Making Oscillator Noise measurements   Kevin Murphy ZL1UJG

Oscillator noise is essentially made up of both amplitude noise, and phase noise. Together they can be described as composite noise. In applications like mixing, the amplitude noise component is reduced when clamping or limiting occurs in the likes of diode mixers and the like.

Fortunately a lot of modern IC based Oscillator designs such as the SILABS SI570, and SI5351A are frequency agile, so that makes the job easier. I have decided to use a technique using a crystal bandpass filter to, take a snapshot of noise in a SSB bandwidth, as one tunes the carrier off frequency..

One requires a number of items to enable testing

1) **Power supply**. (PSU) A linear mains power supply, or a battery supply. A SMPS (switchmode) has many artifacts, and may affect measurements

2) **Attenuators** Switchable or fixed 50 ohm. I think 75 ohms could be used, as long as everything else is matched to that impedance.

3) **SSB filter**. I use an Atlas 210X 5.645 MHz USB replacement filter (2200 Hz Bandwidth, 8 pole, 800 ohm terminating resistance) from Sherwood Engineering, although if you another type in your junk box, that is suitable use that. This should be matched to 50 ohm on both sides. I have used some transformer baluns (4:1 turns ratio or 16:1 Z ratio)

4) **Level indicator.** I have used the Siglent SSA3021X Spectrum Analyser. A good analyser for its price range. It also has features like an internal preamp and Noise marker which make measurement easier. Alternatively, a receiver or SDR, with some sort of level indicator could be used. (an external RF preamp may be required in some cases)

5) Miscellanous coax cables, adapters and DC leads. Pen and Paper or notepad on PC.

6) Optional Limiting amplifier (for reducing the Amplitude noise component..) This is fitted <u>after</u> the 10 dB attenuator.
I use a MCL GALI-3 MMIC amplifier (in a homebrewed setup), although one could use a kit like below.
https://www.minikits.com.au/electronic-kits/rf-amplifiers/rf-wideband/GALI-39-R2
Additional attenuators following the amplifier are required to bring the level down to a few dBm (mW)

Notes
The Oscillator under test, should be powered at its nominal supply voltage, from the PSU. Some of the oscillators run on +5v, or 8-15v.

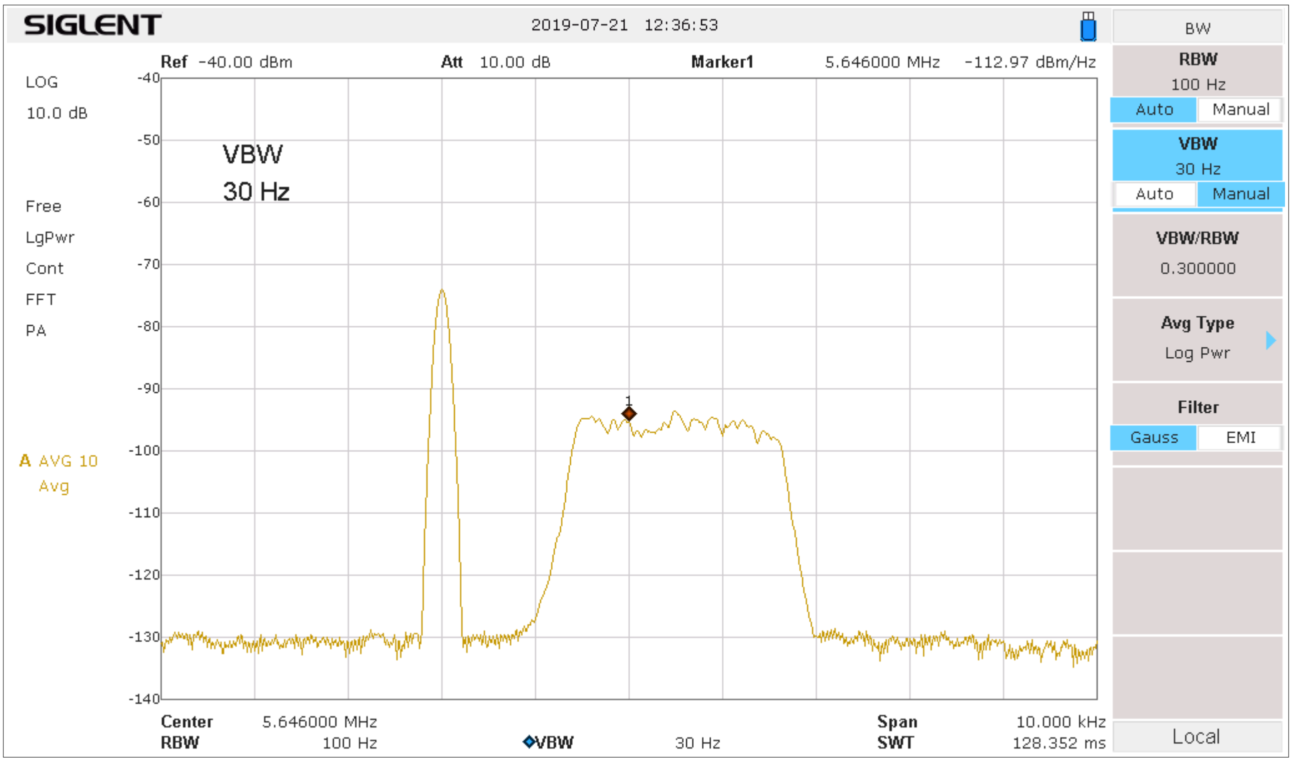
The oscillators can have output levels either around 0 dBm or +12 dBm. An attenuator of the order of 10 dB is used to provide a constant load impedance to the oscillator, and SSB filter while the oscillator is tuned off frequency. The impedance of the crystal filter changes markedly as one tunes away. From a few ohms to several kilo ohms. Additionally it provides some attenuation for the oscillator level, so that it doesnt damage the filter.

The analyser, and Oscillator under test (OUT) are set to the centre frequency for the Atlas crystal filter. Adjust level setting on spectrum analyser so that it is at top of screen. Typically around 0 dBm for the SI5351 and SI570 CMOS units (or possibly -10 dBm for LVDS SI570) The Atlas crystal filter I use has about 2.5 dB loss including transformers. **Note that level**.

The span setting for the analyser is set for 10 kHz, across the screen. The other settings are usually automatically linked, so require minimal adjustment. (I think the Siglent 3021X sets to 100Hz Resolution Bandwidth, but 30 Hz appears more optimum). Averaging is definitely used, as this reduces the peak/trough variations, and makes readings easier (Mine is set to 20 averages in this case, although display settling takes time)

Invoke the Noise marker. This normally reads in dBm/Hz. And takes into account the Bandwidth setting on your analyser, and provides a correction for detecting noise vs carrier. (it should say something like -17 dBm/Hz if on the carrier peak of a 0 dBm source. (at 100 Hz Bandwidth). Note the reference is still 0 dBm, not -17dbm.

Offset the oscillator frequency by + or – 2 kHz, you should see the carrier, step 2 kHz and also drop in level. Adjust the reference level on the analyser to -40 dB to -60 dBm.. You may still not see the noise. Then invoke the internal spectrum analyser preamp.. (If you have an analyser without preamp, then you need an amplifier at this point). The noise through the crystal filter should should appear out of the analyser noise.., like in the image below.

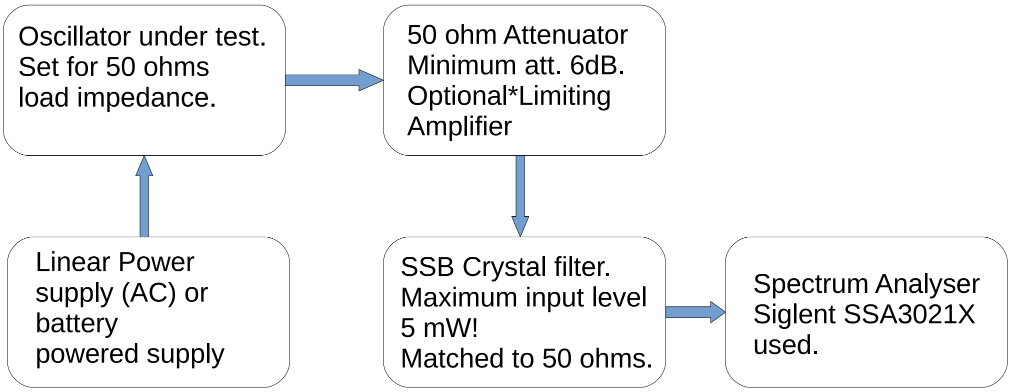


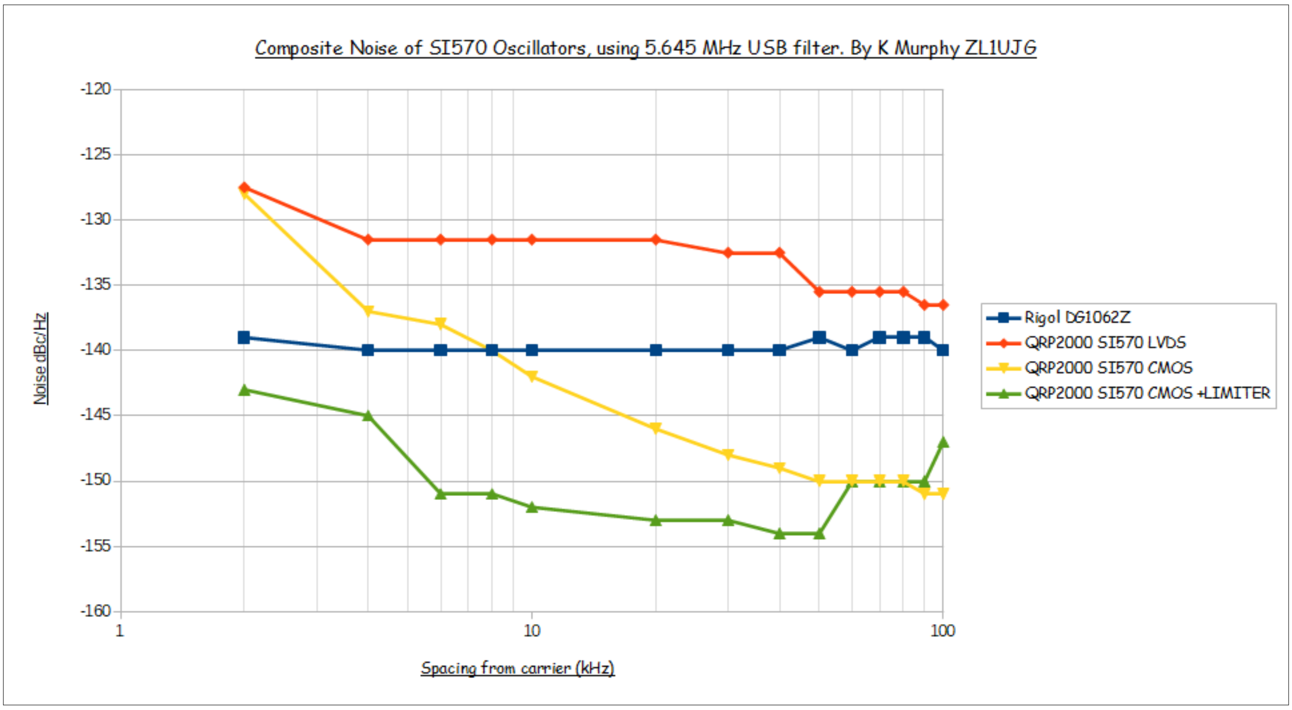
Note the level of the noise marker. If the oscillator was set to 0 dBm on the display originally then the noise marker is the noise difference, however if the level was slightly above 0 dBm or below, then the noise is either slightly higher or lower.. Eg If the level originally was +2 dBm on the plot above, then the noise is-115 dBc/Hz (dB below carrier), but if it was -10 dBm, then it is -103 dBc/Hz.

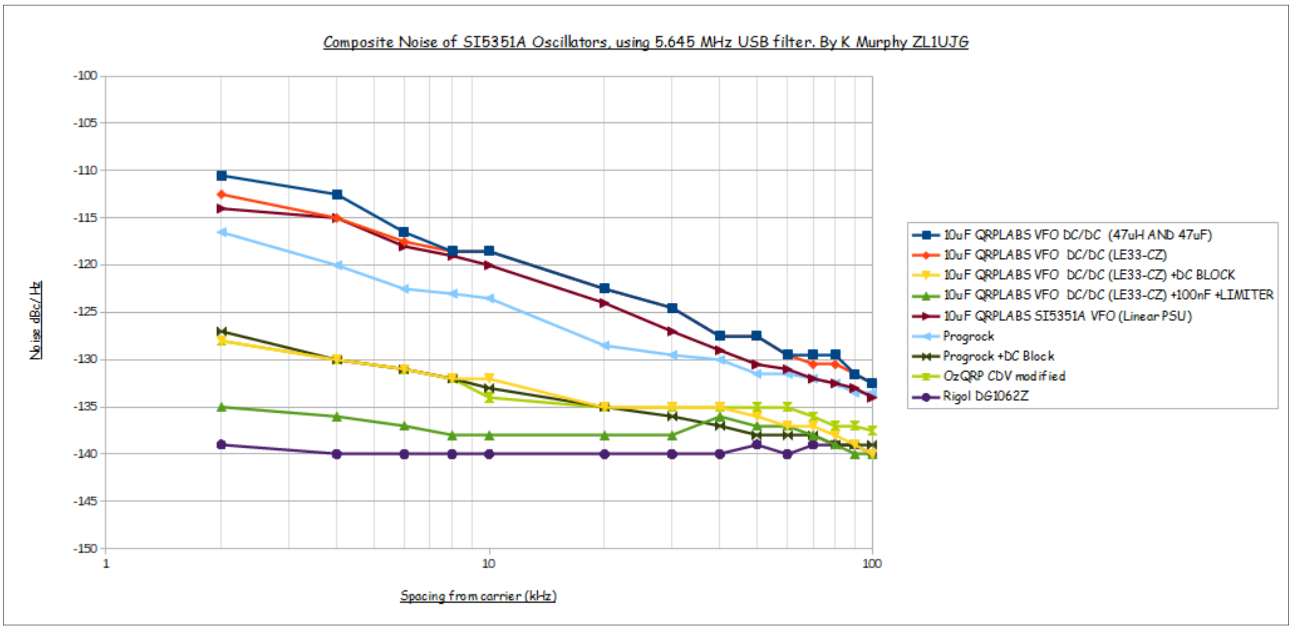
I repeat this for different spacings from carrier, by tuning the oscillator further away, noting figures on a pad, then I put numbers in a spreadsheet, and display them on a graph, like the second and third images below.

Suitable spacings are 2-10 kHz (2 kHz steps), and 10-100 kHz,(10 kHz steps)
I didn't have 2nd or 3rd oscillator outputs running for these tests

References https://www.npl.co.uk/special-pages/guides/gpg68_noise


Oscillator under test.
Set for 50 ohms
load impedance.
50 ohm Attenuator
Minimum att. 6dB.
Optional*Limiting
Amplifier
Linear Power
supply (AC) or
battery
powered supply
SSB Crystal filter.
Maximum input level
5 mW!
Matched to 50 ohms.
Spectrum Analyser
Siglent SSA3021X
used.


Composite Noise of SI570 Oscillators, using 5.645 MHz USB filter. By K Murphy ZL1UJG
Noise dBc/Hz
-120
-125
-130
-135
-140
-145
-150
-155
-160
1
10
100
Spacing from carrier (kHz)
Rigol DG1062Z
QRP2000 SI570 LVDS
QRP2000 SI570 CMOS
QRP2000 SI570 CMOS +LIMITER


Composite Noise of SI5351A Oscillators, using 5.645 MHz USB filter. By K Murphy ZL1UJG
Noise dBc/Hz
-100
-105
-110
-115
-120
-125
-130
-135
-140
-145
-150
1
10
100
Spacing from carrier (kHz)
10uF QRPLABS VFO DC/DC (47uH AND 47uF)
10uF QRPLABS VFO DC/DC (LE33-CZ)
10uF QRPLABS VFO DC/DC (LE33-CZ) +DC BLOCK
10uF QRPLABS VFO DC/DC (LE33-CZ) +100nF +LIMITER
10uF QRPLABS SI5351A VFO (Linear PSU)
Progrock
Progrock +DC Block
OzQRP CDV modified
Rigol DG1062Z