (Work, Home, School etc.).
- Navigate back to the Options > Receivers > Receiver page and Select the location using the Location dropdown. Exit the Options window.

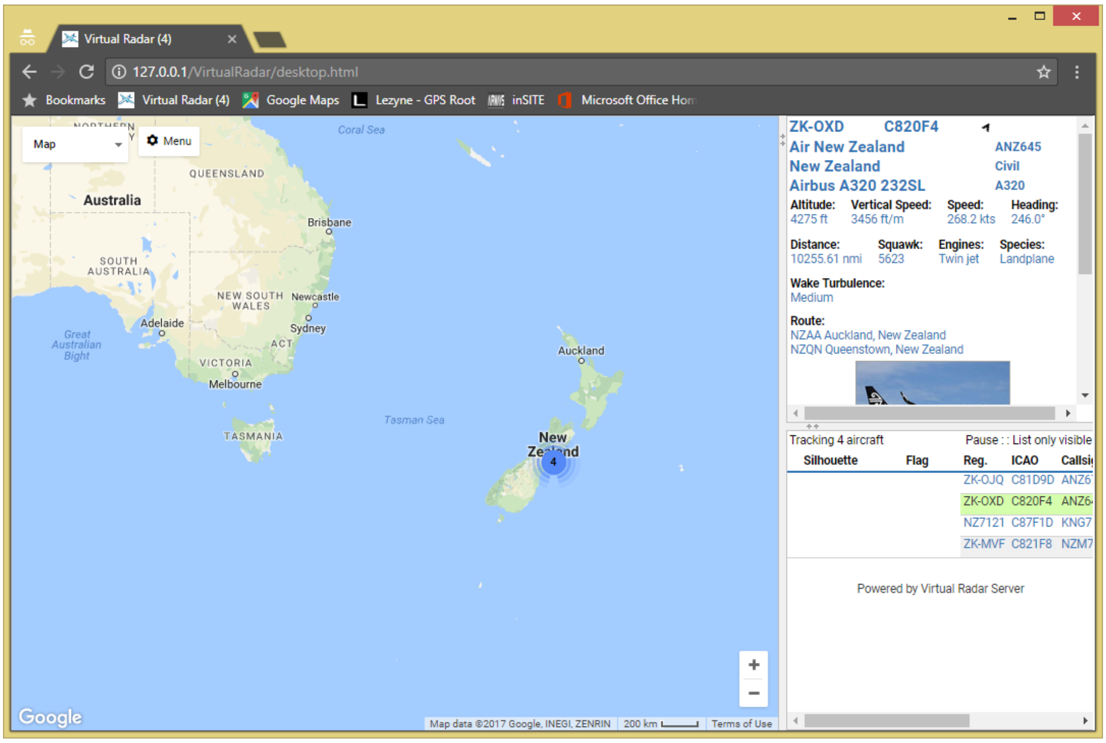
- If RTL1090 is running and connected, the front page will show “connected”. The message count and Aircraft tracked fields should also be populating if there are aircraft nearby.



- Click on the link http://127.0.0.1/VirtualRadar and the webpage will open.
- The first time you visit the webpage, you probably will not see any aircraft. In fact, you will probably not be anywhere in New Zealand. The map seems to default to the United Kingdom (Heathrow), despite the fact that we are tracking aircraft in NZ

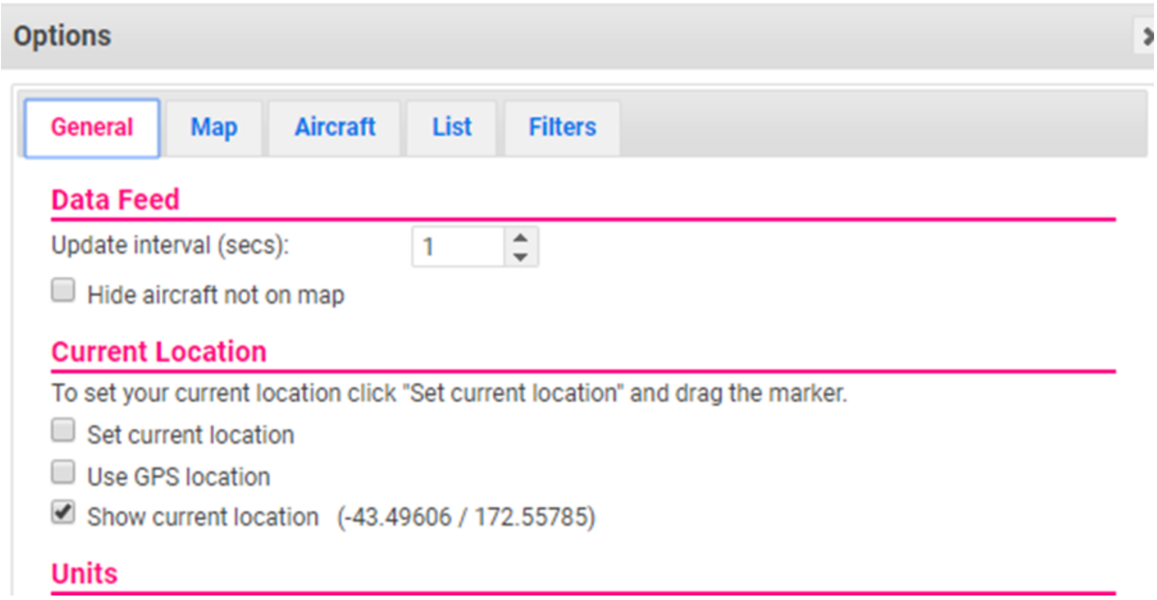


- You can zoom out, navigate to NZ and zoom into your location. A blue bubble with a number in it will indicate the number of aircraft being tracked.

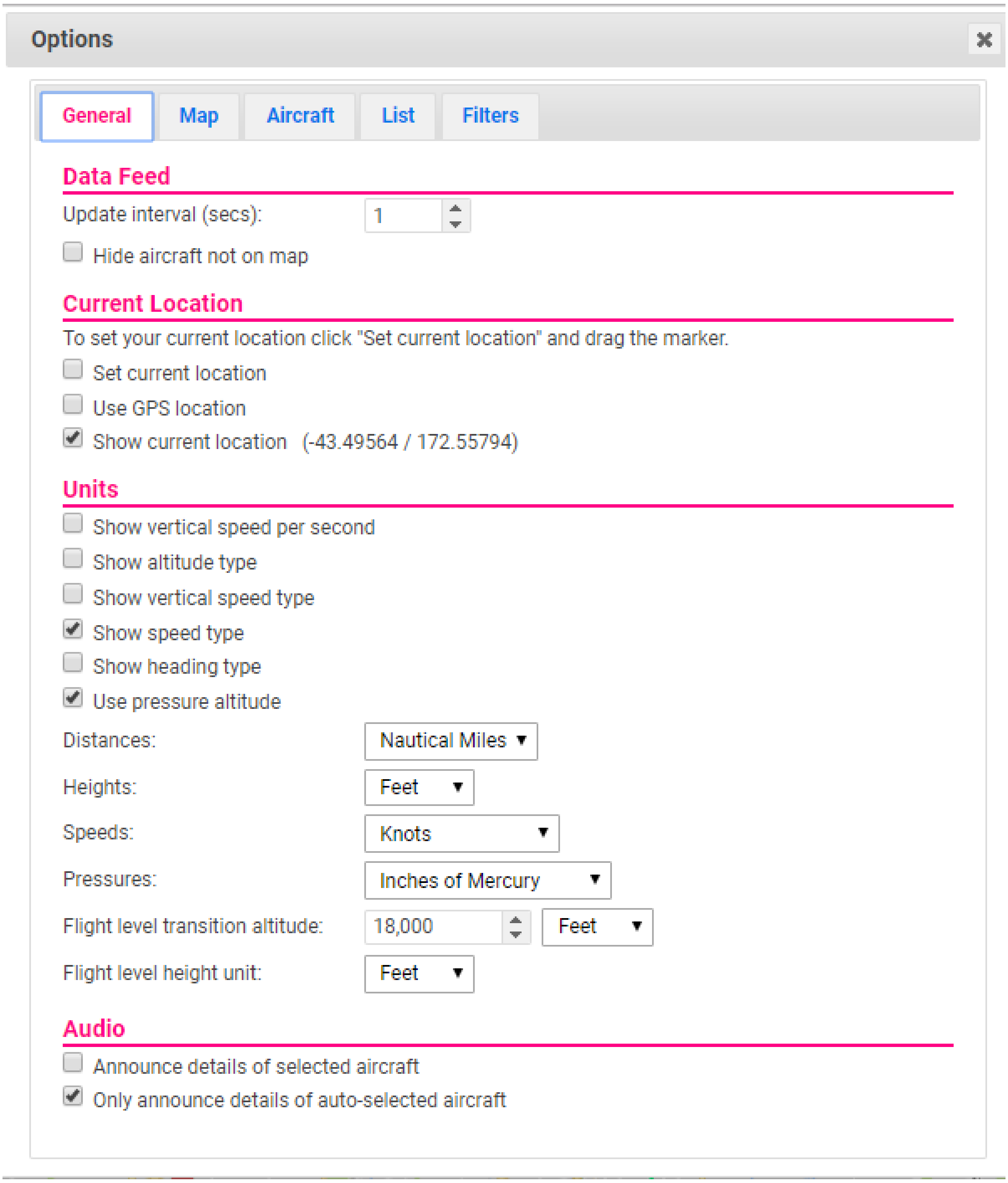


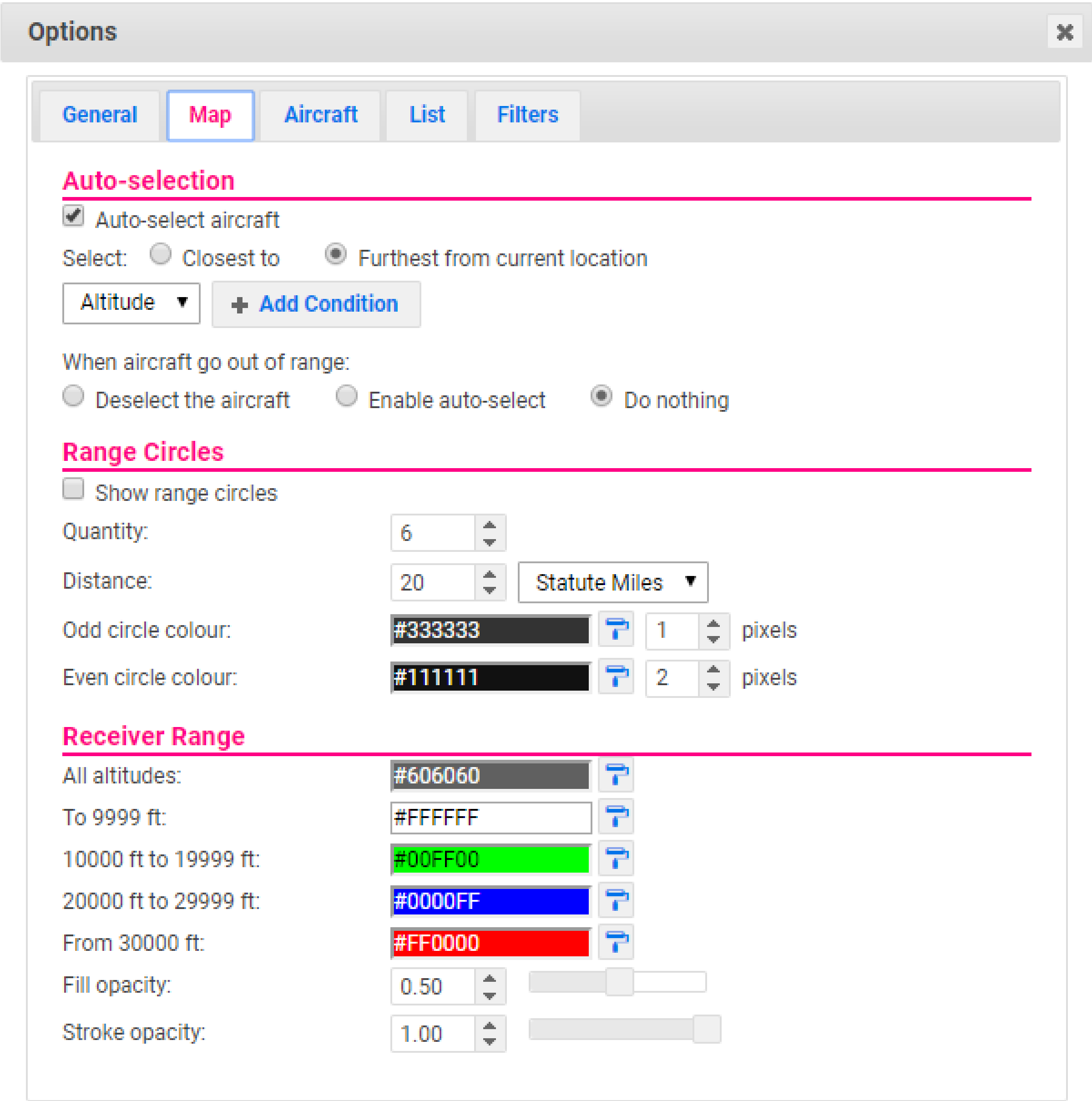
- The next step is to set your location on the map. This means that the map will always return to your location whenever you revisit the webpage.
- Click Menu > Options
- Click > Set current location.
    - This will send you back to the UK but put a big red flag in the centre of the screen.
- Zoom out and drag the red flag to your current location on the map.
    - Sometimes it helps to select the satellite map to put the flag exactly where you are.
    - Click Map > Satellite to change maps.
    - Zoom in and drag the flag to your location.
- Click Menu > Options
- Uncheck > Set Current Location and Check > Show Current Location

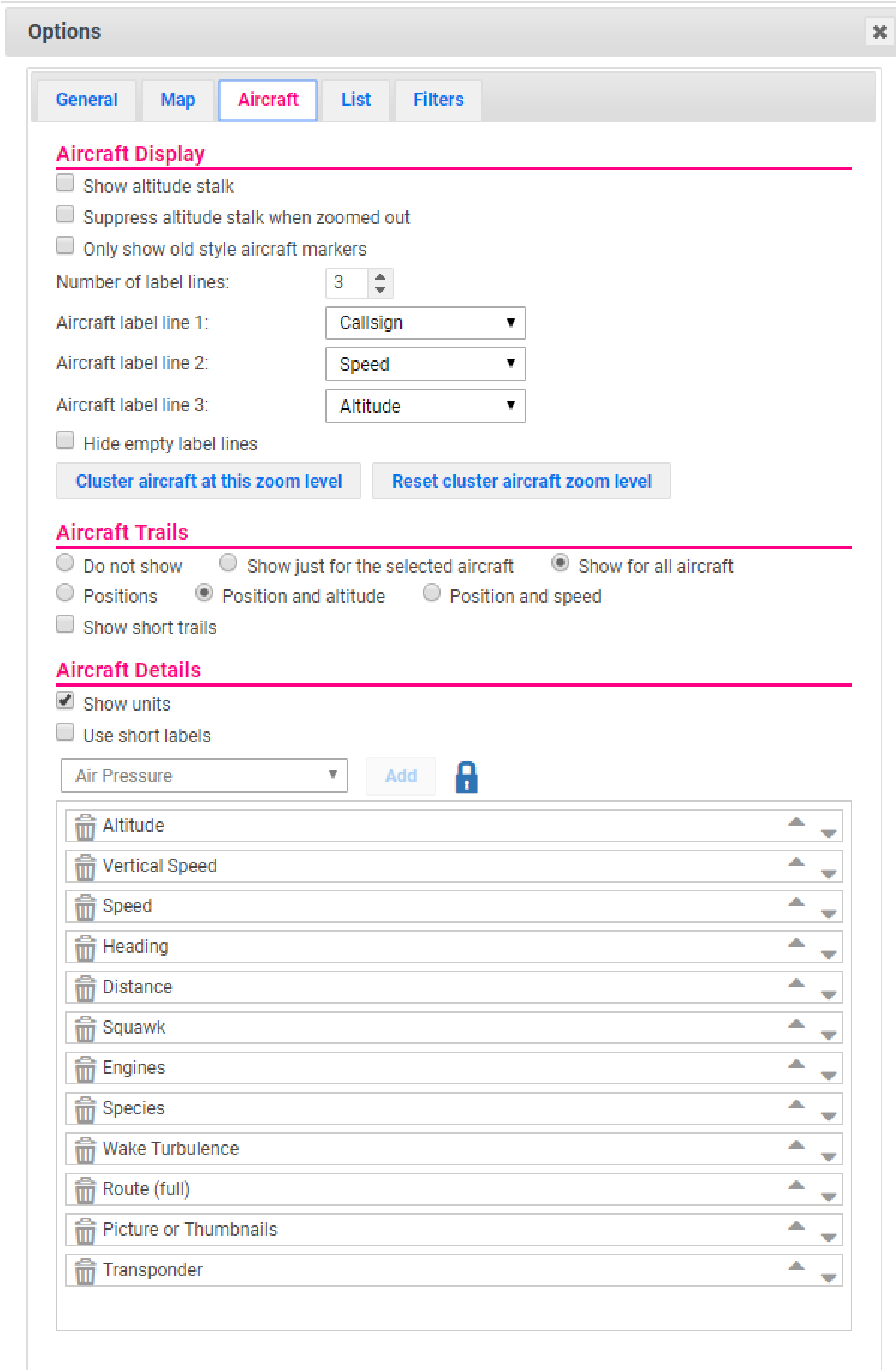
- The Lat/Long of your current location should be displayed in brackets.

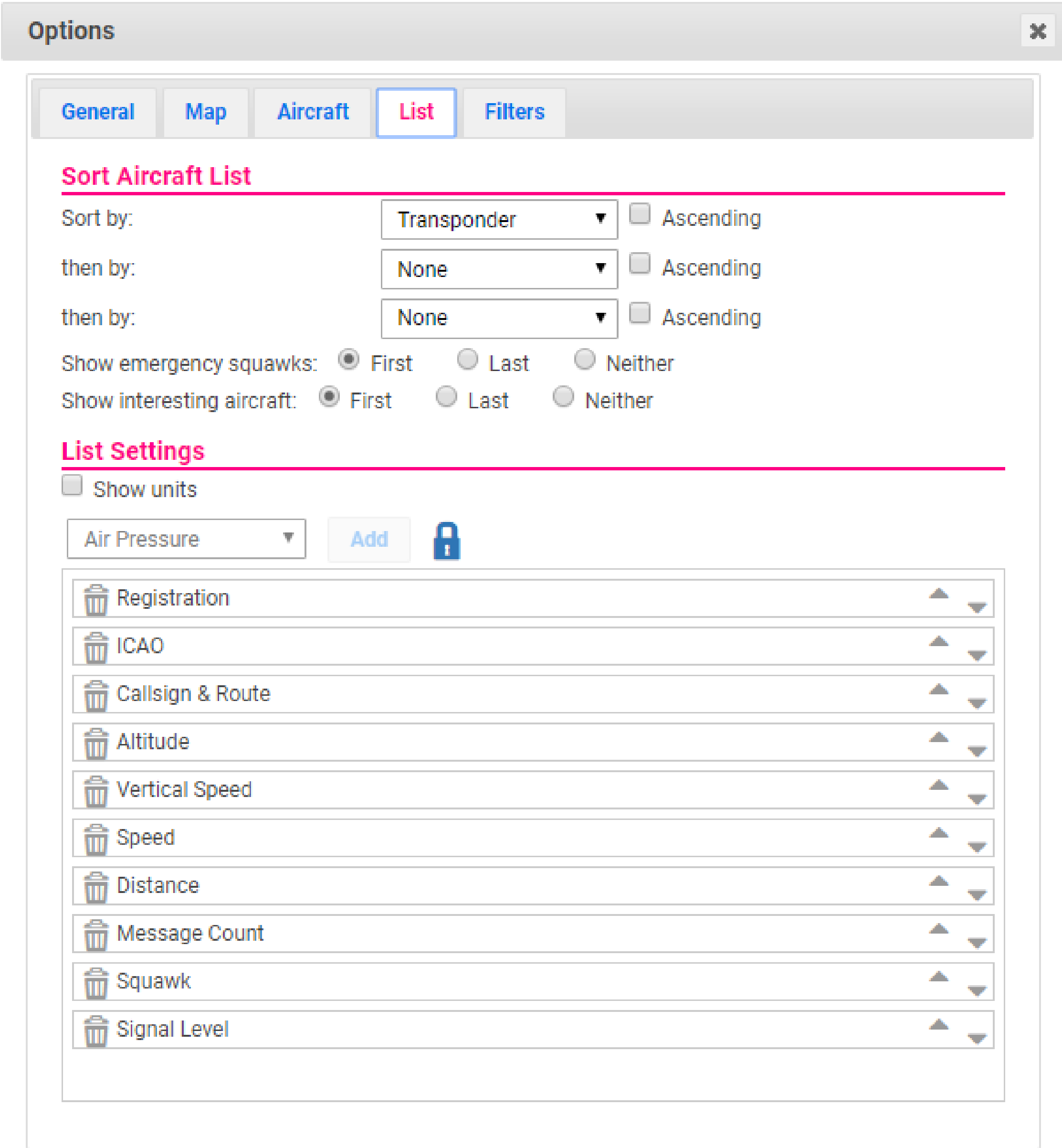


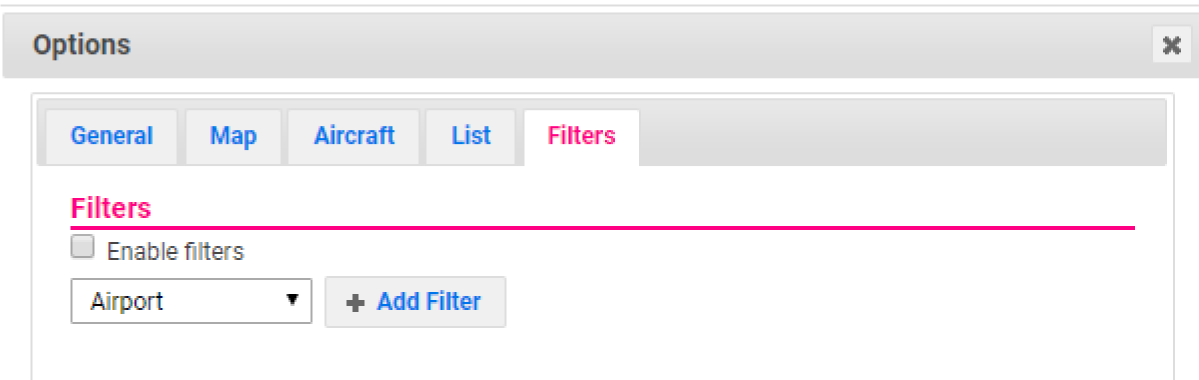
- Close the Options window and a blue dot should show your location.
- There are plenty of other options available to customise VRS to display exactly what you want. I have included screen shots of my options as a good starting point.

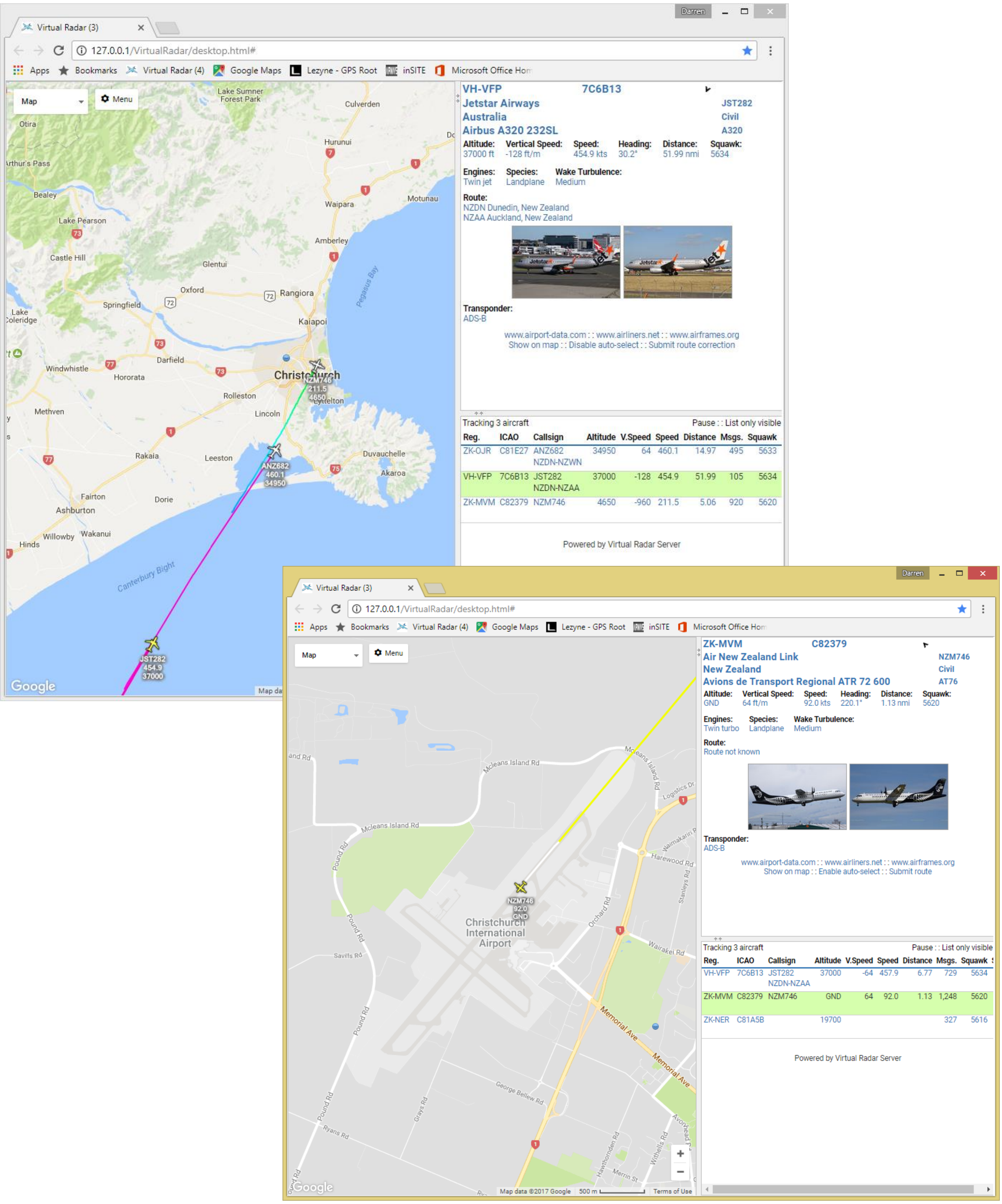

Options
General
Map
Aircraft
List
Filters
Data Feed
Update interval (secs): 1
Hide aircraft not on map
Current Location
To set your current location click "Set current location" and drag the marker.
Set current location
Use GPS location
Show current location (-43.49564 / 172.55794)
Units
Show vertical speed per second
Show altitude type
Show vertical speed type
Show speed type
Show heading type
Use pressure altitude
Distances: Nautical Miles
Heights: Feet
Speeds: Knots
Pressures: Inches of Mercury
Flight level transition altitude: 18,000 Feet
Flight level height unit: Feet
Audio
Announce details of selected aircraft
Only announce details of auto-selected aircraft


Options
General
Map
Aircraft
List
Filters
Auto-selection
Auto-select aircraft
Select:
Closest to
Furthest from current location
Altitude
Add Condition
When aircraft go out of range:
Deselect the aircraft
Enable auto-select
Do nothing
Range Circles
Show range circles
Quantity:
6
Distance:
20
Statute Miles
Odd circle colour:
#333333
1
pixels
Even circle colour:
#111111
2
pixels
Receiver Range
All altitudes:
#606060
To 9999 ft:
#FFFFFF
10000 ft to 19999 ft:
#00FF00
20000 ft to 29999 ft:
#0000FF
From 30000 ft:
#FF0000
Fill opacity:
0.50
Stroke opacity:
1.00


Options
General
Map
Aircraft
List
Filters
Aircraft Display
Show altitude stalk
Suppress altitude stalk when zoomed out
Only show old style aircraft markers
Number of label lines:
3
Aircraft label line 1:
Callsign
Aircraft label line 2:
Speed
Aircraft label line 3:
Altitude
Hide empty label lines
Cluster aircraft at this zoom level
Reset cluster aircraft zoom level
Aircraft Trails
Do not show
Show just for the selected aircraft
Show for all aircraft
Positions
Position and altitude
Position and speed
Show short trails
Aircraft Details
Show units
Use short labels
Air Pressure
Add
Altitude
Vertical Speed
Speed
Heading
Distance
Squawk
Engines
Species
Wake Turbulence
Route (full)
Picture or Thumbnails
Transponder


Options
General
Map
Aircraft
List
Filters
Sort Aircraft List
Sort by:
Transponder
Ascending
then by:
None
Ascending
then by:
None
Ascending
Show emergency squawks: First Last Neither
Show interesting aircraft: First Last Neither
List Settings
Show units
Air Pressure
Add
Registration
ICAO
Callsign & Route
Altitude
Vertical Speed
Speed
Distance
Message Count
Squawk
Signal Level


Options
General
Map
Aircraft
List
Filters
Filters
Enable filters
Airport
Add Filter


Virtual Radar (3)
127.0.0.1/VirtualRadar/desktop.html#
VH-VFP
7C6B13
Jetstar Airways
JST282
Australia
Civil
Airbus A320 232SL
A320
Altitude: 37000 ft
Vertical Speed: -128 ft/m
Speed: 454.9 kts
Heading: 30.2°
Distance: 51.99 nmi
Squawk: 5634
Engines: Twin jet
Species: Landplane
Wake Turbulence: Medium
Route:
NZDN Dunedin, New Zealand
NZAA Auckland, New Zealand
Transponder: ADS-B
www.airport-data.com :: www.airliners.net :: www.airframes.org
Show on map :: Disable auto-select :: Submit route correction
Tracking 3 aircraft
Pause :: List only visible
Reg. ICAO Callsign Altitude V.Speed Speed Distance Msgs. Squawk
ZK-OJR C81E27 ANZ682 NZDN-NZWN 34950 64 460.1 14.97 495 5633
VH-VFP 7C6B13 JST282 NZDN-NZAA 37000 -128 454.9 51.99 105 5634
ZK-MVM C82379 NZM746 4650 -960 211.5 5.06 920 5620
Powered by Virtual Radar Server
Christchurch
Canterbury Bight
ZK-MVM
C82379
Air New Zealand Link
NZM746
New Zealand
Civil
Avions de Transport Regional ATR 72 600
AT76
Altitude: GND
Vertical Speed: 64 ft/m
Speed: 92.0 kts
Heading: 220.1°
Distance: 1.13 nmi
Squawk: 5620
Engines: Twin turbo
Species: Landplane
Wake Turbulence: Medium
Route: Route not known
Transponder: ADS-B
www.airport-data.com :: www.airliners.net :: www.airframes.org
Show on map :: Enable auto-select :: Submit route
Tracking 3 aircraft
Pause :: List only visible
VH-VFP 7C6B13 JST282 NZDN-NZAA 37000 -64 457.9 6.77 729 5634
ZK-MVM C82379 NZM746 GND 64 92.0 1.13 1,248 5620
ZK-NER C81A5B 19700 327 5616
Powered by Virtual Radar Server
Christchurch International Airport

4.4 Build a Long-range Collinear Antenna

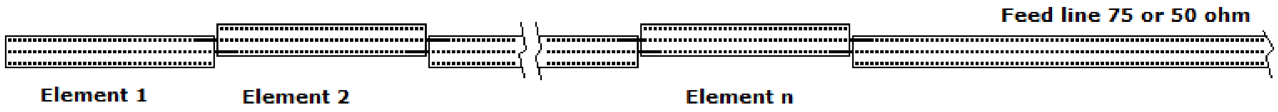
We can build very simple, but effective, collinear antenna using half-wave lengths of co-axial cable. This instruction was derived from a website post found at http://www.balarad.net/ by Dusan Balara.[2]

The cable we will be using is RG58U.

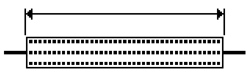
The antenna will be tuned for receiving ADSB broadcasts from an aircraft. ADSB is transmitted at 1090MHz.

The antenna will be constructed of 8 x half wave lengths of coaxial cable connected as shown below. A small feed line will be terminated with a 50-ohm connector.

The connector chosen must match the impedance of the cable. Coaxial cable are, either, 50 ohm or 75 ohm. This is specified in the cable data sheet.



The formula for calculating the length of each element is:



$$L = \frac{\lambda}{2} * velocity\ factor$$

$$\lambda = \frac{c}{f}$$

Where : c is the speed of light (3 x 10^8 m/s) and f is the frequency

[2] Used with permission obtained 27 Sep 2017. Credit Dusan Balara (www.balarad.net/)

The velocity factor is the speed at which the signal travels down the cable, compared to the speed of light. In this case, the velocity factor is 0.66, or 66% of the speed of light (198 000 000 m/sec).

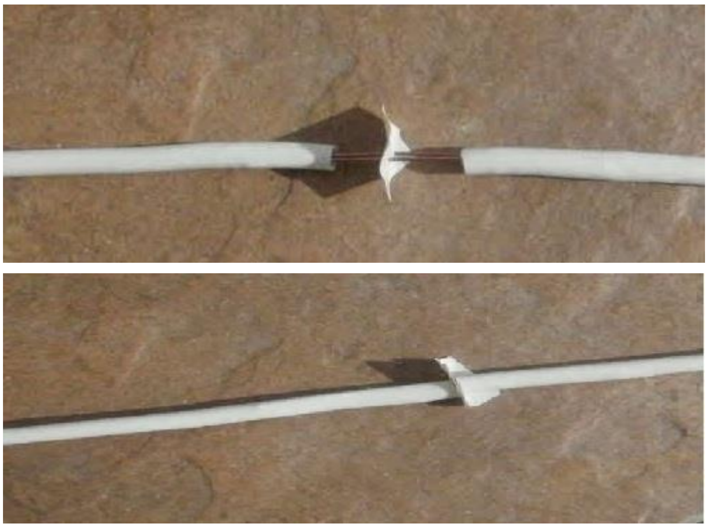
The velocity factor can be found on the attached data sheet for RG58U cable.

Construction

Now we have determined the length of each tuned element, we can now begin measuring and cutting the coaxial cable.

Make sure you add 100mm to each length to allow a 50mm “tail” on each end.

When assembling the components, use a small piece of electrical tape between each element to prevent short circuits. Carefully push each tail between the outer insulation and the braid. Use electrical tape or heat shrink tubing to seal the joins.



Use a final section of the coaxial cable as the feed. This needs to be terminated with a Radio Frequency connector (BNC or N-Type).

I have my antenna (in true backyard engineering style) stuck to the inside of my office's north-facing window with duct tape!

However, this thin antenna can be sealed inside some electrical conduit for mounting outside. Instructions are included in the blog post at http://www.balarad.net/.

The blog also provides a lot of information about lightning protection for outdoor antennas. Any outdoor antenna we use at Airways has lightning arrestors to protect the equipment connected to it.

If you are planning to setup a permanent installation; then lightning protection should be considered.

The antenna is installed vertically.

Detailed Specifications & Technical Data

METRIC MEASUREMENT VERSION

9201 Coax - RG-58/U Type

For more Information
please call

1-800-Belden1

General Description:

RG-58/U type, 20 AWG solid .033" bare copper conductor, polyethylene insulation, bare copper braid shield (80% coverage), PVC jacket.

Physical Characteristics (Overall)

Conductor

AWG:

# Coax	AWG	Stranding	Conductor Material	Dia. (mm)
1	20	Solid	BC - Bare Copper	0.8382

Total Number of Conductors:	1

Insulation

Insulation Material:

Insulation Material	Dia. (mm)
PE - Polyethylene	2.9464

Outer Shield

Outer Shield Material:

Type	Outer Shield Material	Coverage (%)
Braid	BC - Bare Copper	80.000

Outer Jacket

Outer Jacket Material:

Outer Jacket Material
PVC - Polyvinyl Chloride

Overall Cable

Overall Nominal Diameter:	4.902 mm

Mechanical Characteristics (Overall)

Operating Temperature Range:	-40°C To +80°C
Non-UL Temperature Rating:	75°C
Bulk Cable Weight:	34.229 Kg/Km
Max. Recommended Pulling Tension:	164.583 N
Min. Bend Radius/Minor Axis:	50.800 mm

Applicable Specifications and Agency Compliance (Overall)

Applicable Standards & Environmental Programs

EU Directive 2011/65/EU (ROHS II):	Yes
EU CE Mark:	Yes
EU Directive 2000/53/EC (ELV):	Yes
EU Directive 2002/95/EC (RoHS):	Yes
EU RoHS Compliance Date (mm/dd/yyyy):	01/01/2004
EU Directive 2002/96/EC (WEEE):	Yes
EU Directive 2003/11/EC (BFR):	Yes

Detailed Specifications & Technical Data

METRIC MEASUREMENT VERSION

BELDEN
SENDING ALL THE RIGHT SIGNALS

9201 Coax - RG-58/U Type

CA Prop 65 (CJ for Wire & Cable):	Yes
MII Order #39 (China RoHS):	Yes
RG Type:	58/U

Plenum/Non-Plenum

Plenum (Y/N):	No

Electrical Characteristics (Overall)

Nom. Characteristic Impedance:

Impedance (Ohm)
52

Nom. Inductance:

Inductance (µH/m)
0.262808

Nom. Capacitance Conductor to Shield:

Capacitance (pF/m)
93.5085

Nominal Velocity of Propagation:

VP (%)
66

Nominal Delay:

Delay (ns/m)
5.05274

Nom. Conductor DC Resistance:

DCR @ 20°C (Ohm/km)
32.81

Nominal Outer Shield DC Resistance:

DCR @ 20°C (Ohm/km)
18.0455

Nom. Attenuation:

Freq. (MHz)	Attenuation (dB/100m)
1	0.9843
10	3.6091
50	8.2025
100	12.4678
200	18.3736
400	27.5604
700	38.3877
900	44.9497
1000	47.5745

Max. Operating Voltage - Non-UL:

Voltage
1400 V RMS

Put Ups and Colors:

Item #	Putup	Ship Weight	Color	Notes	Item Desc
9201 010U1000	305 MT	11.340 KG	BLACK		#20PE BRD PVCRG58/U TYPE
9201 010U500	152 MT	5.897 KG	BLACK		#20PE BRD PVCRG58/U TYPE
9201 0101000	305 MT	11.340 KG	BLACK	C	#20PE BRD PVCRG58/U TYPE
9201 010500	152 MT	6.124 KG	BLACK		#20PE BRD PVCRG58/U TYPE

Notes:
C = CRATE REEL PUT-UP.

5 FURTHER EXPLORATION

Now you can track aircraft that are within radio range of your antenna. However, there are plenty of other challenges to accept.

Some of these include:

- Setup your system to serve the VRS webpage around the school network.
- Embed a link to your VRS Webpage on the school website.
- Setup your system to provide a feed to an aggregation service such as:
    - FlightRadar24
    - FlightAware
    - PlaneFinder
    - ADSB Exchange
- Design and build a better antenna.
- Investigate the ADS-B signal structure.
- Use your RT820T2 to listen into an Air Traffic Control radar.
- Find alternative Decoder programs and use those.
- Find alternative display applications and try those.
- Setup a Raspberry Pi based ADS-B system.
- Write a Plane Tracker App that uses your tracker's data.
- Integrate other open-source aviation data (such as Weather, Flight Departures/Arrivals) into the system
- Subscribe to a Blog https://www.rtl-sdr.com/tag/ads-b/
- Get into some podcasts.
- Use your imagination.
- Be inspired.

Student Notes