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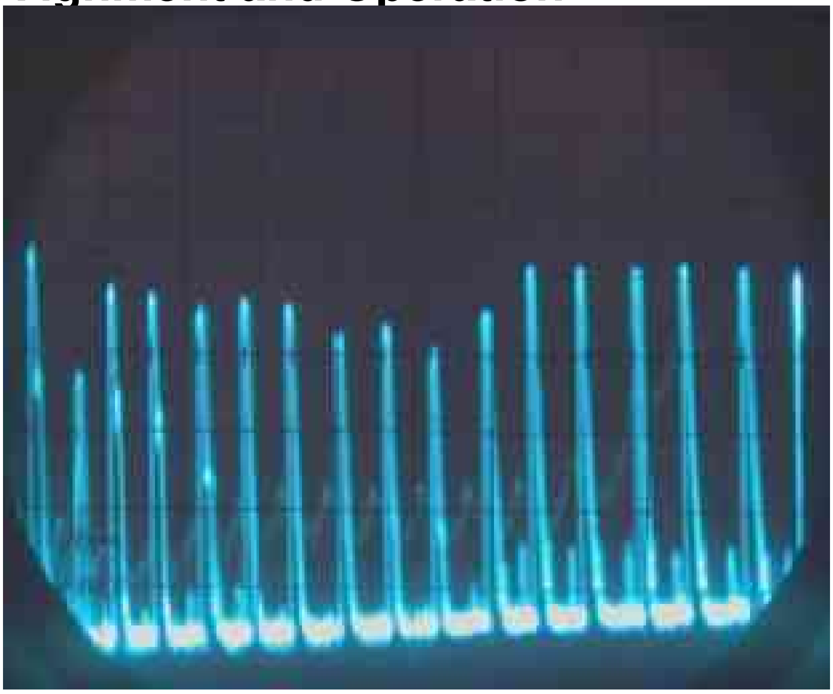
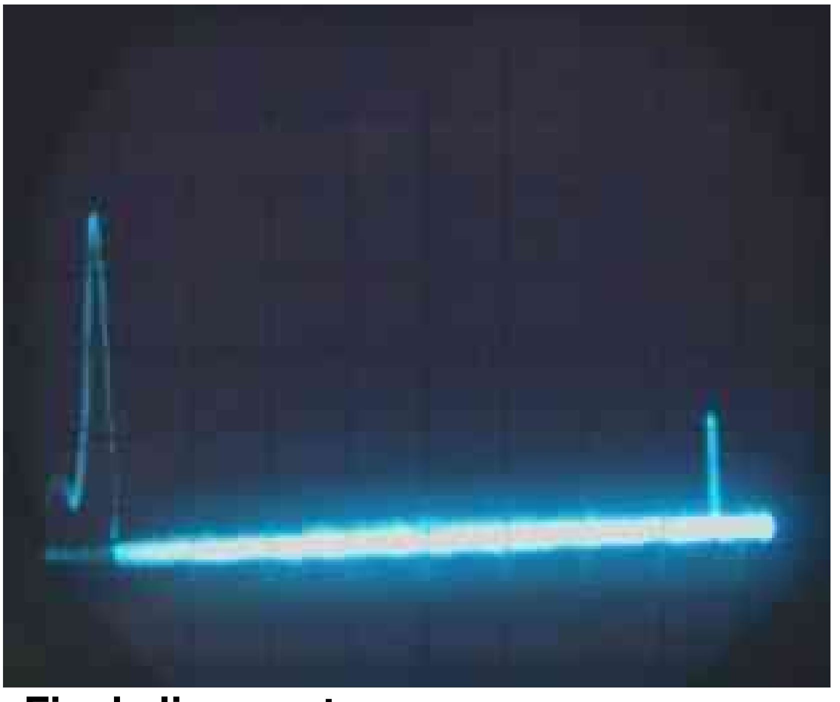
The simple man's Spectrum Analyser
Alignment and Operation





Final alignment

There isn't much to do in the way of final alignment. The simple man's spectrum analyser is designed particularly to avoid any complicated and difficult alignment or construction procedures. The hardest part is getting the 2nd local oscillator tuned to 153MHz, but that has already been taken care of.

As a final alignment, the only thing needed is to make sure the tuning range of the VCO is just right. The sweep generator should be outputting the maximum voltage range without clipping, if it has been correctly set as described. Now the oscillator coil in the VCO can be adjusted. The ideal sweep range of the VCO is 145 - 295MHz, giving analyser coverage of 0 - 150 MHz. That's actually quite an impressive range.

This adjustment is best made with no signal to the analyser. The frequency span control should be set to maximum, and the adjustment made by squeezing or expanding the turns of the air-wound coil in the VCO . It might be necessary to add or remove coil turns, or perhaps very small (pF) capacitors in parallel with the coil. The centre frequency control should be used to view the lower and upper frequency bounds.

The 0 MHz spur will be visible at the left of the screen when the lower end of the VCO range is at or below 145MHz. This spur is generated when the VCO passes through the first IF frequency. Similarly, when the upper end of the range is at or above 295MHz another spur will be generated corresponding to an input frequency of 145MHz.

After a lot of fiddling around, if all is Ok both the 0 and 145MHz spurs will be visible on the screen at the same time, as shown in this photograph. When this is the case, by definition the analyser is covering at least the range 0 - 145MHz.

Operation hints

In use the spectrum analyser should be easy and intuitive to operate. If the user wants to use narrow sweeps and finds the centre frequency too difficult to set, then a multi-turn potentiometer could be used in the Sweep Generator , or a separate fine-tuning potentiometer adjustment.

Of absolutely crucial importance is the input attenuator . This spectrum analyser is by design simple to build and align, the use of the SA602 IC is particularly beneficial in this respect. However the SA602 does suffer from limited strong signal handling performance which can cause many spurious signals in the analyser in the presense of large input signals. This is a penalty of using such a simple design. Yet with careful use, this limitation need not prevent the analyser from being extremely useful and making great observations.

It is usually easy to identify spurious signals by switching in a little attenuation. The amplitude of the true signals will change by the expected amount according to the selected attenuation, whereas the spurious responses will appear to be reduced in amplitude by a larger amount. Sometimes this effect is quite marked: just switching in 1dB of attenuation which hardly affects the true signals has a drastic effect on the spurii. If the input signal is strong enough to cause spurious responses I usually select attenuation such that all the spurious responses dissappear.

Obviously switching in attenuation also reduces the signals you do want to see. Sometimes weak frequency components could drop below the noise floor. So it may be desirable to use less attenuation than would be necessary to remove any spurious responses altogether. In this case it is often useful to temporarily use larger attenuation in order to identify any spurious responses present.

Another way to identify some spurious responses, is by tuning the centre frequency. For example as you increase the centre frequency, the spectrum will scroll towards the left of the display. However, some peaks might move to the left much faster than the main "true" peaks, or even move in the opposite direction! These peaks are the result of residual high harmonics which make it through the input low pass filter.

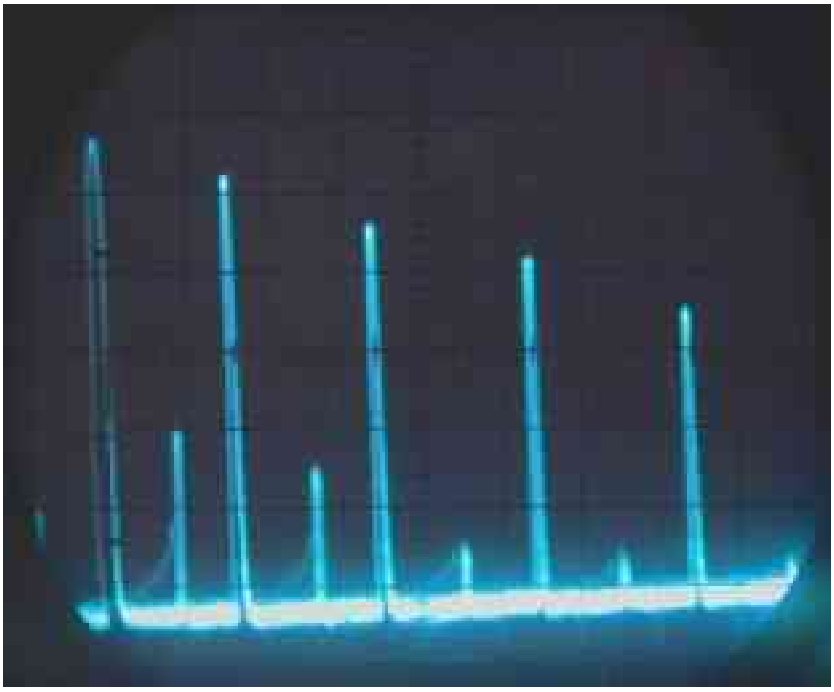
For transmitter testing, a short piece of wire connected to the analyser input is sufficient to show the output spectrum. But for accurate measurements you need to make a proper connection between the transmitter and the spectrum analyser. Unless the transmitter is extemely low power (mW) the spectrum analyser input will be overloaded and most probably damaged. Therefore you would need a power attenuator, providing say 20dB attenuation (or more for a QRO transmitter) and of appropriate wattage rating.

The high impedance input is more sensitive and vulnerable to damage than the 50-ohm input and accordingly care should be taken. I managed to destroy a MAX4178 amplifier IC by unplugging the signal generator while it was switched on. Since my signal generator is an old Heathkit type using valves, high voltages are present and I suspect that the earth connection was broken before the inner coaxial signal connection, resulting in a large DC bias on the signal input. I find it useful to normally use the 50-ohm input and only switch in the high impedance input when it is needed.

Resolution Bandwidth

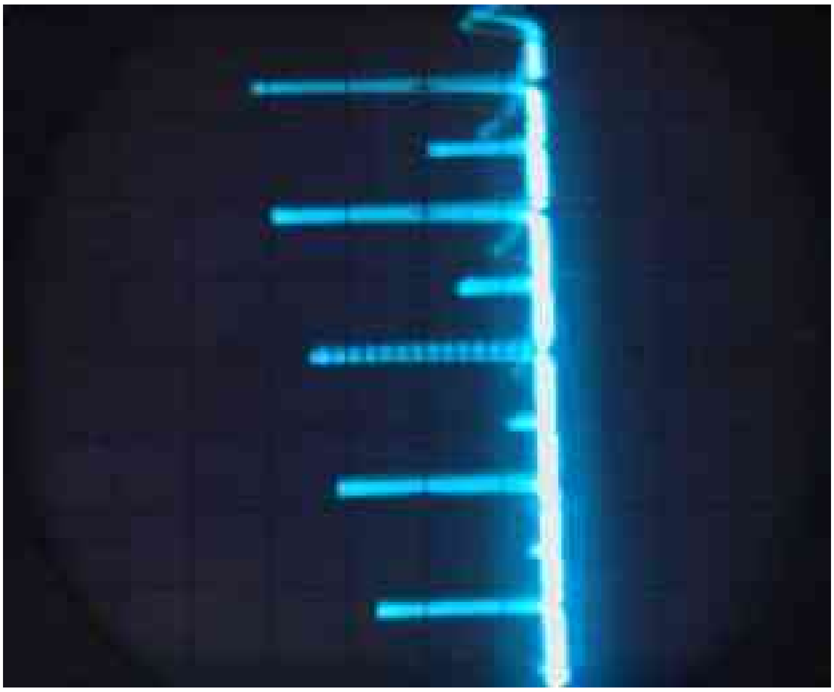
By close in observations on the signal generator output and switching in different attenuations I have been able to approximately determine that the resolution bandwidth of this spectrum analyser is about 200KHz. In analyser specifications this is defined as the point at which adjacent signals can be separated with a 3dB dip between their peaks.

The resolution bandwidth is completely dependent on the characteristics of the 2nd IF filter. In my case, I used ceramic resonator filters from the junk box having unknown characteristics. Certainly filters are available (e.g. 10.7MHz) with narrower bandwidths than this. Alternatively crystal filters could be used. A future version of the spectrum analyser will include several 2nd IF filters with different bandwidths, selectable via a front panel switch.



Frequency axis linearity

Precise linearity of the frequency axis is hard to achieve in such as simple design. Any VCO using a varicap diode for tuning will exhibit some non-linearity. The reverse capacitance of varicaps is not linear with applied voltage, nor is the the VCO frequency linear with capacitance. Given these inherent limitations I am extremely surprised at the excellent linearity shown by this circuit.

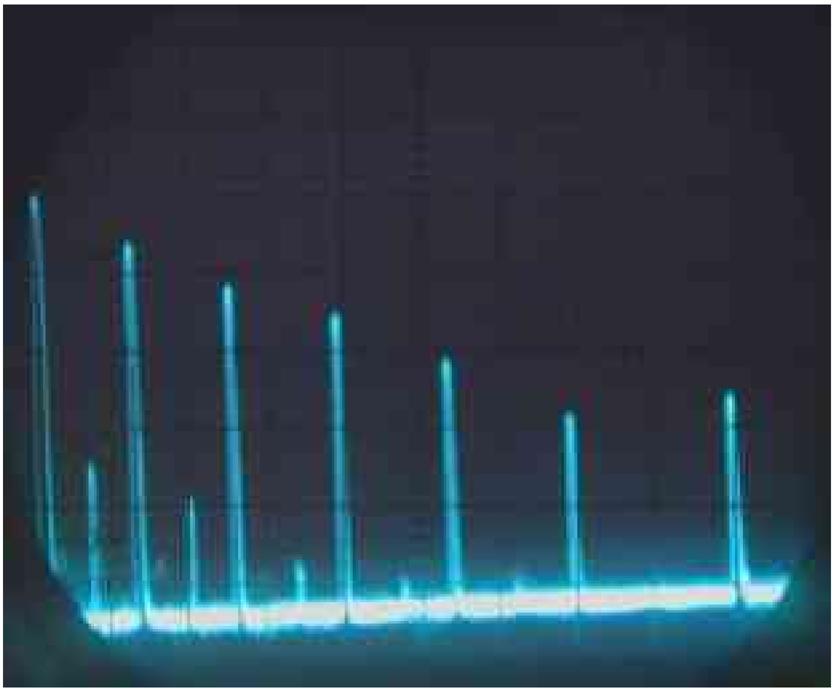


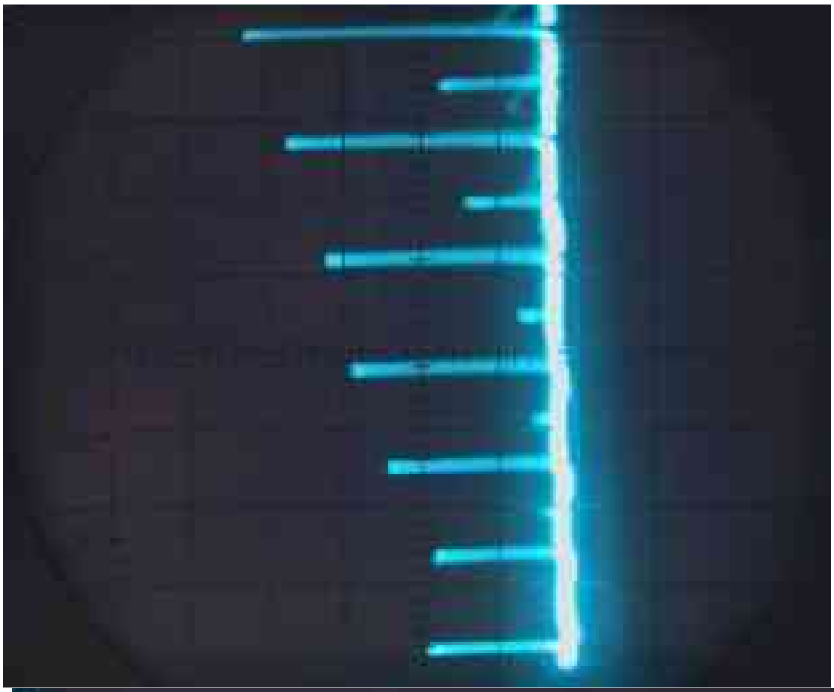
The photograph (right) shows the spectrum of the internal 10MHz crystal calibrator oscillator over the range 0 - 100MHz. Some non-linearity is visible at the right of the display but in general the linearity is very good.

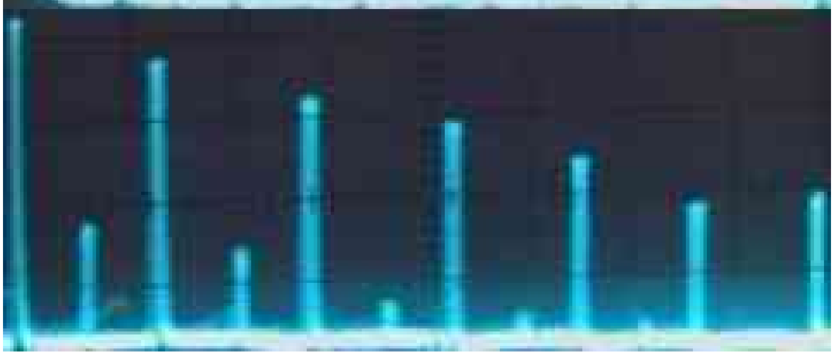
Always suspicious of my cheap 5Mhz Kenwood oscilloscope, I decided to try the same trace but swap the oscilloscope X and Y connections. Because of the scales of the voltages involved and the considerably lesser amplification available on the oscilloscope X input, the size of the peaks in this mode is smaller (see photo, left).

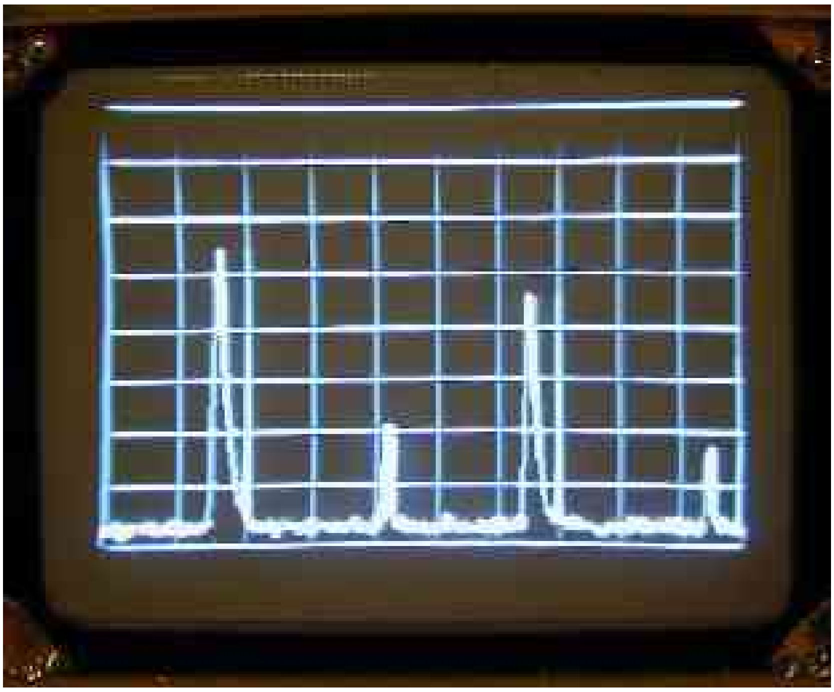
The experiment shows that the frequency axis linearity is greatly improved. This means that much of the non-linearity visible in the normal trace is due to imperfections in the oscilloscope rather than true non-linearity in the spectrum analyser.

To further illustrate this point and make a nice comparison - here's an experiment with the frequency linearity over the whole frequency coverage 0 - 140MHz. The photograph below left shows the spectrum from 0 - 140 MHz of the 10MHz calibration oscillator. Below centre is the same trace, with the X and Y inputs swapped. Below right: the digitally remastered composite image. Here I used Microsoft PhotoEditor to remove the axis tilt and size the pictures to the same scale. The upper trace is the normal configuration, the lower half is the X-Y swapped version. Here it's clear to see that the linearity of the oscilloscope X axis is questionable.









Other Oscilloscope problems

You can't fail to have noticed the annoying upward slope of the baseline from left to right, in all the oscilloscope photographs. Is this a problem in the analyser or another 'scope defect? Quite possibly the response of circuits in the analyser could create this effect, indicating a design fault. Fortunately this one is easy to blame on the 'scope: the upward slope is present even when the spectrum analyser is disconnected.
I am developing a new spectrum analyser which uses digital storage and a 4.5-inch television tube for the display. This photograph shows the display section of the new project, connected to the output of this spectrum analyser. The spectrum of the 10MHz calibration oscillator is being displayed, the frequency range is about 2 - 42 MHz. The baseline is perfectly horizontal against the digitally generated graticule.

Some more screenshots

Here's a few more examples. Left: 10MHz calibration oscillator spectrum, 8 - 32 MHz showing fundamental at 10MHz, with 2nd and 3rd harmonics. Note the very much reduced amplitude of the 2nd harmonic. In a perfect square wave oscillator there are no even-order harmonics. The output of the calibrator approximates a 10MHz square wave which is why the even harmonics are always much lower in these photographs. Centre: Closeup on the 10MHz peak, showing the shape of the 2nd IF filtering. Right: spectrum of my Heathkit signal generator tuned to approximately 1MHz. The even-order harmonics are of lower amplitude but still visible out to about 40MHz.