

## **Receiving and decoding multiple C-Band Inmarsat Transmissions**

Many enthusiasts have succeeded in decoding SatcomACARS using a parabolic dish equipped with a C-Band LNB, which feeds the down-converted signal into a RTL based SDR. Decoding is accomplished by feeding the SDR audio to JAERO, which in turn outputs decoded texts which can then be integrated with the Plane Plotter software.

Satellite channel distribution of ACARS signals varies and in my case 4F1 appears to include 2 channels using the 10500bps burst protocol and at least 10 channels which transmit 1200bps burst signals. In order to take advantage of all the available data transmissions a receiving system capable of tuning to all of these channels has to be deployed. Not only does the receiver have to be tuned to the correct frequencies, it must also be adjusted to accommodate the different channel band-widths used by the two types of transmissions.

### **Decoding 10500bps burst signals**

In the case of 10500bps burst transmissions, accurate band-width adjustment is not overly critical. Because the two 10500bps burst channels are widely separated, a wider than strictly necessary signal or filter band-width can be used, in order to compensate for frequency drifts introduced by the LNB. These frequency variations are mainly the result of temperature changes, which affect the frequency of the local oscillator inside the LNB.

### **The RTL-SDR**

In the simplest version of the RTL-SDR, frequency accuracy may also vary due to temperature variations caused by changes in ambient temperature, which affect the frequency generated by the internal crystal oscillator. To compensate for this thermal drift, RTL-SDR devices provided with a TCXO (Temperature Controlled Crystal Oscillator) are available and are recommended for use in C-Band decoding, where frequency stability is essential. In general the frequency stability of a TCXO SDR is adequate for 10500bps burst decoding, because as mentioned earlier we can use a very wide channel band-width when setting the receive parameters. I have found a band-width of 15.0kHz adequate for 10500bps burst signals.

### **Decoding the 1200bps burst signals**

The situation becomes significantly more critical when decoding 1200bps burst signals. These channels are often clustered in lots of three and band-widths cannot be set too wide in order to avoid encroaching on adjacent signals, as is illustrated in figure 1 in the image on the next page.



3 \* 1200bps burst channels clustered together

Figure 1

In my case I have concluded that a band-width of 3.0kHz is just about maximum. Unfortunately this band-width is not sufficient to allow reliable decoding if you live in an environment where the LNB is subject to even moderate temperature variations, which causes frequency changes in the LNB output. Remember that in many climates temperatures can drop significantly during the night. In order to minimise temperature related frequency drifts, I built a 25.0MHz TCXO disciplined oscillator, with which I inject the 25.0MHz clock frequency into a modified LNB. Details of the LNB modification and external TCXO can be found on the Plane Plotter Wiki.

<http://planeplotter.pbworks.com/w/page/106135098/Satellite%20Ground%20Station> .

### Setting up the SDR software

There are many excellent programs available to function as Software Defined Radios and many of them are capable of allowing simultaneous use of several VFOs (Variable Frequency Oscillators), or to keep things simple; “channels”. All of these programs have pros and cons and in this article I describe how to set up Simon Brown’s [SDR Radio](http://www.sdr-radio.com/), which I find to be most suitable for my purposes. Again keep in mind there are other programs, which may do the job equally well. Download the SDR Radio software and install it <http://www.sdr-radio.com/> . When you open SDR Radio and assuming that you have plugged your RTL-SDR device into an USB port, the program will ask you to select a radio from a list in a small window, as shown in figure 2. If this window is blank, it means that SDR

Radio was unable to find a suitable receiver. This is more than likely due to the fact that Windows in its infinite wisdom (more like complete lack of it) has loaded drivers for the DVB-T+DAB device, which was the original purpose of these, “Dongles”. You will have to run a small utility called “Zadig”. Details on how to use it are beyond the scope of this discussion and I would refer you to the SDR-RTL website <https://www.rtl-sdr.com/tag/zadig/> .

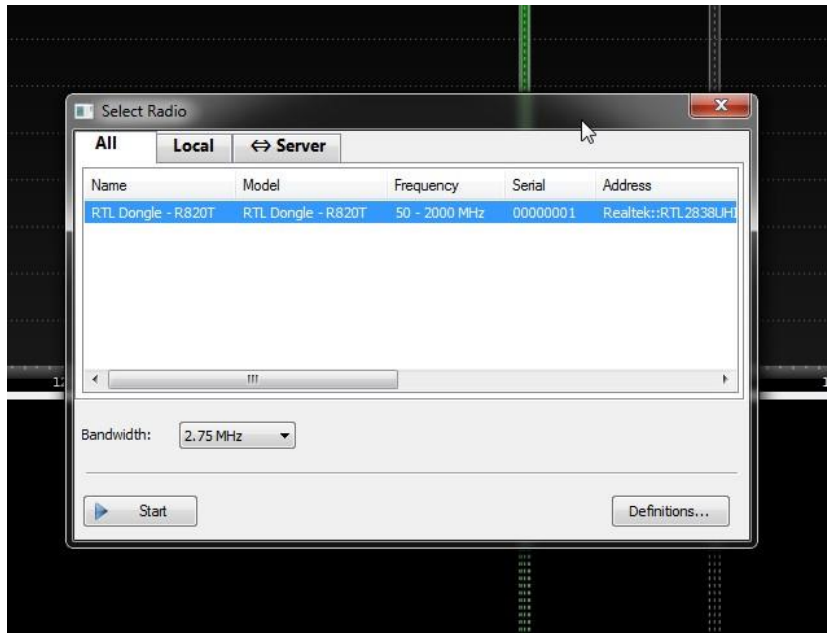


Figure 2

Once you have installed the correct driver for your SDR device, it should be listed in the above window. Highlight the receiver selection and click “start”.

When the SDR Radio panel opens you will NOT see the DSP window shown in figure 3 – more about that later. If all is well and you tune to around 1.545,500GHz, you should see some activity in the SDR main display. The default gain setting for the SDR is “automatic” and I suggest you initially leave it at that setting. Once everything is running properly, experiment with some manual gain settings to obtain an optimum S/N ratio.

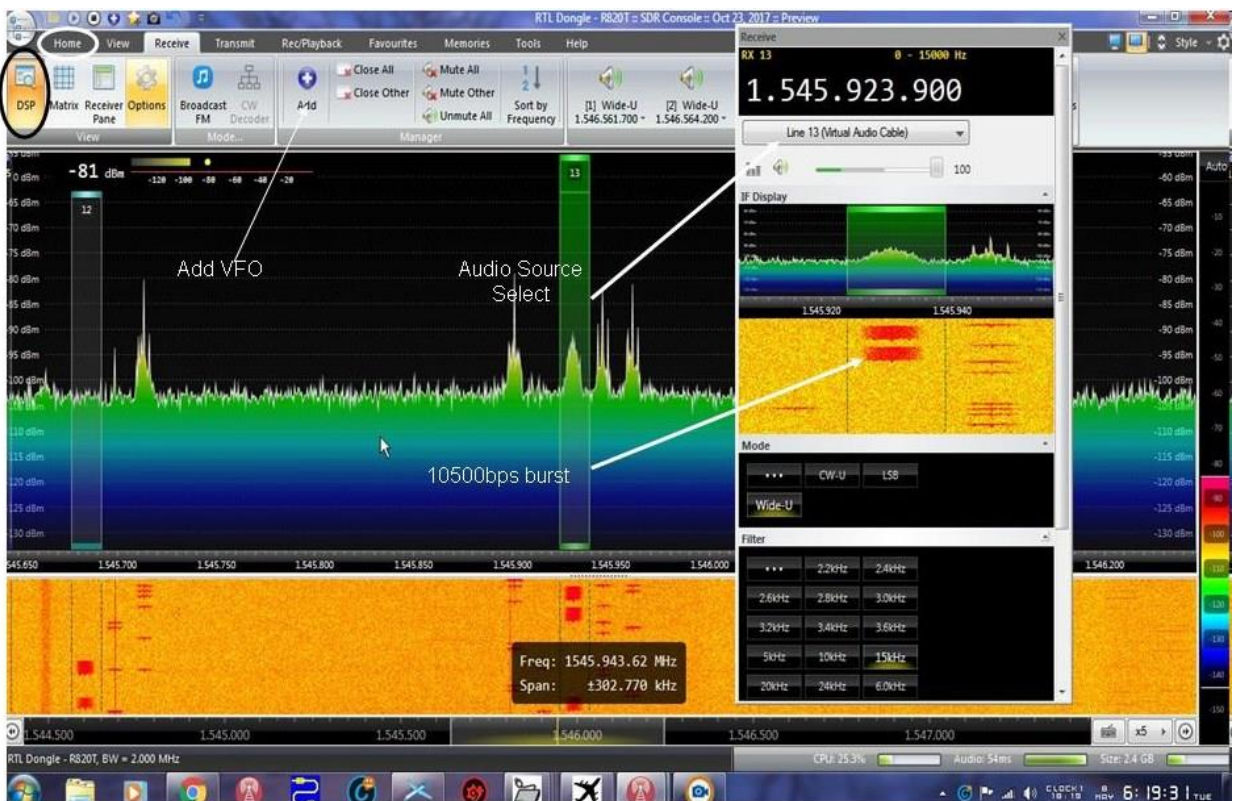


figure 3

Again the top “taskbar” will by default open in the “Home” window (figure 3 - white ellipse – I know the figure shows it in “Receive” mode). In this “Home” mode you will be able to adjust the gain, and additionally the receiver band-width. I have found that a band-width of 1.5MHz is adequate. You can use wider band-width settings, but keep in mind that this increases CPU load. Once gain and band-width have been set, we need to tell SDR Radio what frequency and demodulation mode to use. Click on “receive” in the top taskbar (highlighted in figure 3). Now click on the “DSP” icon (black ellipse in figure 3). In the DSP panel which opens, select “Wide-U” which stands for wide USB (Upper Side Band) - (refer figure 3a).

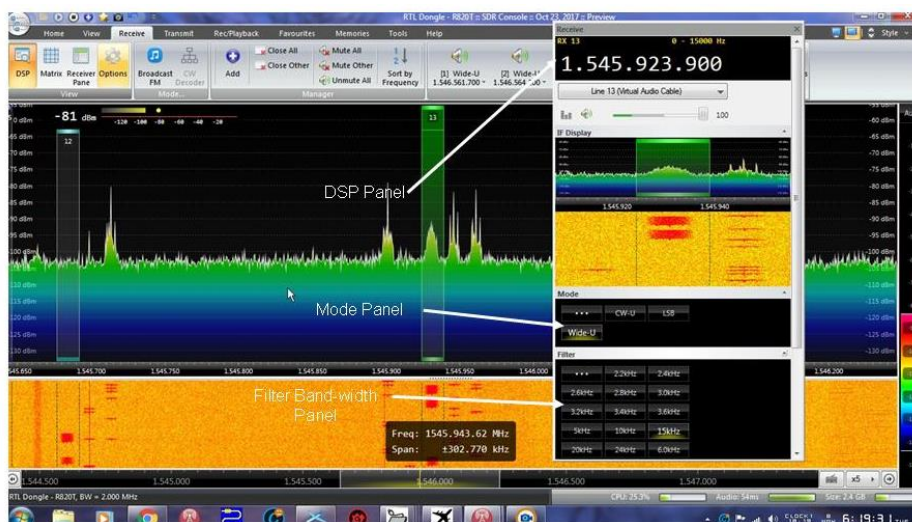


Figure 3a

It is possible that mode “Wide-U” does not show in your “DSP Mode” window. If that is the case, click on the three dots in the “Mode” panel (figure 3a) this opens the window shown in figure 3b.

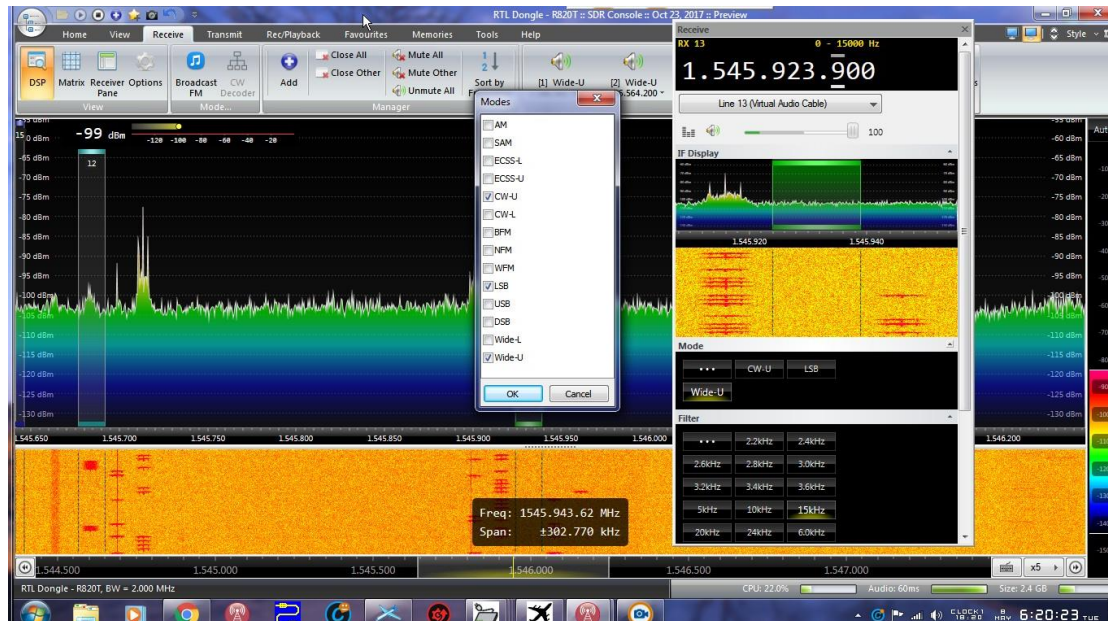


Figure 3b

Tick the “Wide-U” box and click “OK”. You can now select “Wide-U” in the DSP panel. Choose 15.0kHz for the “filter” (the signal band-width), as we are decoding 10500bps burst signals. The DSP panel will show “RX 1”. We will now tune to a signal. If the dish is aligned properly you should see some peaks on the main display. You can select the frequency by hovering and turning your mouse wheel over the digits in the top of the DSP panel display (figure 3a). Try and find a signal which looks like the one in the DSP panel in figure 3. This in fact is a 10500bps burst signal. It will not show up continuously, but will pop up every few seconds as it is a burst signal.

### Selecting an audio source

Great – we now have a usable signal, which we will send to JAERO. Because this article focuses on receiving multiple Inmarsat channels, using physical audio cards will not be practicable, because the majority of us will have only one, or maximum 2 physical audio cards. Fortunately there is an elegant software solution, allowing the use of an almost unlimited number of audio channels, in the form of a Virtual Audio Card (VAC). I use Eugene Muzychenko’s VAC software which is great value for money (<http://software.muzychenko.net/eng/vac.htm>). Once you have installed VAC, select the number of VACs you are planning to use. Leave all other settings in the software window in their default state. Remember that in order to configure the VAC software you need to be logged in as administrator. Only adjust the number of VACs you require and leave other settings to default. We

can now select an audio channel for our SDR. Click on the down arrow on the “audio channel select” window of the DSP channel (red ellipse in figure 4).

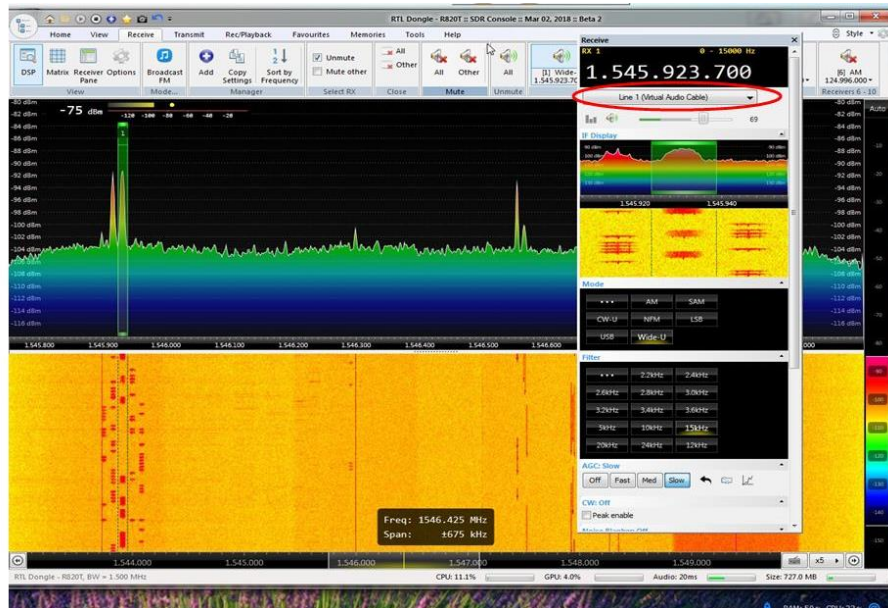


Figure 4

This allows us to select an audio source (figure 5). In addition to any physical soundcards you may have, the VACs you have just installed should also be listed. Select “Line 1 (Virtual Audio Cable)” The volume control is just below the audio source selection window. Initially I suggest you set that to 75. It can be changed as needed later when you have JAERO running. Always make sure that the “RX #” in the DSP panel corresponds to the audio device selected in the panel just below the frequency read-out.

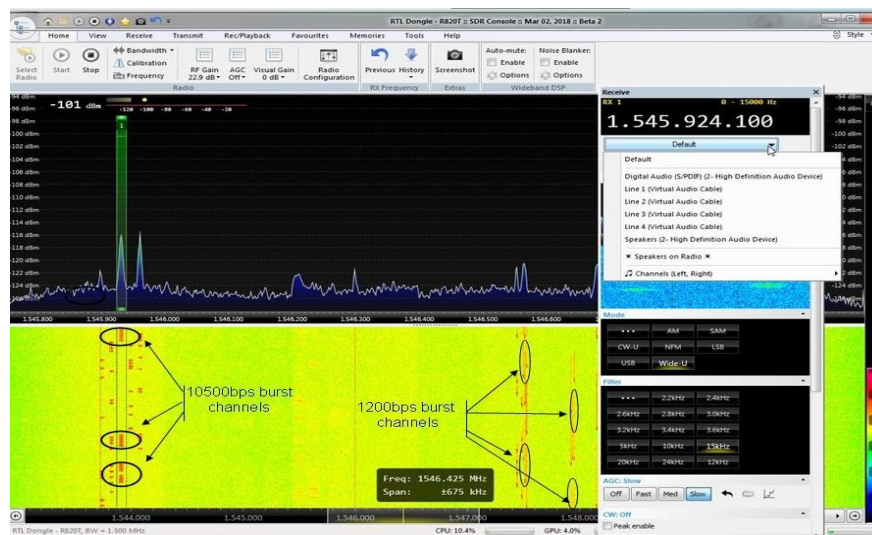


Figure 5

## JAERO

We now have SDR running and VAC installed and we should be ready to start decoding Inmarsat satACARS signals. Because the plan is to decode multiple ACARS transmissions, using multiple VFOs and VACs, we will need to open multiple instances of JAERO. The JAERO software can be downloaded <http://jontio.zapto.org/hda1/jaero.htm> Jonti has put a tremendous amount of work into this software, allowing us to enjoy this sophisticated software completely gratis! For the purposes of this article let us assume that we want to decode 4 channels simultaneously. Hence we will need:

- 4 VFOs tuned on SDR Radio
- 4 VACs
- 4 instances of JAERO opened.

We can open 4 instances of JAERO by simply clicking 4 times on the JAERO icon. This can be a bit time consuming, especially if later on you are going to open many more JAERO instances, like in my case 15. There is an easier way as follows: Write a batch file "JAERO.bat", containing the following instructions:

```
"@ECHO OFF  
CD c:\  
CD\Program Files\JAERO  
start c:\program files\jaero\  
start jaero.exe -s 1  
start jaero.exe -s 2  
start jaero.exe -s 3  
start jaero.exe -s 4  
start jaero.exe -s 5  
start jaero.exe -s 6  
start jaero.exe -s 7  
start jaero.exe -s 8  
start jaero.exe -s 9  
start jaero.exe -s 10  
start jaero.exe -s 11  
start jaero.exe -s 12  
start jaero.exe -s 12  
start jaero.exe -s 13  
start jaero.exe -s 14 "
```

Obviously you need to modify this batch file to suit your needs in terms of directory locations and numbers of JAERO instances to be opened.

Assuming that we have loaded the required instances of JAERO, we can now open JAERO instance 1 and prepare to decode ACARS messages.

When JAERO is first opened we see the window shown in figure 6. We need to tell JAERO which audio source we are going to use. Click on the "settings" cog. (figure 6)

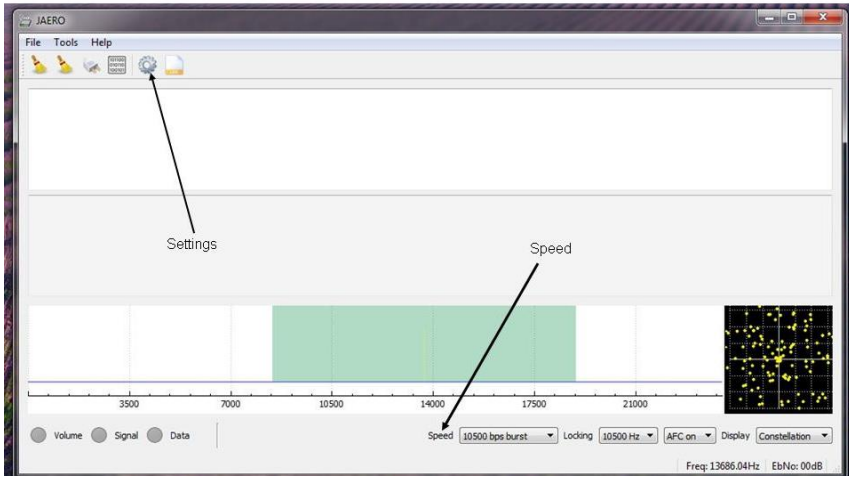


Figure 6

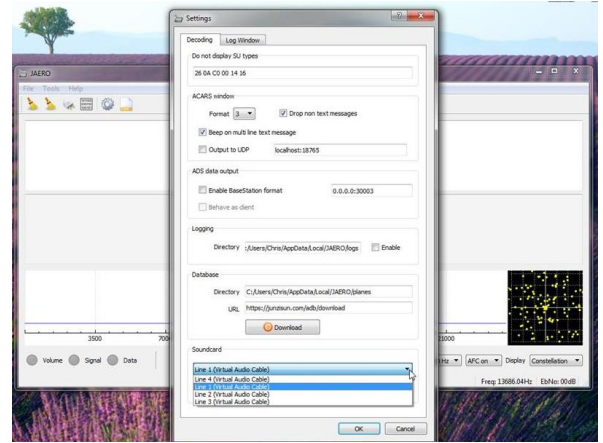


figure 7

In the “soundcard” field select your VAC - in this example “Line 1 (Virtual Audio Cable)”. Leave all other parameters in this window at their default setting and click “OK”. This will take you back to the window shown in figure 6, but there should now be a blue wiggly signal line showing inside the turquoise coloured rectangle, indicating that JAERO is receiving audio. (figure 8). We now need to tell JAERO the type of transmission we are decoding. In our example we are tuned to a 10500bps burst signal and this value needs to be entered in the “Speed” window (figure 6). Do not change any of the values displayed to the right. The green “LEDs” indicate in order: - a signal is present, - data is being received, the data integrity is sufficient for decoding

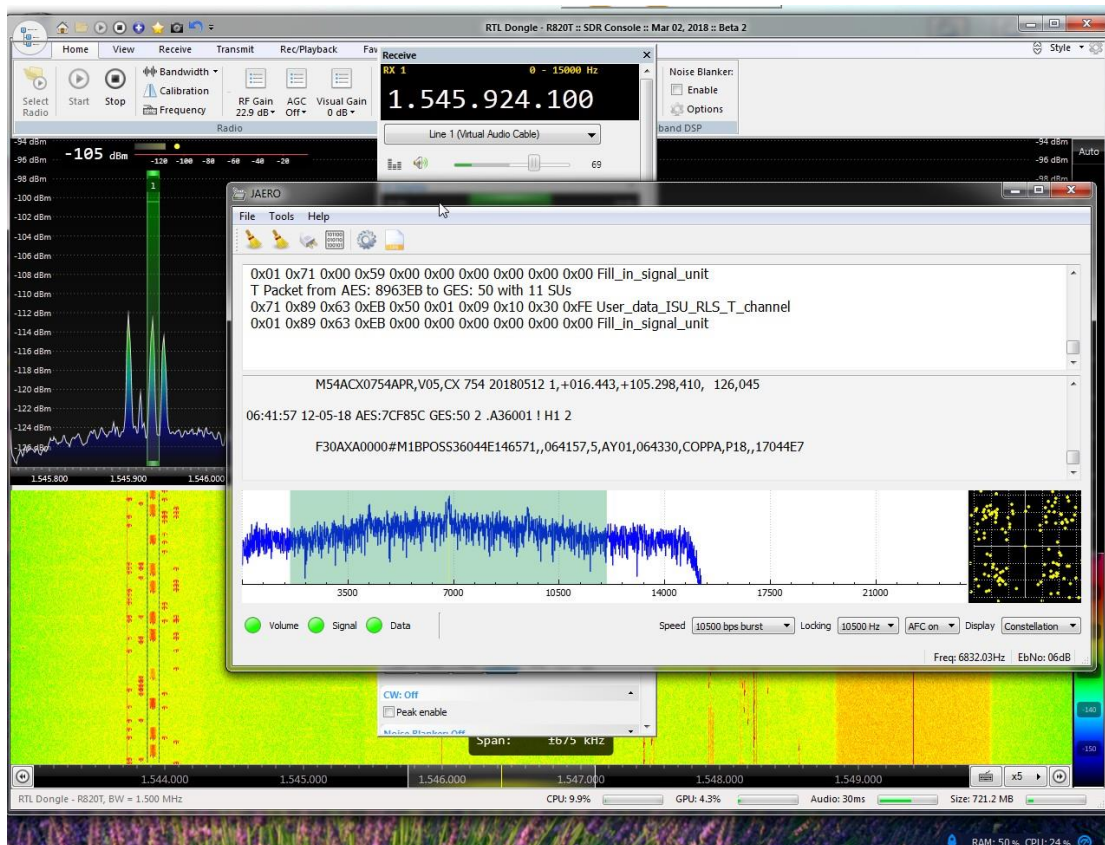


Figure 8



### Moving on...

So far we are receiving and decoding a single channel and we are now ready to add additional channels (VFOs). On the SDR receiver this involves adding VFOs. Refer back to figure 3. Click on the “+” icon. This will open a new DSP window called “RX2” and as explained earlier in this article you can assign a VAC to this frequency. In order not to lose track, I suggest selecting “Line 2 (Virtual Audio Cable)”. In JAERO instance 2, go to the “settings” menu and select “Line 2 (Virtual Audio Cable)” as the audio source. Repeat this procedure until you have configured all VFOs and JAERO instances.

### Decoding 1200bps burst signals.

Assuming that you have taken the necessary steps to ensure frequency stability, you should now be ready to have a go at decoding 1200bps burst transmissions. If we go back to figure 1, you will note that a number of 1200bps burst transmissions occur in groups of three, which makes them easier to identify. To view these channels in relation to the 10500bps burst signals look back at figure 5, where the channels are identified. In the case of 4F1 the 1200bps burst channels are approximately half-way between the high 10500bps burst and the low 10500bps burst channels. This statement may initially appear to be the wrong way around. The fact is that as the frequency read-out on the SDR increases, the actual frequency of the received signal decreases. This is because the LO (Local Oscillator) of the LNB is running at 5,150.000MHz. The frequency of the signal to be received is deducted from the LO, as in the following calculation:  $5,150.000 - 1,545.924$  equals a 3,604.076MHz received frequency. Similarly if we wish to receive a signal at a higher frequency; say 3,603.438MHz, our SDR tuner would need to be set to  $5,150.000 - 3,603.438 = 1,546.562$ MHz., in other words a lower SDR frequency. By the way, if you do not already have a C-Band LNB and you are contemplating buying one, be aware that not all C-Band LNAs cover the same frequency range. Some will only go as low as 3.7 – 4.2GHz. Since the signals we are interested in are around 3.6GHz, make sure you choose a model which covers 3.4 – 4.2GHz. So far, so good. We have located some 1200bps burst transmissions. Select the appropriate audio channel – Line 3 (Virtual Audio Cable), in what would now be DSP panel RX3 and select the same audio channel in JAERO. Make sure that in the main JAERO window you select “1200bps burst” in the “Speed” rectangle and you should now see decoded 1200bps burst signals coming through. The 1200 bps burst signals are much weaker compared to their 10500bps burst counter-parts and if your dish size or alignment is not optimal, you may miss a few packets. You can now decide how many 10500bps burst and 1200bps burst channels you wish to decode, the only limitation being your CPU capacity. Both the additional VFOs and increased numbers of JAERO instances will add to your CPU loading.

The next logical step would be to feed the decoded data to Plane Plotter. To do this you will need to tick the “output to UDP” box in the JAERO settings menu. The “localhost:18765” setting is incorrect and should be changed to 8765. In Plane Plotter I/O settings (PP NOT running), tick “Acars from JAERO” and “UDP/IP data from net”. Turn on PP and aircraft should now start popping up on your PP chart.

Hope this all makes sense and have fun!

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