MARTIN - G8JNJ

ECLECTIC AETHER - ADVENTURES WITH AMATEUR RADIO

REDUCING RTL DONGLE INTERNAL SPURII AND NOISE SIGNALS

I’ve recently bought quite a few RTL DVB-T RTL 2832U / Rafael Micro R820T dongles to use for various purposes.

Whilst experimenting with these devices, I’ve noticed that one or two have much higher levels of internally generated unwanted signals and broadband noise than the others.

Prodding around with a spectrum analyser I’ve found that there are three main sources of internally generated noise.

1. Carriers at multiples of the 28MHz clock oscillator
2. Wideband noise with spurs from the USB data lines
3. Wideband noise with spurs from the on board 3.3v to 1.2v DC-DC convertor

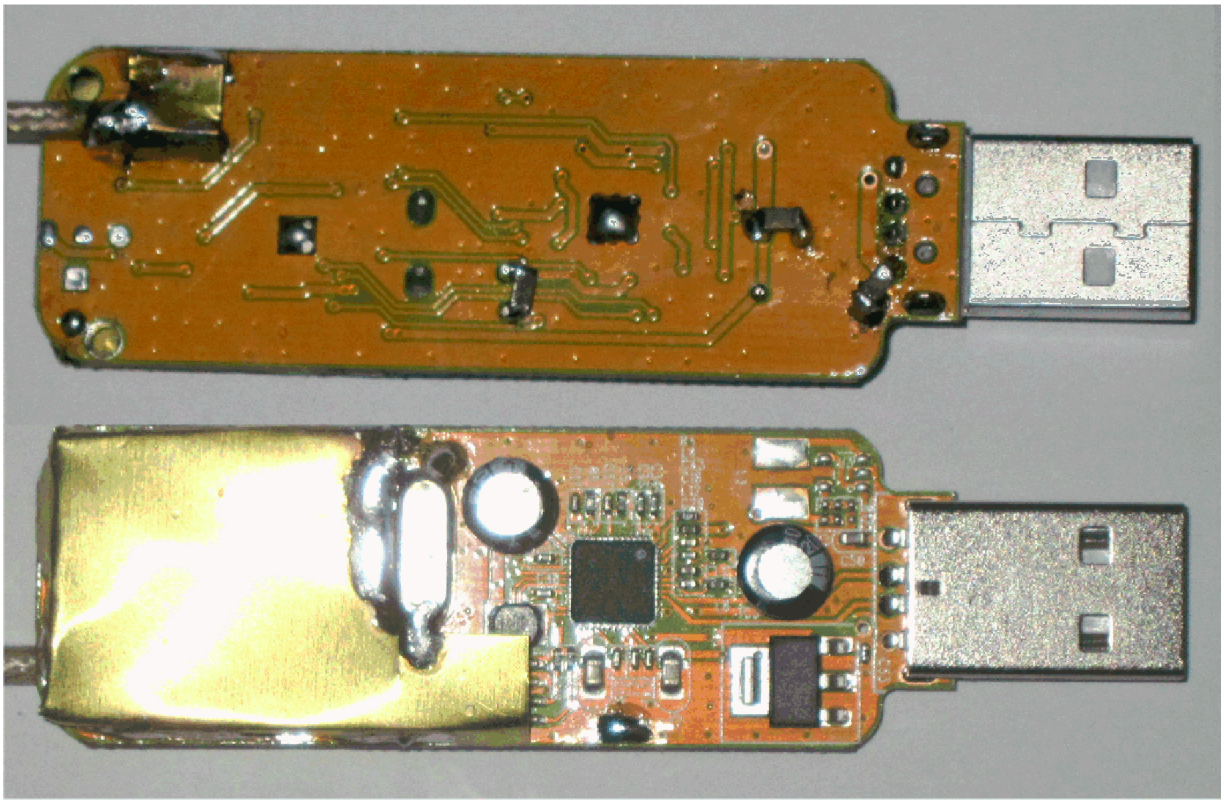
Plus received noise on the connecting cables which can be from any of the above, or external sources.

Looking first at the three internally generated noises.

The 28MHz oscillator is a fairly integral part of the design, so there’s not a lot that can be done to reduce these signals. Soldering the oval shaped metal can of the crystal to the PCB ground plane can reduce the level of some harmonics slightly, but I found that any improvement was hardly noticeable.

Wideband noise with spurs from the USB data lines and the on board 3.3v to 1.2v DC-DC convertor could be dramatically reduced by adding some metal screening around the RF input stage. I used some very thin brass sheet that I obtained from a model shop for this purpose, but some metal from a tin can would work just as well. I found that this was easier to implement if I removed the IR receiver, blue LED and associated surface mount resistors from the top side of the board. Adding a small patch of metal across the underside of the RF connector pins on the reverse side of the PCB also made a big difference. Note that placing the whole dongle inside a tin can didn't seem to help. The noise seems to be coupled directly between components on the topside of the PCB.

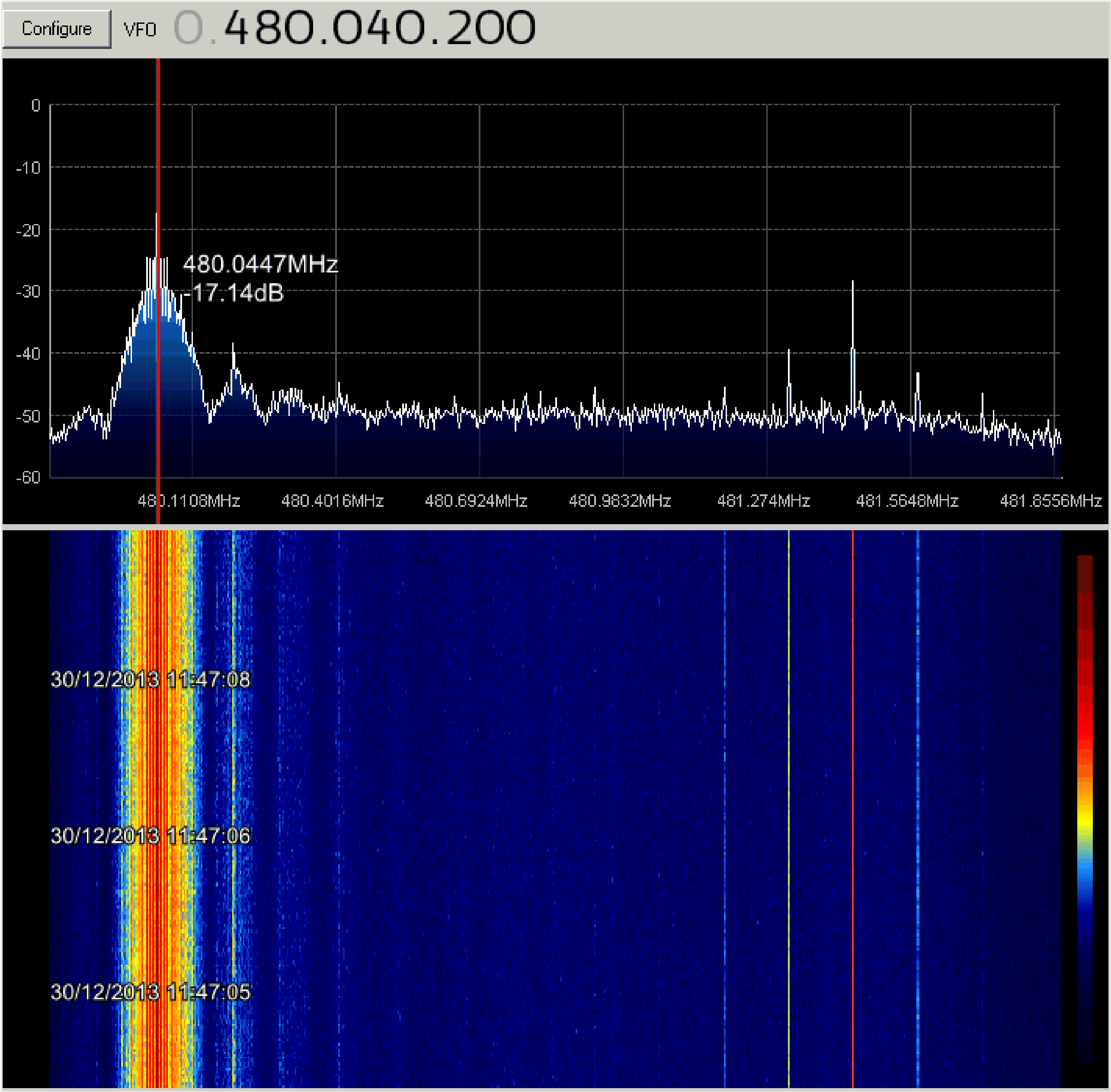
I decided to try fitting 0.1uF chip caps across all the main electrolytic capacitors and DC rails. None of these seemed to make much of a difference to the remaining spurious signals that could be observed with the antenna disconnected, but I thought it was worth adding them for the sake of completeness.



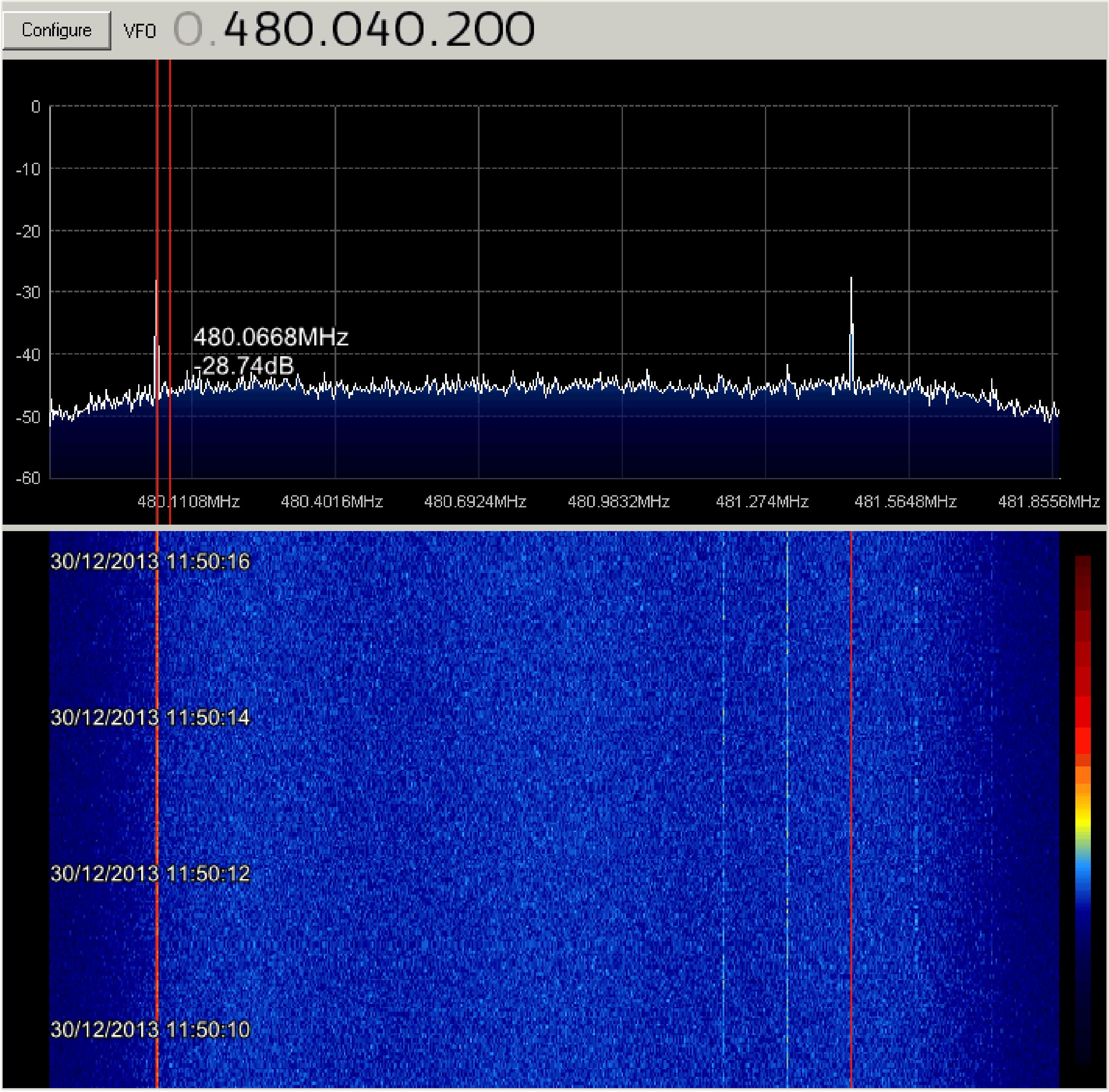
If these modifications are done carefully, the plastic case will snap back on without any problems.

All of these modifications made a significant reduction of unwanted signals. The next two photos show the ‘before’ and ‘after’ unwanted signal levels at around 480MHz. Note that these signal levels were with the dongle set for the maximum RF gain of 42dB. When used at a more reasonable gain setting of 30dB, all unwanted signals (with the exception of harmonics of the crystal oscillator) were usually at a level near or below the dongle noise floor.

Before the modifications



After the modifications



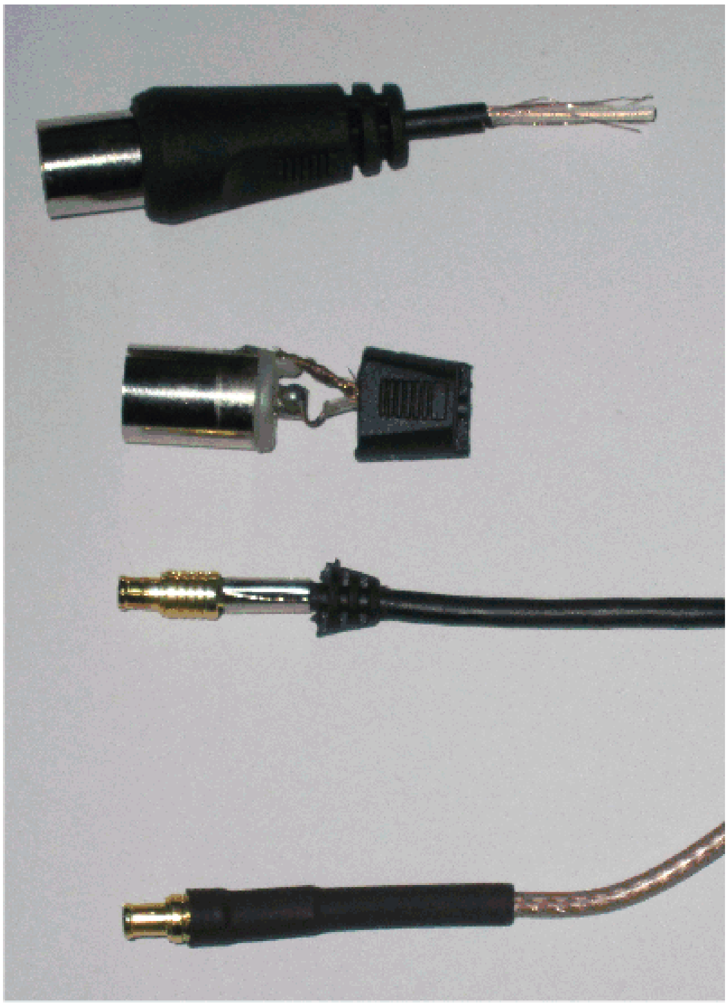
I also noticed that the 820 sticks have got a back to back SMD package strapped directly across the RF input. It may be worth checking to see if that has got popped by static if you have a broken one.

Once I had sorted out the internal noise sources I took a look at what external factors could be causing problems.

I noticed that when I connected the short RF fly-lead that was supplied with the dongle to the input, a lot of noises I'd just got rid of had returned. These were not detectable when the input RF cable was removed. The main problem was the poorly screened fly-lead.

Unfortunately the connector is a male MCX, which I didn't have in my junk box. So in the end I just ran a small length of thin PTFE 50 ohm coax with good screening from the rear of the connector to a BNC plug. A quick melt of the plastic case and the cable exits OK, and the case will fit back together again. Fortunately this solved the problem almost completely.

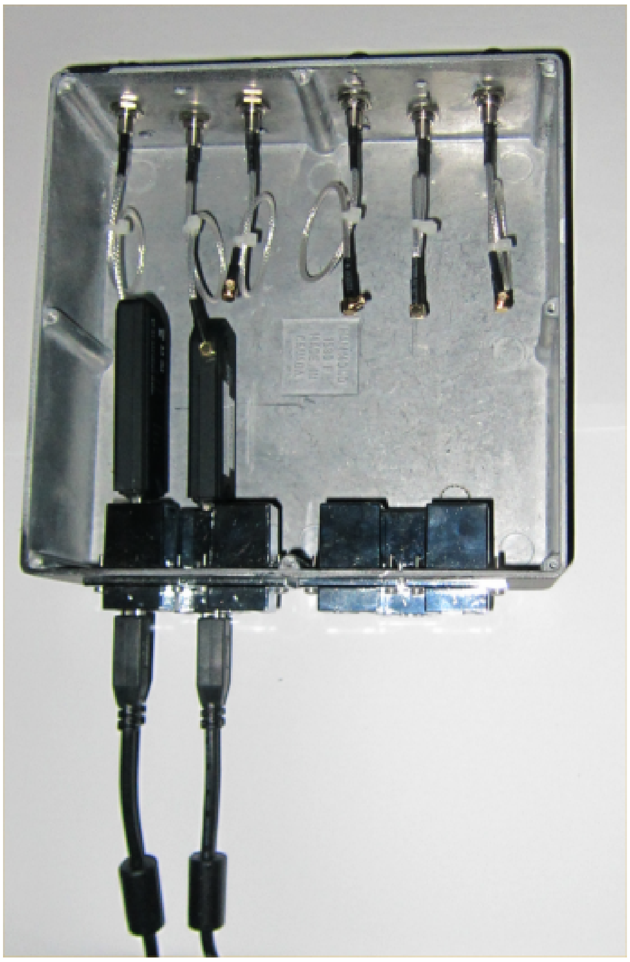
I decided to cut up one of the dongle fly-leads in order to see if I could figure out why it was so problematic. As soon as I stripped back the coax and plastic moldings it was obvious that there was hardly any copper in the non-overlapped screen, and a very poor termination at the TV connector end.



Fortunately it's easy to take apart the crimped connector at the MCX end and fit to some proper PTFE coax. So this is what I've now done rather than wire directly to the board.

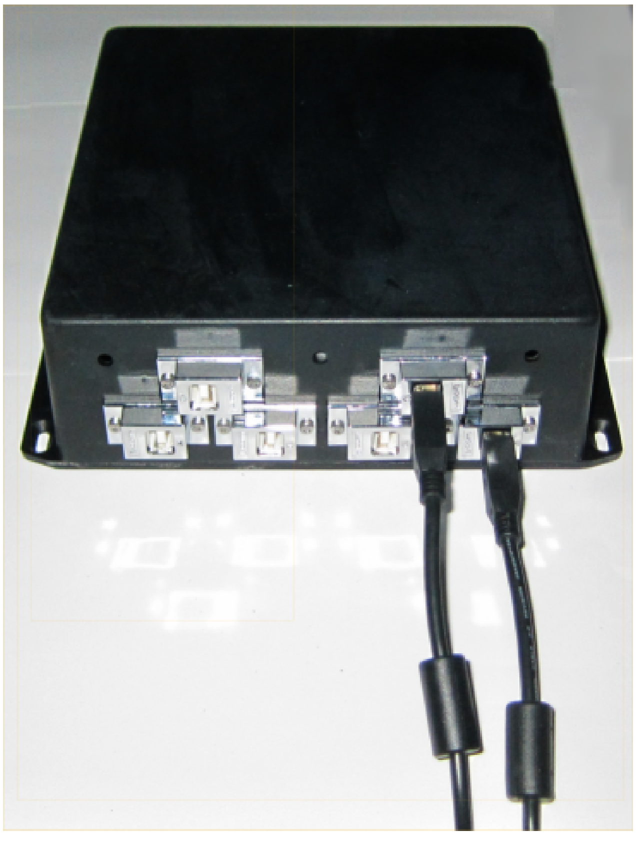
In order to further improve the dongle screening and make them more robust. I made up this de-cast metal box for use on our uWave WEB SDR (http://websdr.suws.org.uk/).

A photo of inside of box prior to fitting ferrite beads on the coax between the Dongle and a bulkhead RF connector., in order to help reduce the likelihood of RF current loops between coax screen and chassis. I had to characterise suitable ferrites for the best VHF / UHF choking impedance, as most clip-on types or similar don't do anything at these frequencies.



The USB screen needs a good low Z connection to the box metalwork and to the RF connector on the box. I found that if I didn't do this the screening was not as effective. Also any AC potential difference between the antenna coax and PC chassis resulted in current flow across the RTL PCB. This added multiple 50 / 100Hz noise sidebands to the LO.

The type of USB connector I used was a chrome plated A to B bulkhead version from LCOM ECF504-BAS (http://uk.farnell.com/l-com/ecf504-bas/adapter-usb-a-recpt-usb-b-recpt/dp/2293818?Ntt=2293818)



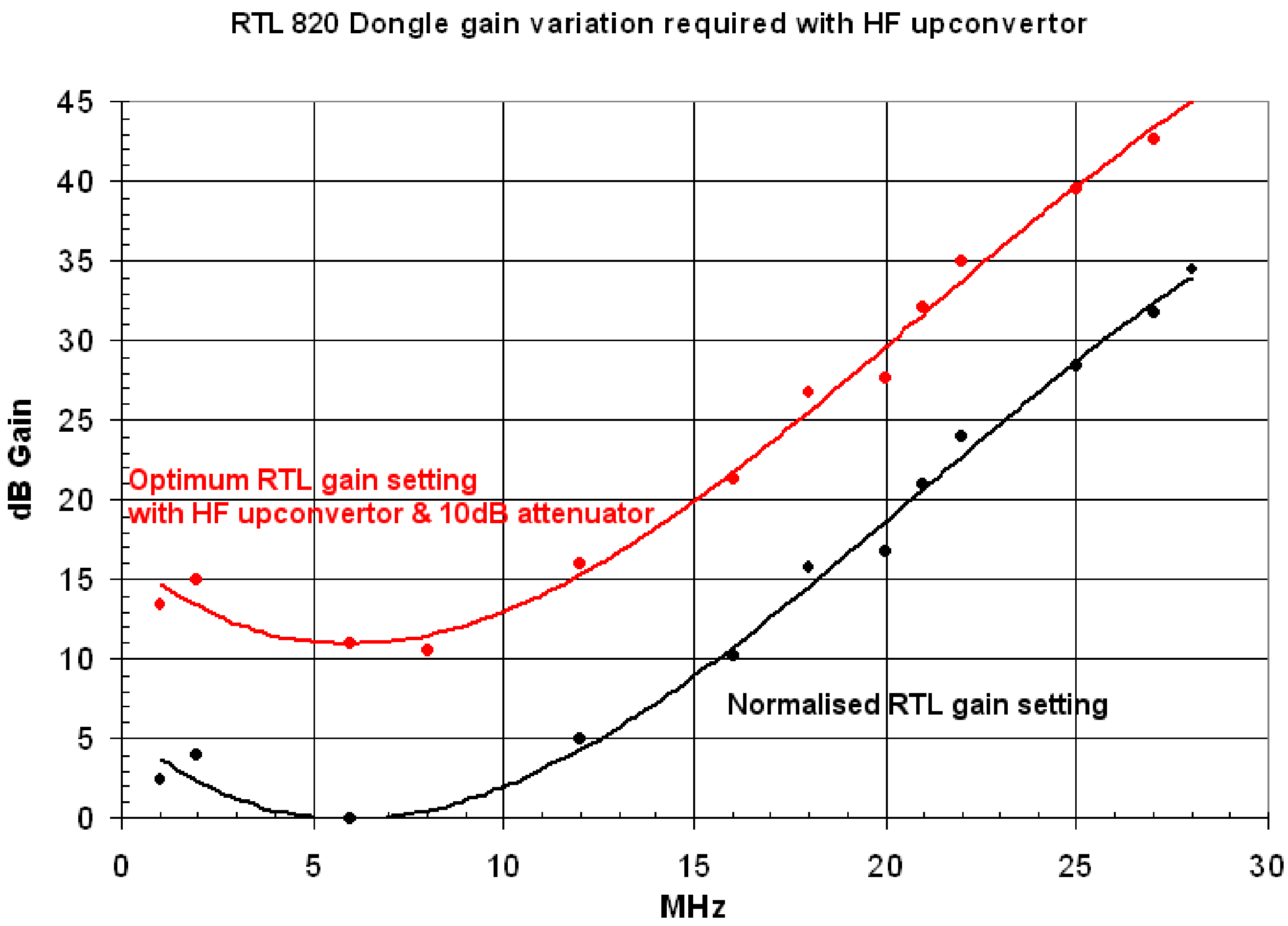
HF UP-CONVERTORS & RTL DONGLES

I've been experimenting with an HF up-convertor and RTL DVB-T RTL 2832U / Rafael Micro R820T. The Up-convertor consisted of a 50MHz input low pass filter, high level double balanced mixer, 100MHz Local Oscillator and Output filter. Total conversion loss was approximately 7dB plus an additional 10dB attenuator on the output to reduce the signal level going into the dongle.

I tested the up-convertor and dongle with a variety of antennas, including a 10m vertical, two different active antennas and a 100ft doublet with ATU.

I measured the gain levels for different frequencies at which the dongle performed at the optimum performance in terms of S/N, dynamic range and low levels of IMD. I also made sure that there was enough headroom to cope with short duration increases in signal levels when operating at the optimum levels at different times of the day and night.

I then averaged all the results and plotted them in Excel.

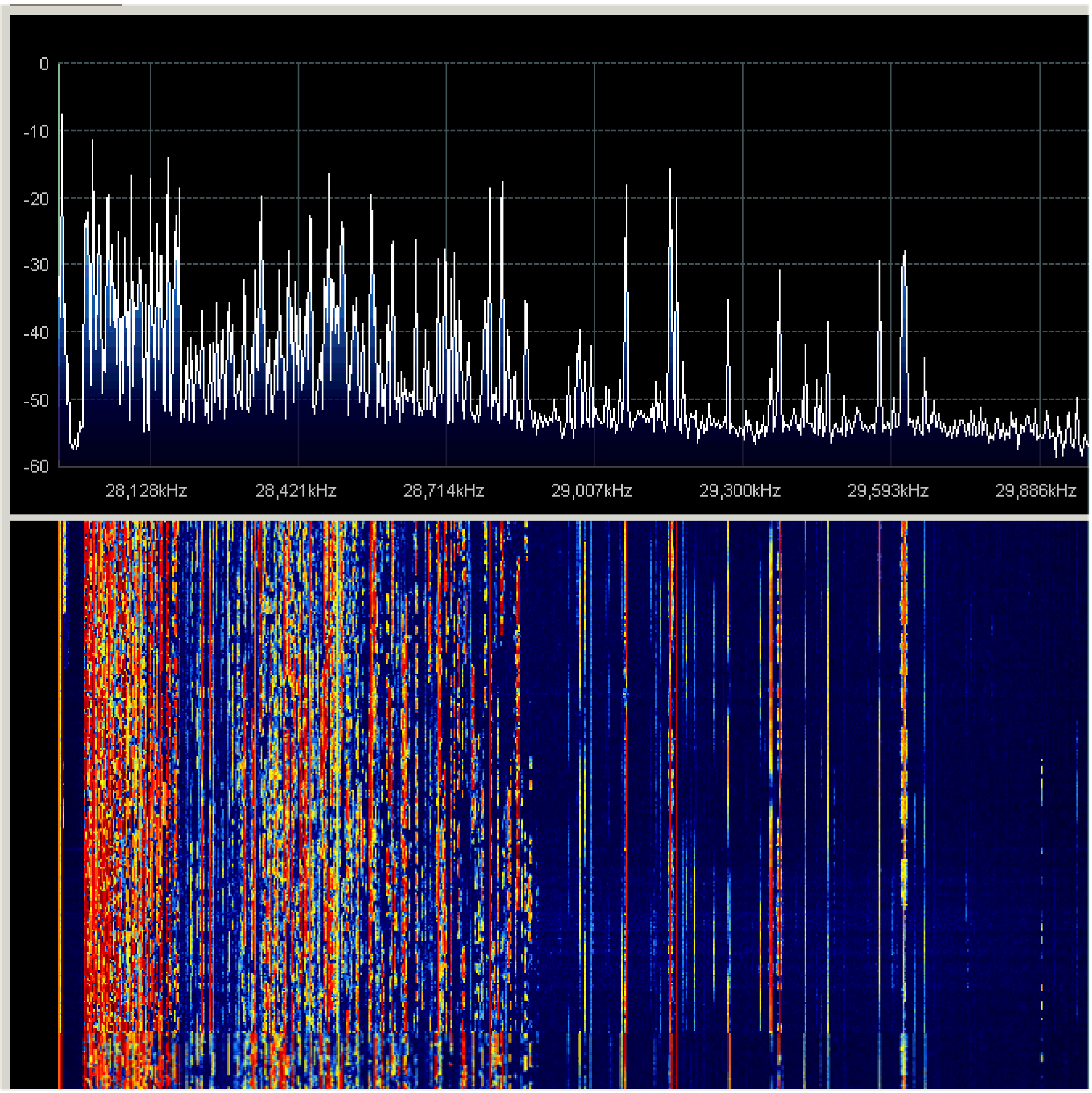


The shape of the general gain / frequency curves tend to remain fairly consistent between day and night. The only real difference is that the overall gain has to be reduced by abut 10dB at night to prevent overload at some frequencies between 5 and 15MHz.

My thoughts are to build up a 3 section band notch filter with a center frequency just low of the Up-convertor LO frequency, so that I can obtain the required 30dB slope characteristic and use the dongle and up-convertor without having to change the gain setting every time I move frequency.

Whilst experimenting I discovered that there was a major contest running and that 10m was wide open

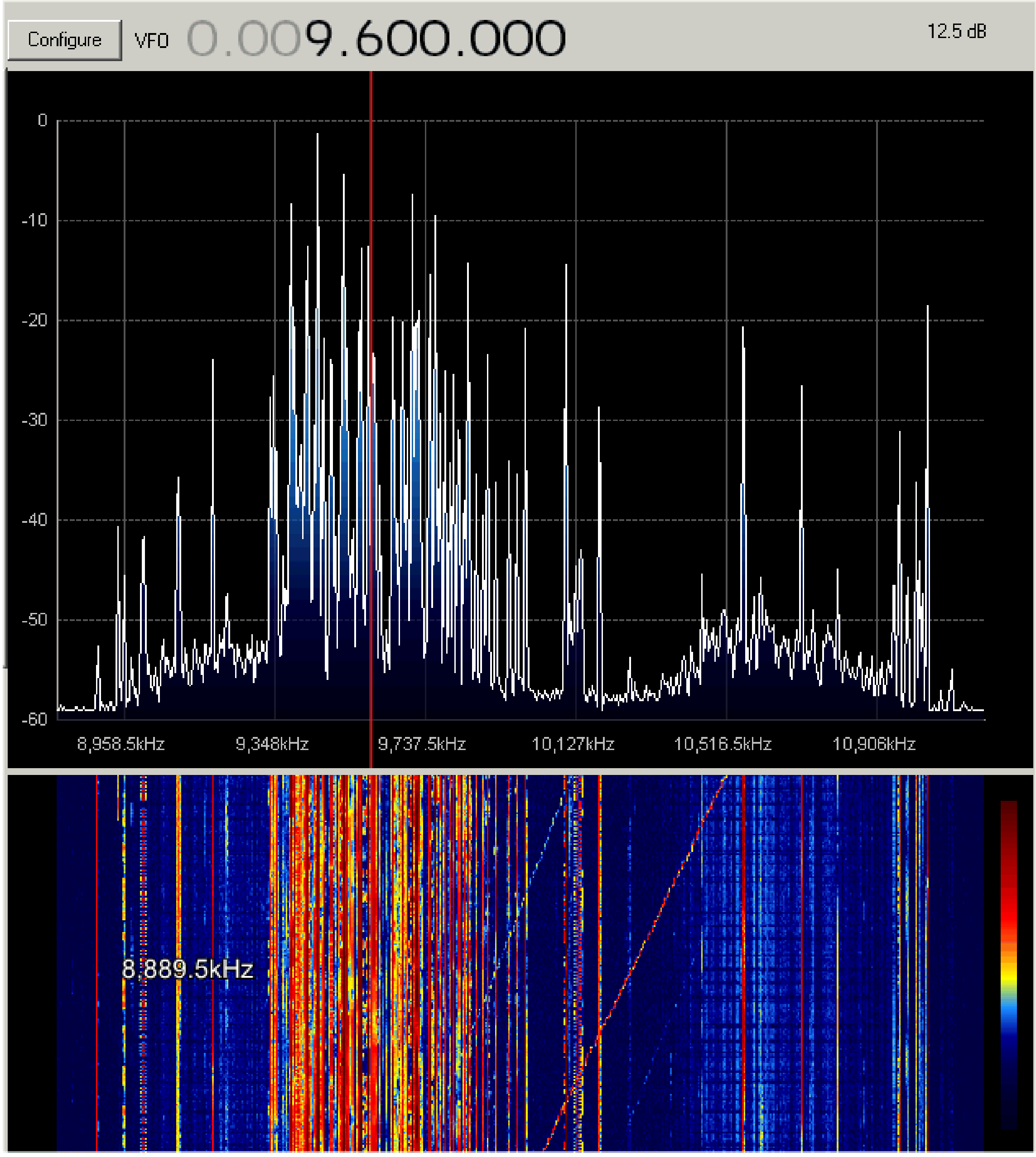
Here’s a screen grab of the SDR Sharp spectrum display. A pretty impressive number of stations I think – have you ever seen 10m so busy ?



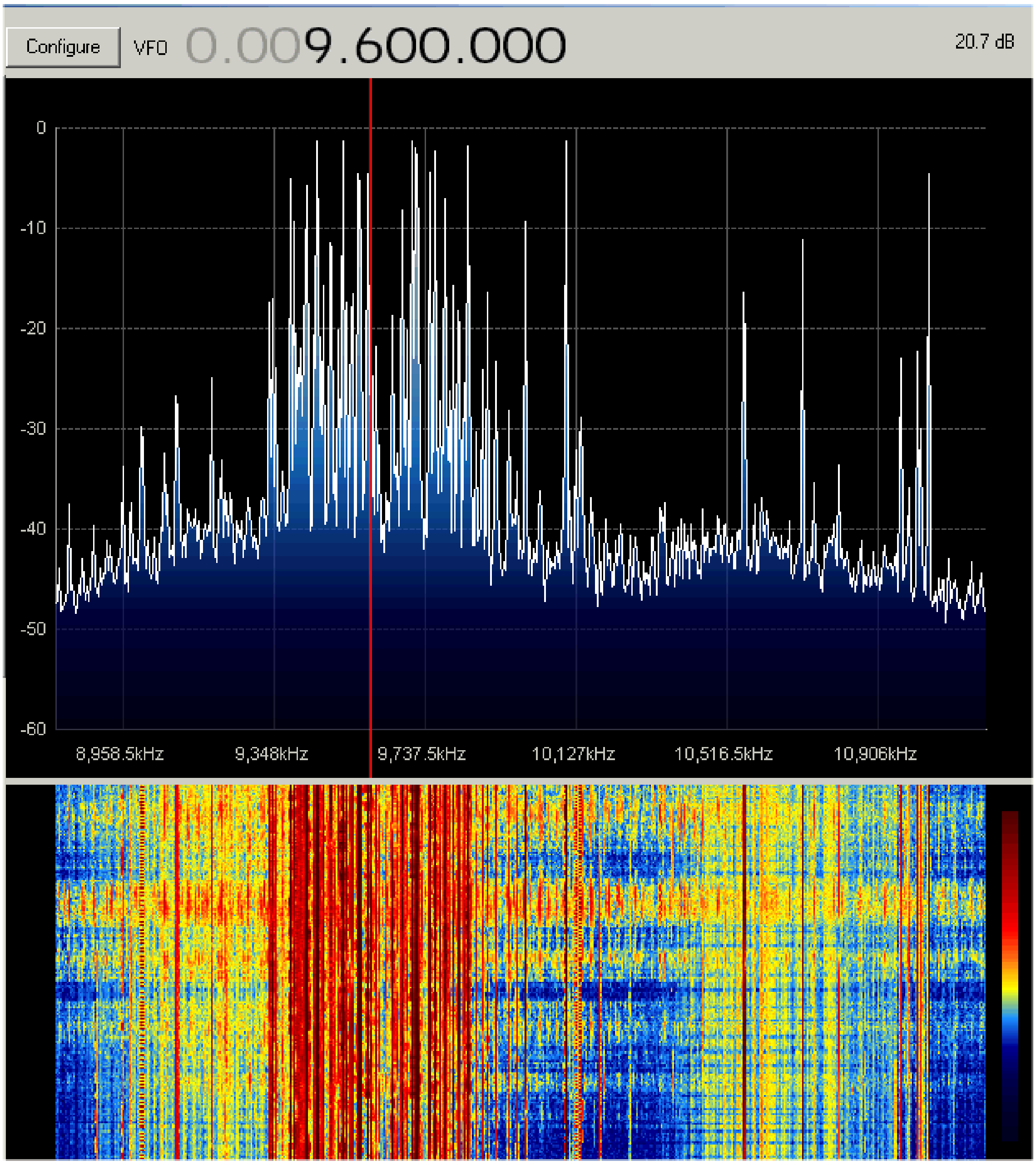
As part of this assessment I've also been testing to see if the limited dynamic range can provide adequate performance on the more crowded bands such as 7MHz. For these tests I have used a passive broadband vertical antenna in conjunction with an up-convertor and RTL820 dongle. I used SDR Sharp with various gain settings but no AGC selected. In order to find a worst case scenario with very high level signals I chose frequencies near the 9MHz AM broadcast band.

First 12dB gain - note the level of noise floor relative to the maximum signals - looks clean with about 60dB dynamic range

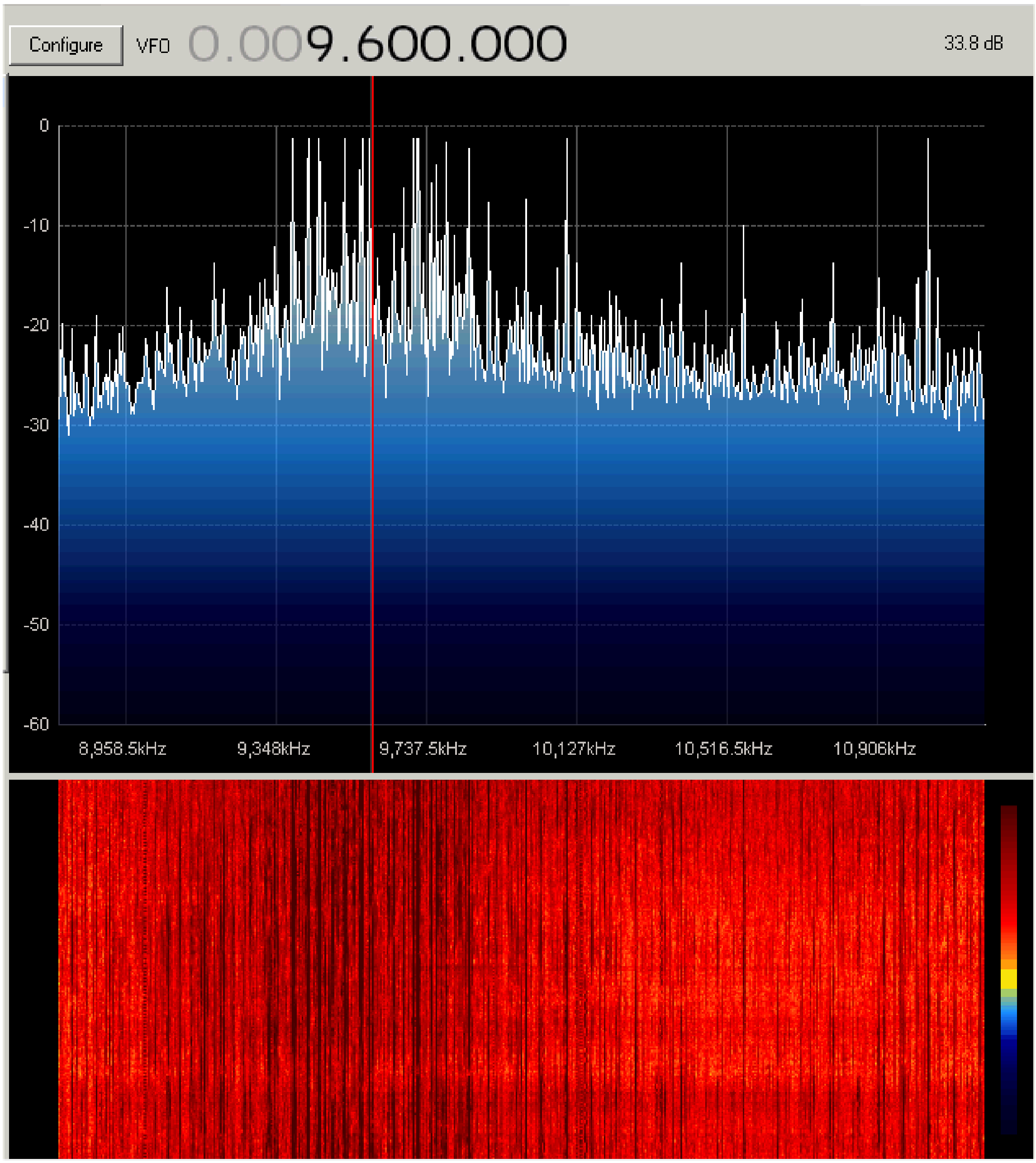
Notice the two diagonal traces from Ionospheric sounders gradually sweeping upwards in frequency.



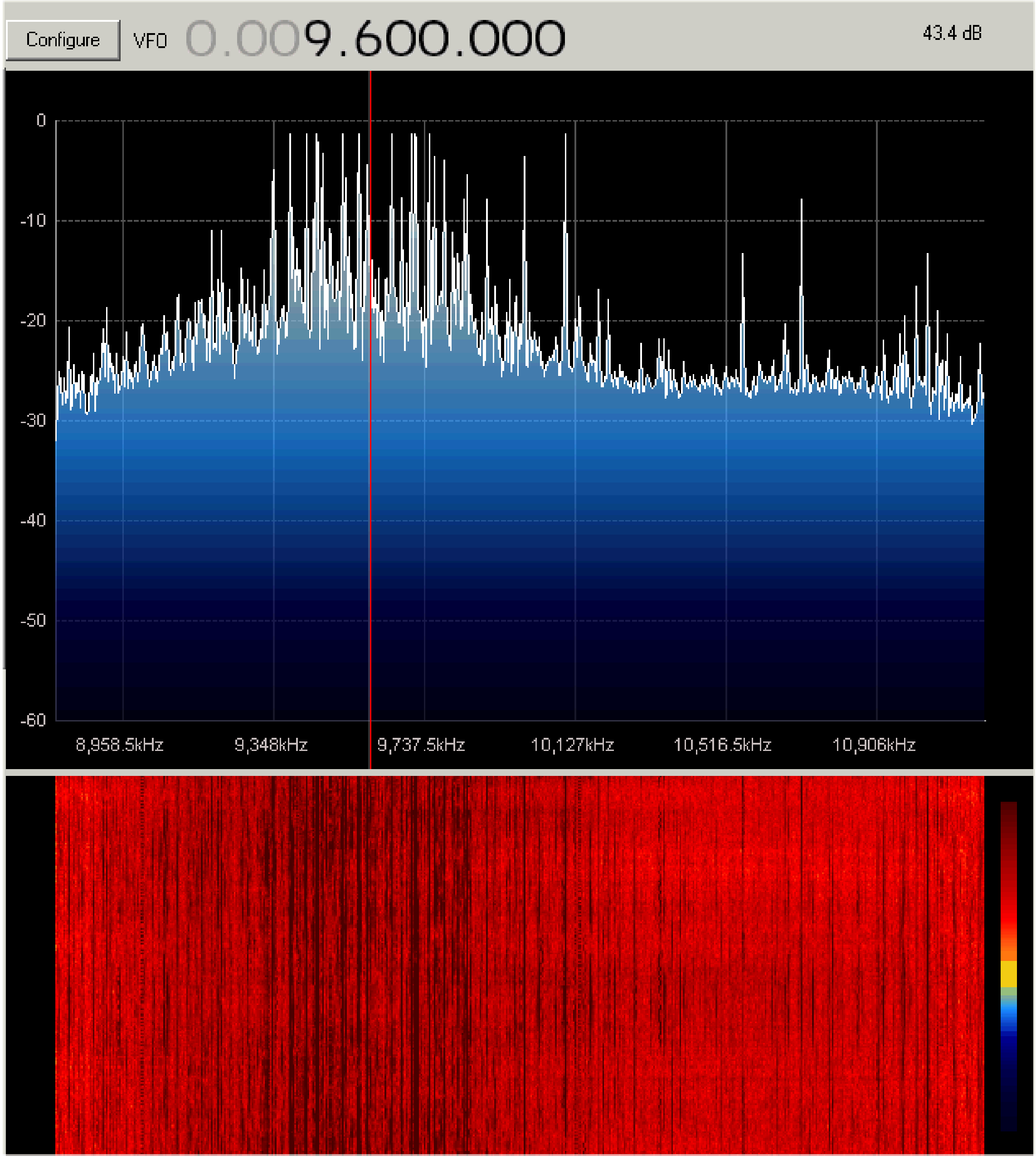
21dB gain - note the rising level of noise floor relative to maximum signals - Start of severe intermodulation and reduction to 40dB dynamic range



34dB gain - note the very high level of noise floor in relation to maximum signals - very bad intermodulation products and only about 25dB dynamic range

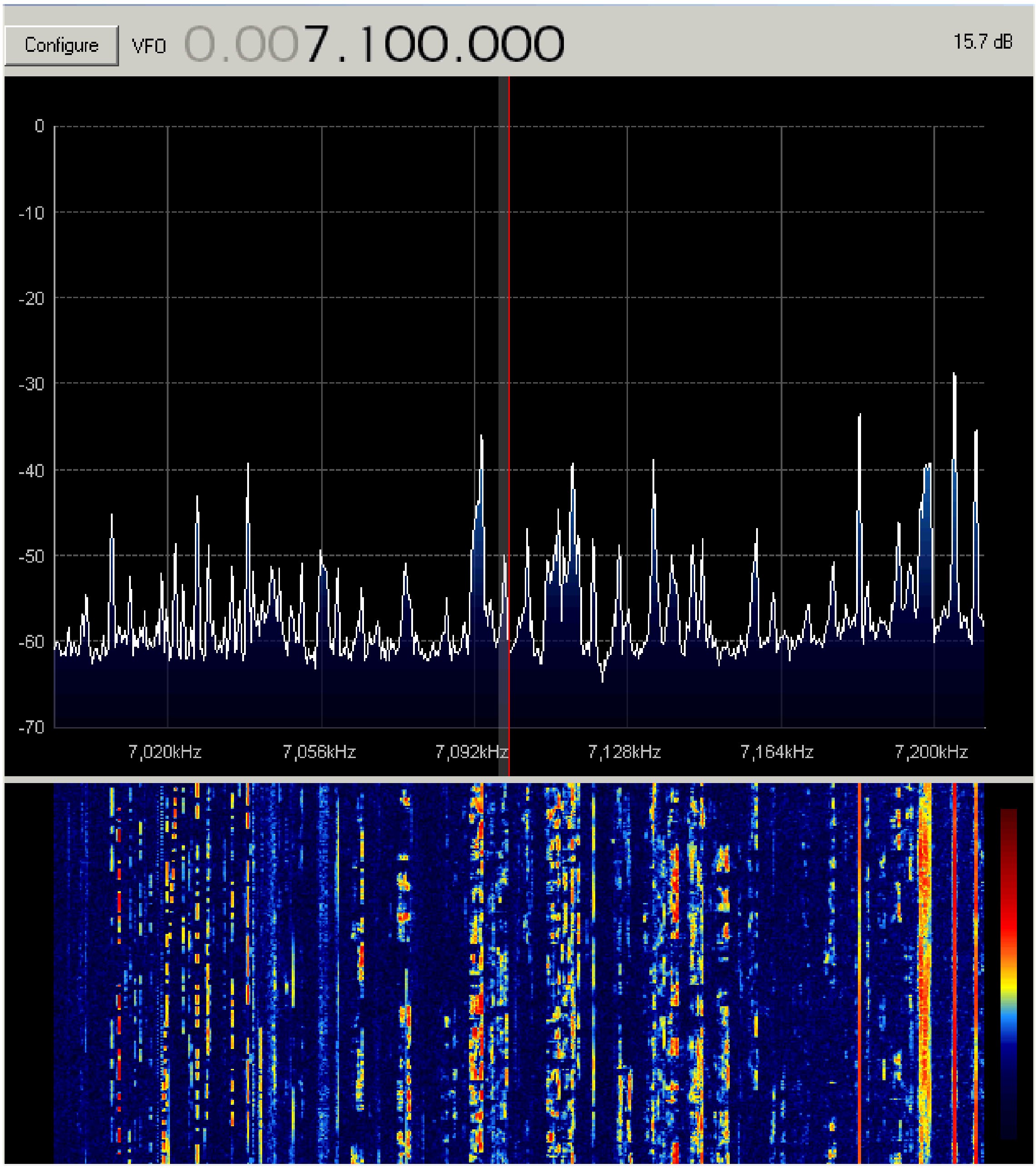


Finally 44dB gain - note the levelling off of maximum signal levels and excessive intermodulation products

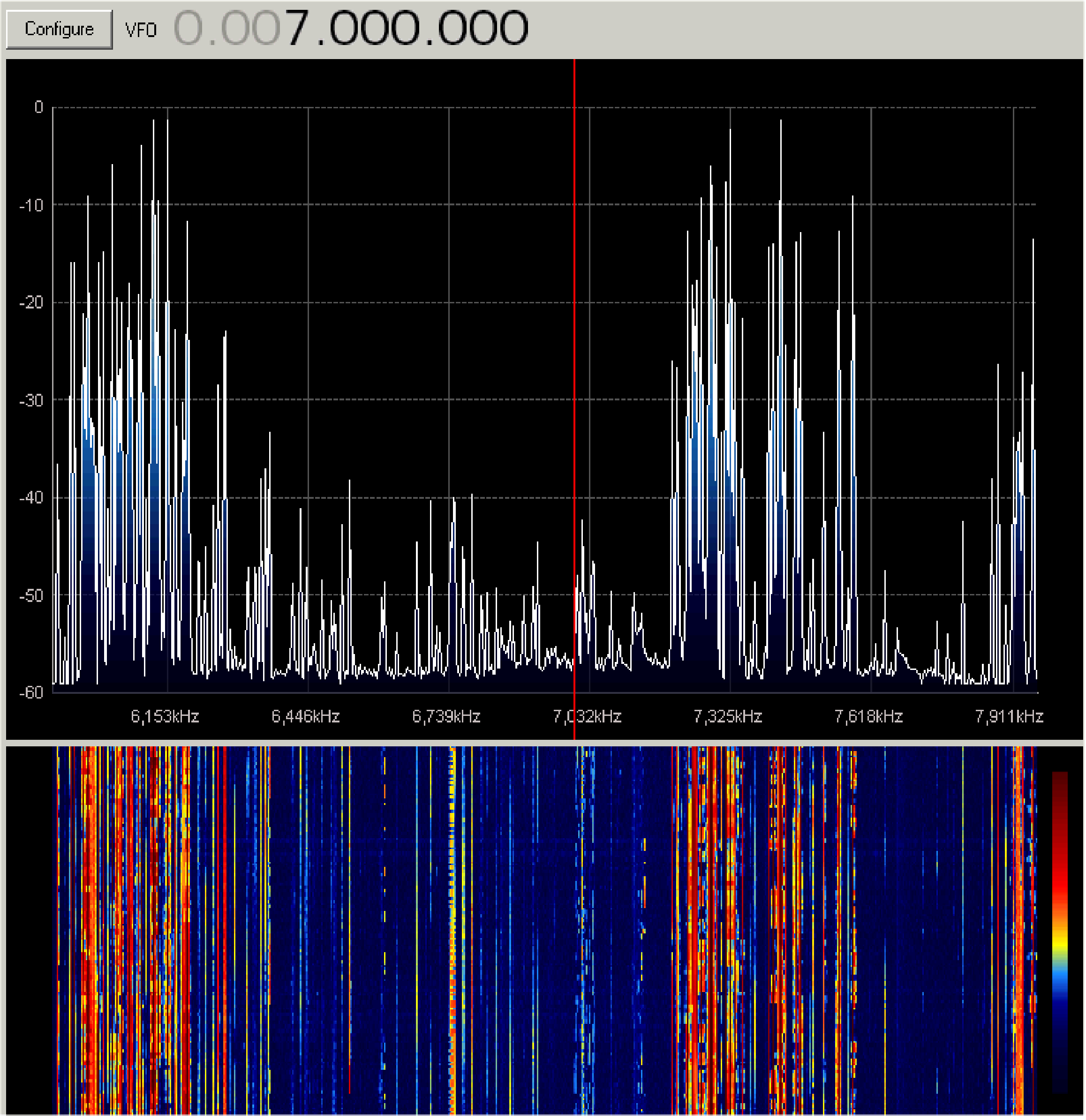


Here's another trace of the 7MHz amateur band with about 12dB of gain.

No problems this time with intermodulation products, as the maximum signal levels are a lot lower than those from the AM broadcast stations on 9MHz.



Just to prove that I wasn't cheating with the above screen grab, here's a wider view of the night-time spectrum, with high power broadcast stations either side of the 40m amateur band.



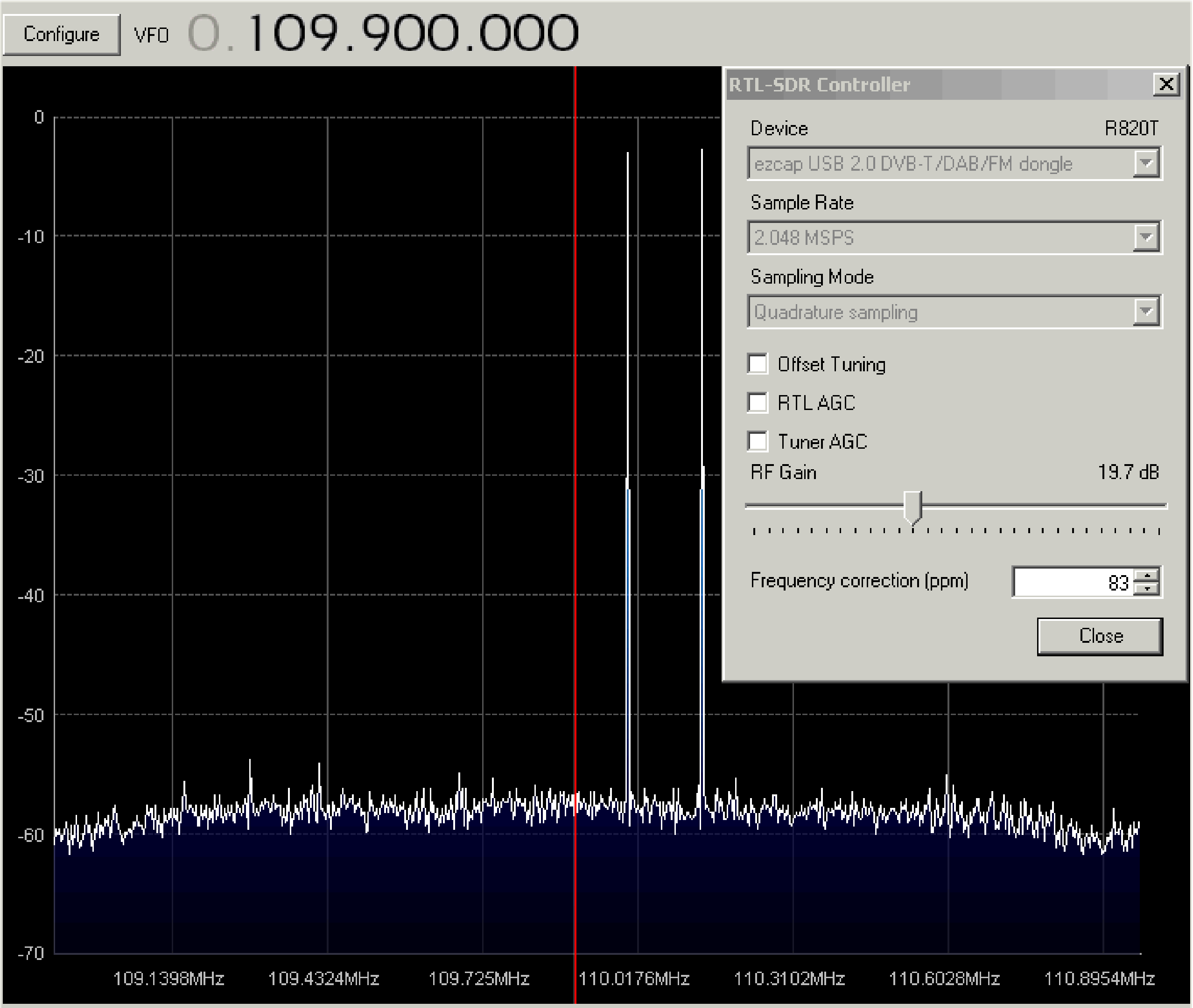
I also performed some two tone IMD measurements on the RTL DVB-T RTL 2832U / Rafael Micro R820T dongle.

The three screen grabs show in successive order.

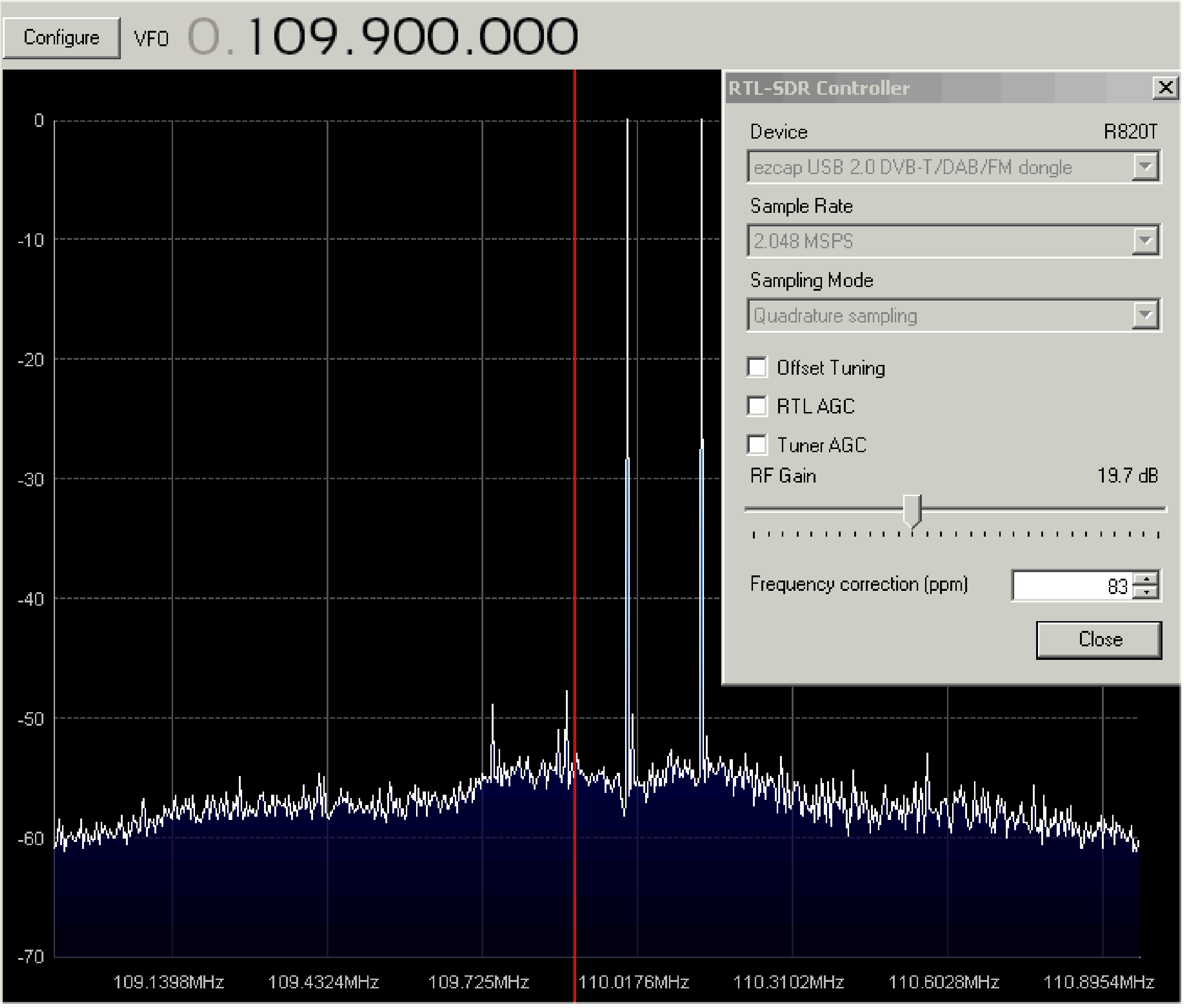
1. 3rd order products with two carriers each at -3dB WRT 0dB reference line on SDR Sharp

2. As 1 but at 10dB higher level

2. As 1 but at 20dB higher level



Configure
VFO
0.109.900.000
RTL-SDR Controller
Device
R820T
ezcap USB 2.0 DVB-T/DAB/FM dongle
Sample Rate
2.048 MSPS
Sampling Mode
Quadrature sampling
Offset Tuning
RTL AGC
Tuner AGC
RF Gain
19.7 dB
Frequency correction (ppm)
83
Close
0
-10
-20
-30
-40
-50
-60
-70
109.1398MHz
109.4324MHz
109.725MHz
110.0176MHz
110.3102MHz
110.6028MHz
110.8954MHz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Tuner AGC
RF Gain 19.7 dB
Frequency correction (ppm) 83
Close
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-10
-20
-30
-40
-50
-60
-70
109.1398MHz
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109.725MHz
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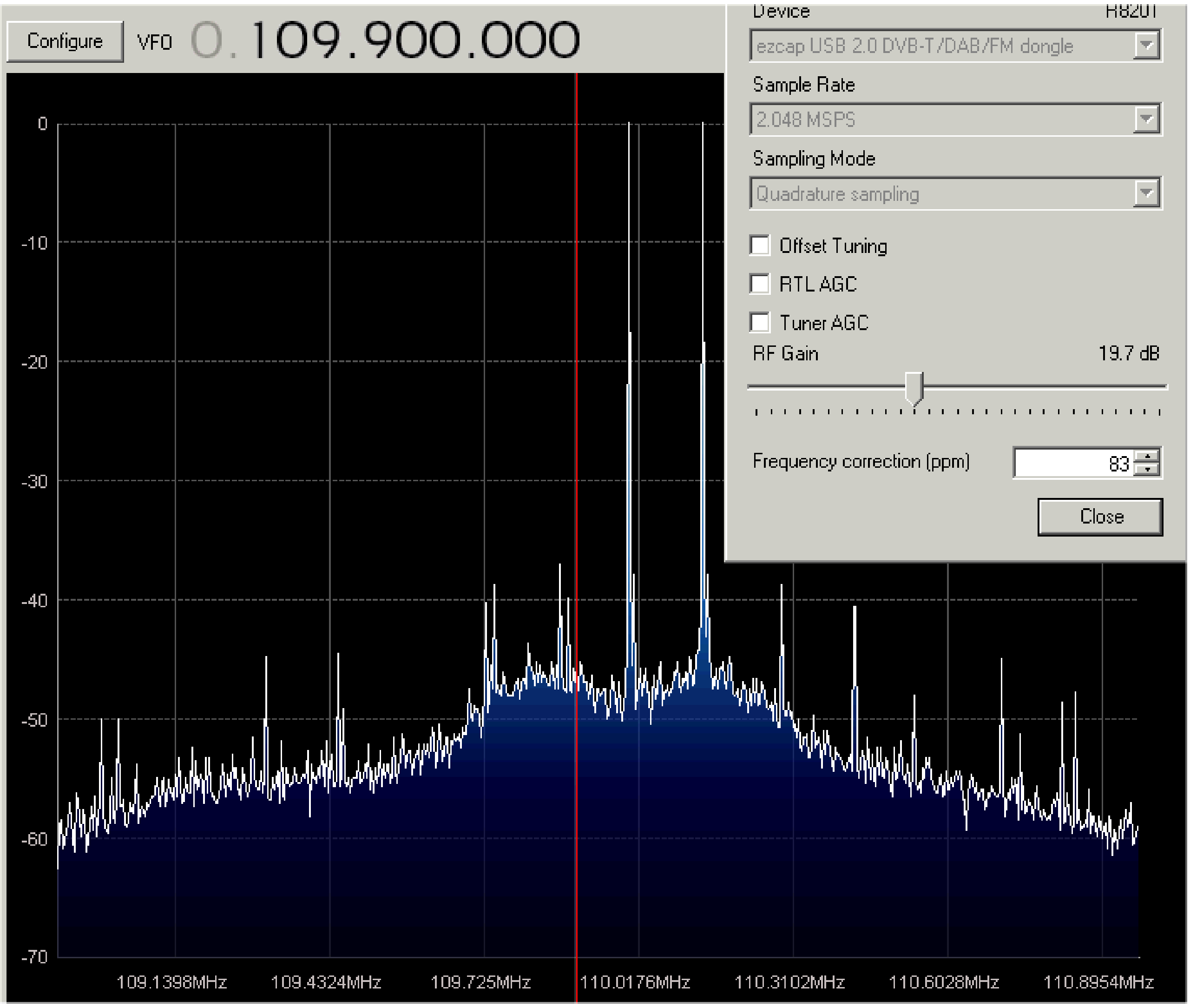
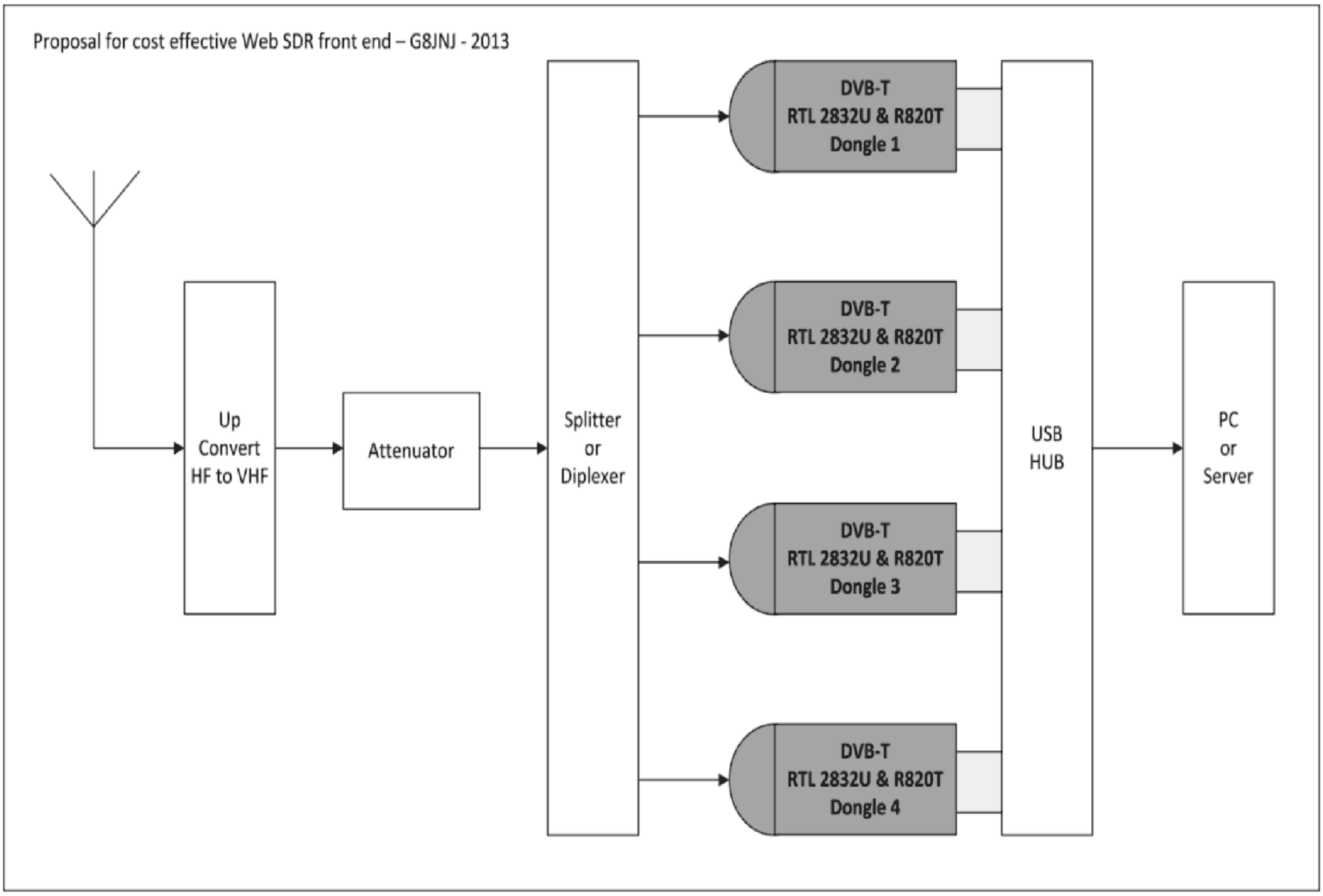


I believe this demonstrates that if the SDR dongle gain is set appropriately, it’s perfectly possible to use them for reception of the HF bands with a simple block up-convertor.

Note that in all of the above cases I was feeding the block up-convertor directly from a large broadband antenna with no additional filtering. I have no doubt that the performance could be further improved by the addition of suitable band pass filters before the SDR dongle, if a greater dynamic range is desired on a particular band.

Here’s my suggestion of how to use multiple SDR dongles with a single HF up-convertor for a WEB SDR front end.


Proposal for cost effective Web SDR front end – G8JNJ - 2013
Up
Convert
HF to VHF
Attenuator
Splitter
or
Diplexer
DVB-T
RTL 2832U & R820T
Dongle 1
DVB-T
RTL 2832U & R820T
Dongle 2
DVB-T
RTL 2832U & R820T
Dongle 3
DVB-T
RTL 2832U & R820T
Dongle 4
USB
HUB
PC
or
Server
