RF2K5 Output Filtering

An Assessment of Filtering Requirements

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1. Regulations/Recommendations on Spectral Purity for Amateur Radio Transmitters.

Requirements for spectral purity of amateur radio transmitters are set out in CEPT/ERC/Recommendation 74-01E Unwanted Emissions in the Spurious Domain. These recommendations are incorporated in ETSI EN 301 783-1 which applies to commercially produced amateur radio equipment but not to equipment which is homemade including that assembled from commercially produced kits. However this exclusion from the ETSI standard represents something of a hollow victory given CEPT/ERC/Recommendation 74-01E is in its material effect the same and applies to all amateur radio transmitters, commercial and homemade. The requirements are essentially as follows:

Below 30MHz all spurious emissions should be - (43 + 10 x log (PEP)) or -50dBc whichever is higher. Above 30MHz all spurious emissions should be - (43 + 10 x log (PEP)) or -70dBc whichever is higher.

For avoidance of doubt, the term “whichever is higher” means whichever is <u>less</u> demanding.

At 1kW PEP output this translates to exactly - (43+3) =-46dBc. Not until output power reaches 10kW would this become - (43+4) =-47dBc so for our purposes -46dBc is close enough.

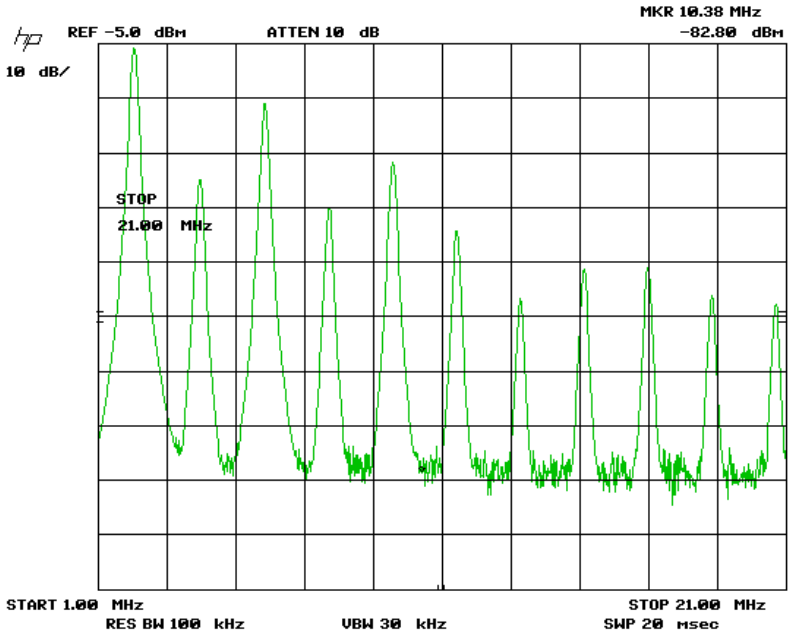
Although this requirement is echoed in ITU-R SM.329 to which the USA are a signatory the FCC has so far chosen to retain a less demanding requirement of simply -43dBc.

2. Assessment of Output Filtering Requirement for RF2K5

The unfiltered output from RF2K5 was sampled using a high power coupler flat +/-0.5dB from 1-70MHz and +/-1.0dB to 110MHz. The RF2K5 was driven to 1500W on each of the 9 bands from 160-10m and to 400W on 6m. The output spectrum was plotted using an HP8568b spectrum analyser.

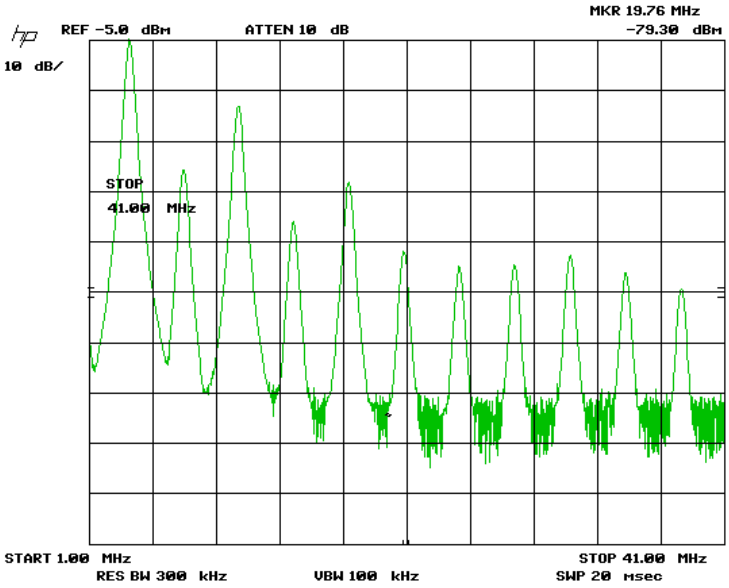
Minimum LPF performance by band required to meet CEPT/ERC/Recommendation 74-01E of -46dBc is determined from each of these plots.

160m



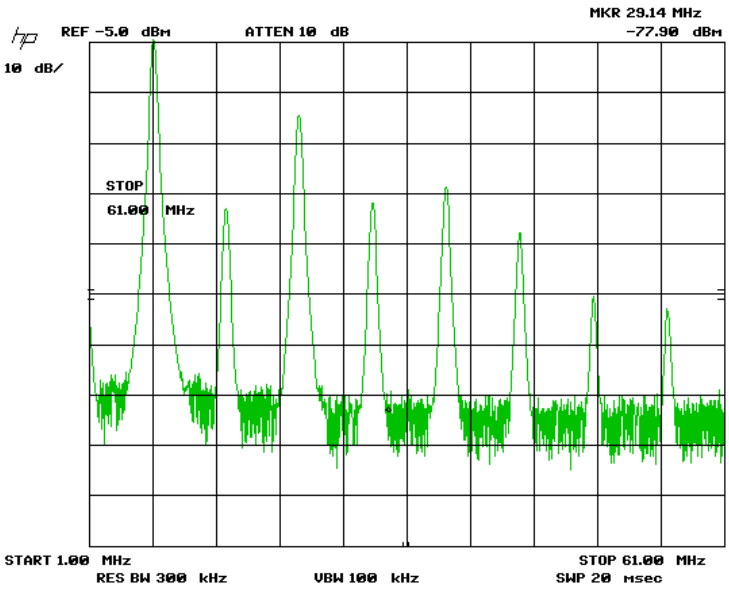
Output at the 2nd harmonic is -25dBc and at the 3rd is -11dBc. The 160m LPF needs to provide a minimum attenuation of 21dB at 3.6MHz and 35dB at 5.4MHz.

80m



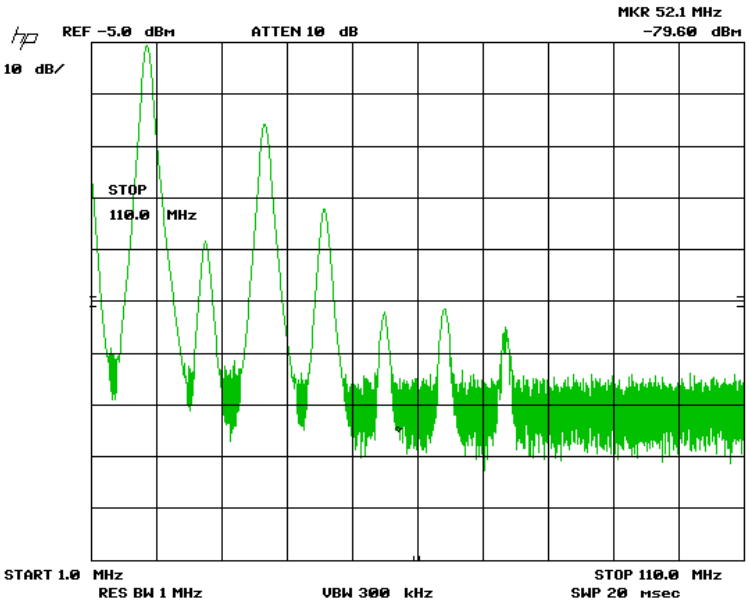
Output at the 2nd harmonic is -26dBc and at the 3rd is -13dBc. The 80m LPF needs to provide a minimum attenuation of 20dB at 7MHz and 33dB at 10.5MHz.

40m



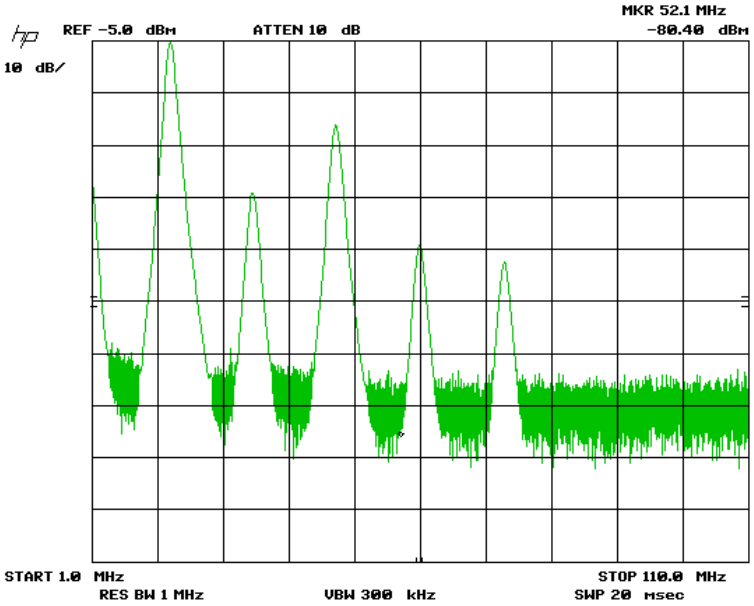
Output at the 2nd harmonic is -33dBc and at the 3rd is -15dBc. The 40m filter needs to provide a minimum attenuation of 13dB at 14MHz and 31dB at 21MHz.

30m



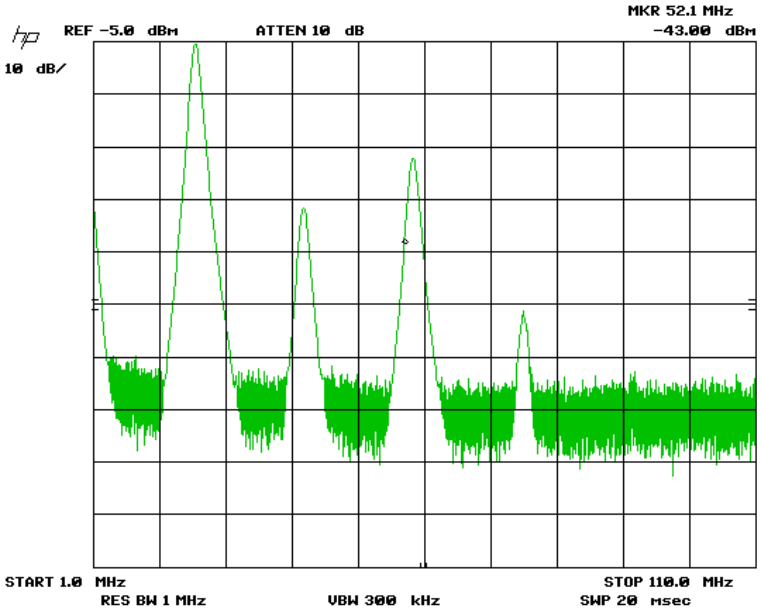
Output at the 2nd harmonic is -38dBc and at the 3rd is -16Bc. The 30m filter needs to provide a minimum attenuation of 8dB at 20.2MHz and 30dB at 30.3MHz.

20m



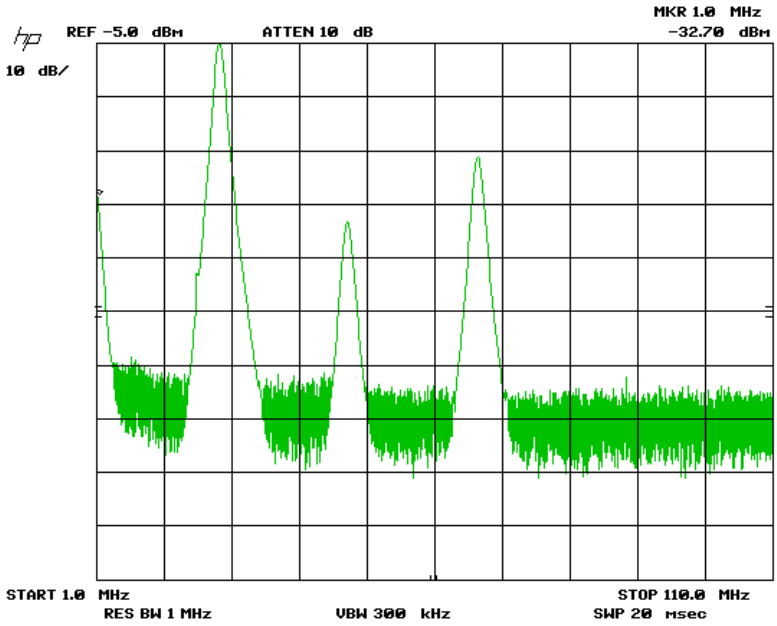
Output at the 2nd harmonic is -30dBc and at the 3rd is -17dBc. The 20m filter needs to provide a minimum attenuation of 16dB at 28MHz and 29dB at 42MHz.

17m



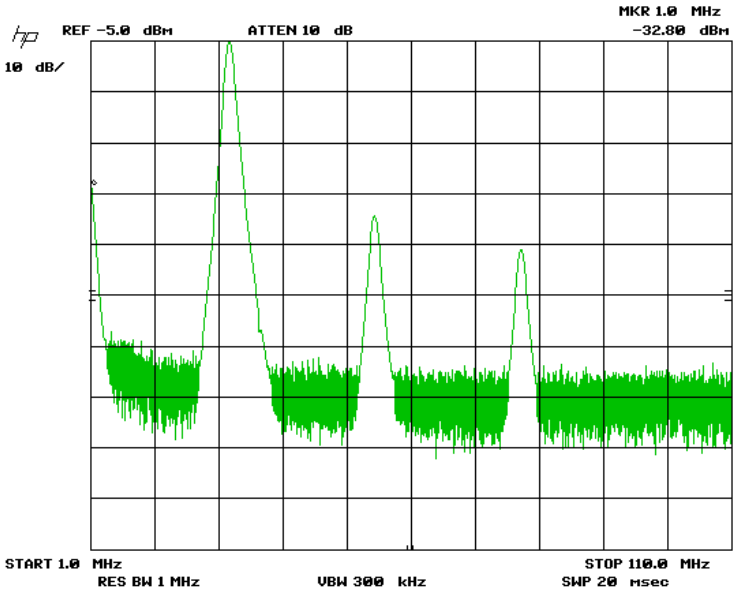
Output at 2nd harmonic is -32dBc and at the 3rd is -22dBc. The 17m filter needs to provide a minimum attenuation of 14dB at 36.1MHz and 24dB at 54.2MHz.

15m



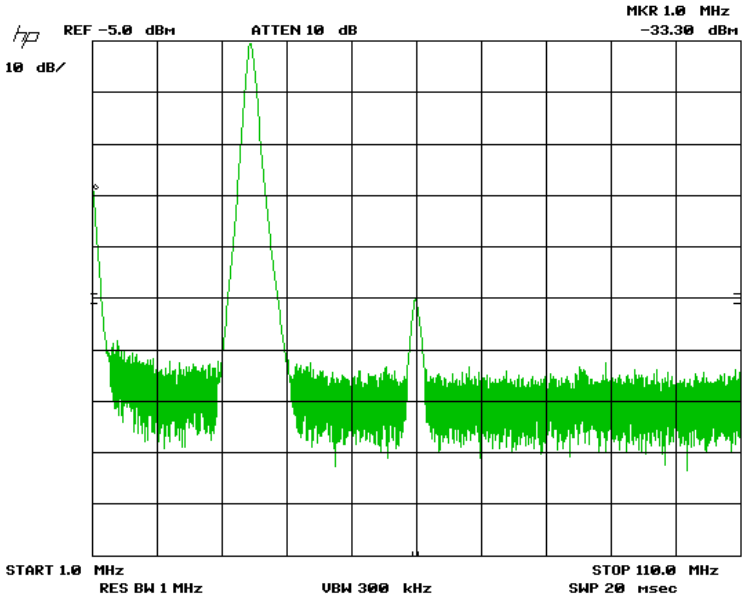
Output at 2nd harmonic is -33dBc and at the 3rd is -21dBc. The 15m filter needs to provide a minimum attenuation of 13dB at 42MHz and 25dB at 63Mhz.

12m



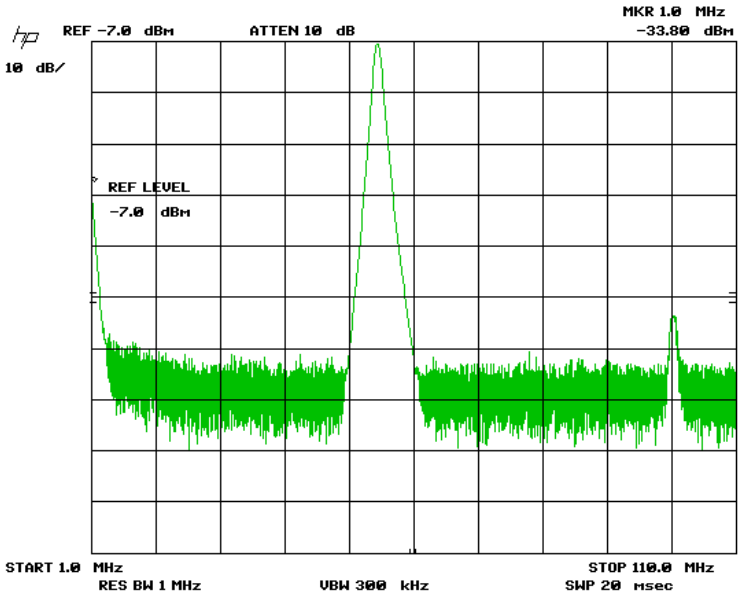
Output at the 2nd harmonic is -34dBc and at the 3rd is -41dBc. The 12m filter needs to provide a minimum attenuation 10dB at 49.8MHz and 5dB at 74,7MHz.

10m



Output at the 2nd harmonic is -50dBc and at the 3rd is just discernible at around -65dBc. On 10m the RF2K5 is 74-01E compliant without additional output filtering.

6m

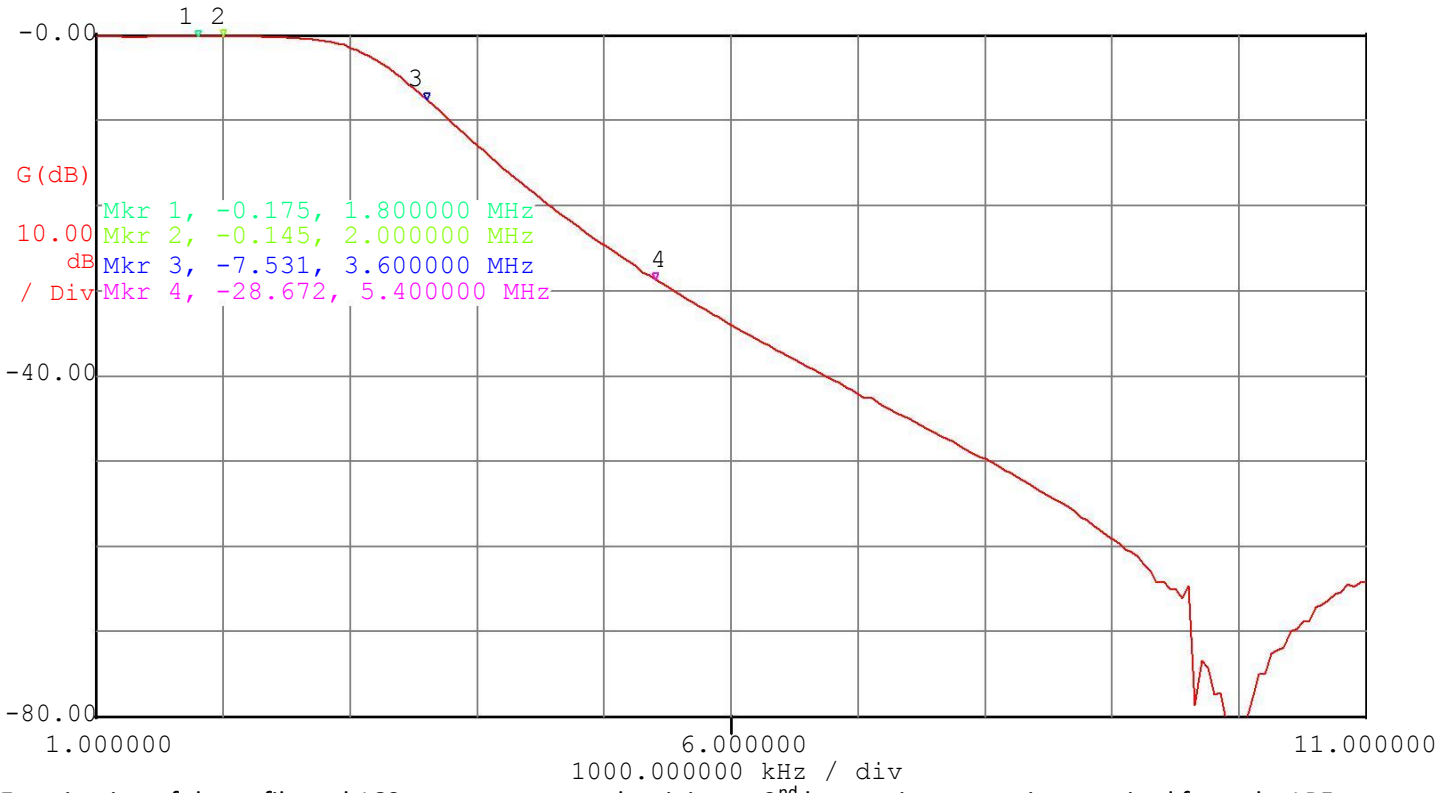


Output at the 2nd harmonic is -54dBc purely due to RF2K5 pallet design. The RF2K5 appears 74-01E compliant on 6m without additional output filtering.

3. Evaluation of Suitability of W6PQL LPF for Use in RF2K5

Plots produced using an N2PK VNA as this offers greater accuracy than the HP8568b analyser between 1-60MHz.

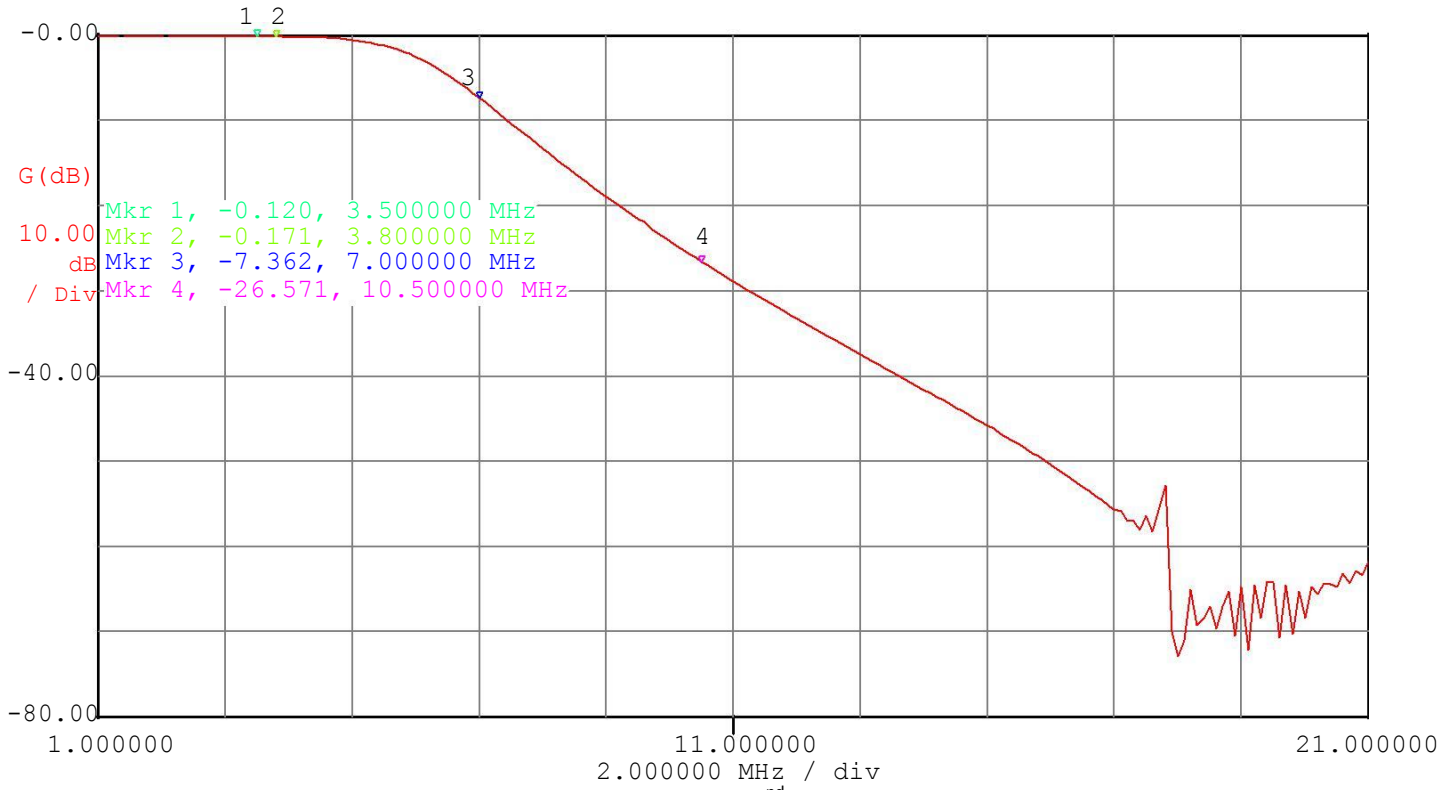
W6PQL 160m LPF



Examination of the unfiltered 160m spectrum reveals minimum 2nd harmonic attenuation required from the LPF to be 21dB and 3rd harmonic 35dB. The W6PQL LPF is hopelessly inadequate. The -7.5dB attenuation at 3.6MHz would result in 2nd harmonic at -32.5dBc some 13.5dB short of the minimum suppression recommended under CEPT/ERC/Recommendation 74-01E. The 3rd harmonic would be at -39.5dBc some 6.5dB short.

UNSUITABLE

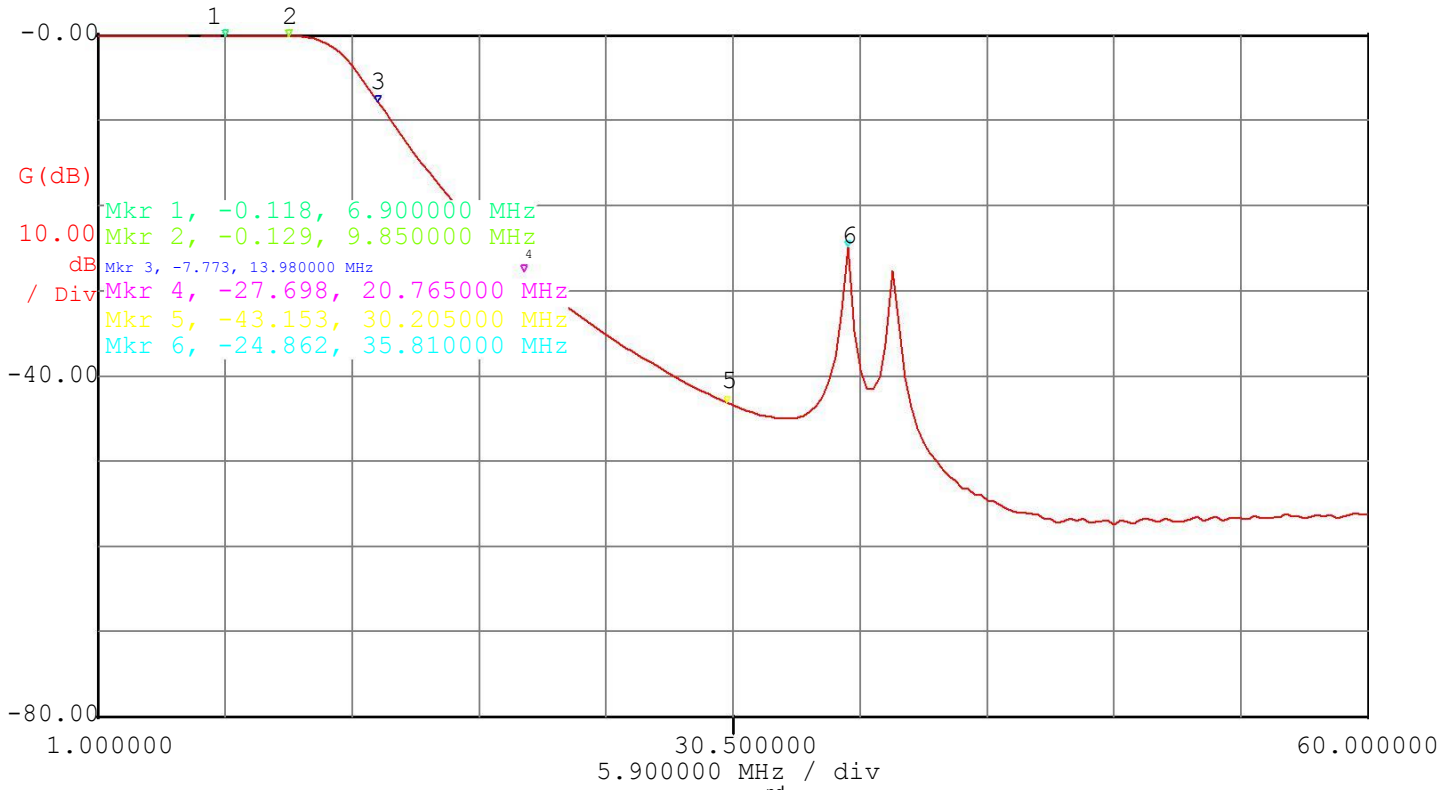
Evaluation of W6PQL 80m LPF for use in RF2K5



Examination of the unfiltered 80m spectrum reveals minimum 2nd harmonic attenuation required from the LPF to be 20dB and 3rd harmonic 33dB. The W6PQL LPF is hopelessly inadequate. The -7.5dB attenuation at 7.0MHz would result in 2nd harmonic at -33.5dBc some 12.5dB short of the minimum suppression recommended under CEPT/ERC/Recommendation 74-01E. The 3rd harmonic would be at -39.5dBc some 6.5dB short.

UNSUITABLE

Evaluation of W6PQL 40/30m LPF for use in RF2K5

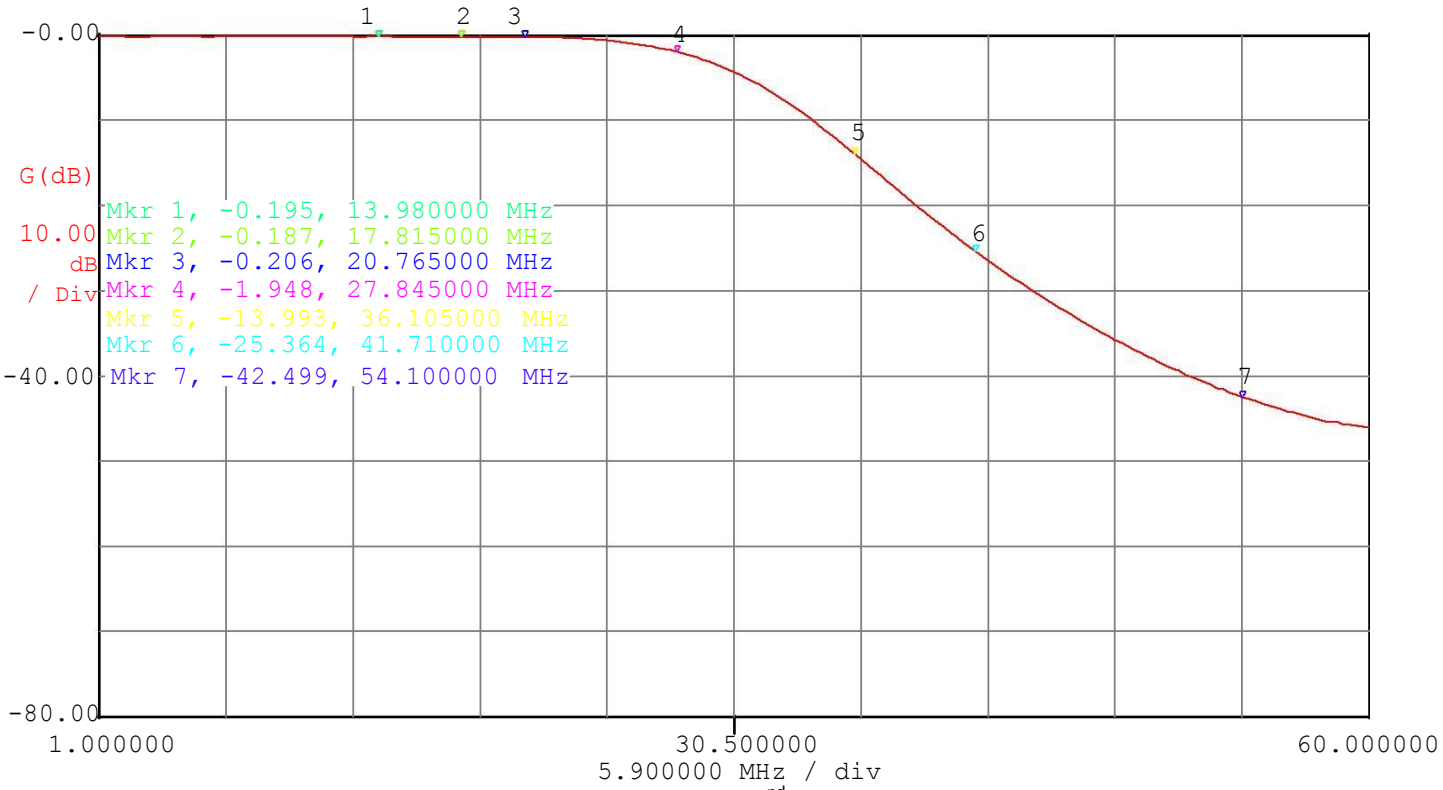


Examination of the unfiltered 40m spectrum reveals minimum 2nd harmonic attenuation required from the LPF to be 13dB and 3rd harmonic 31dB. This W6PQL LPF is inadequate for use on 40m. The 7.8dB attenuation at 7.0MHz would result in 2nd harmonic at -40.8dBc some 5.2dB short of the minimum suppression recommended under CEPT/ERC/Recommendation 74-01E. The 3rd harmonic would be at -43dBc some 3dB short.

Examination of the 30m spectrum reveals minimum 2nd harmonic attenuation required from the LPF to be 8dB and 3rd harmonic 30dB. This W6PQL LPF would be adequate for use on 30m but not on 40m.

UNSUITABLE

Evaluation of W6PQL 20/17/15m LPF for use in RF2K5



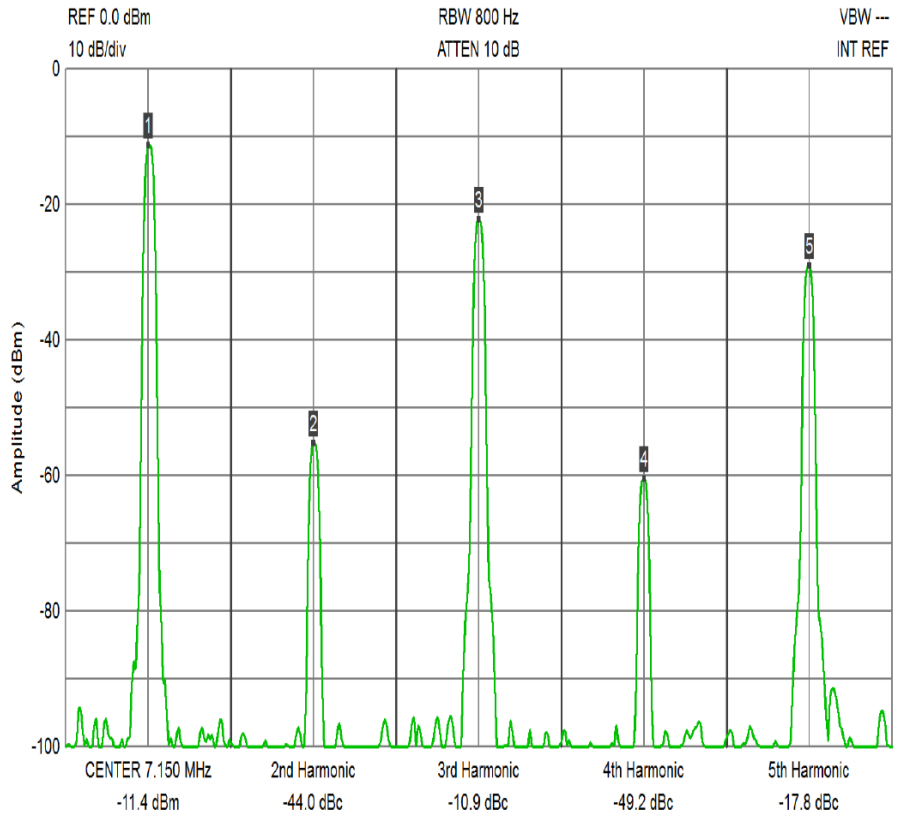
Examination of the unfiltered 20m spectrum reveals minimum 2nd harmonic attenuation required from the LPF to be 16dB and 3rd harmonic 29dB. The W6PQL LPF is hopelessly inadequate. The -2.0dB attenuation at 28MHz would result in 2nd harmonic at -32dBc some 13dB short of the minimum suppression recommended under CEPT/ERC/Recommendation 74-01E. The 3rd harmonic would be at -42dBc some 4dB short.

This LPF would be adequate for use on 17/15m bands but far from adequate on 20m.

UNSUITABLE

W6PQL LPF Evaluation Summary

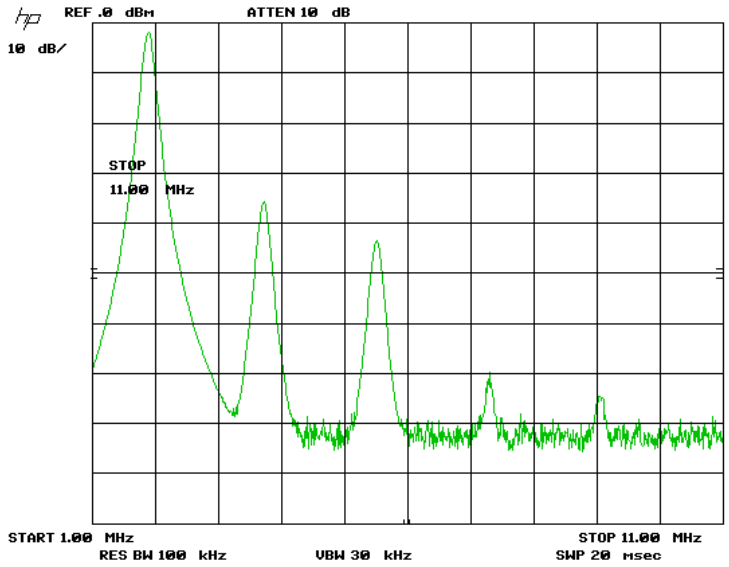
With four of the six W6PQL LPFs clearly not up to the filtering task required by the RF2K5 I ceased evaluation. Aside from the inadequate harmonic rejection afforded by this unit, the smaller cores specified are marginal at this power level. Measured levels of attenuation fell somewhat short of those quoted by W6PQL but there is a more fundamental issue. The W6PQL assessment was made using a single BLF188XR PA with the single substrate LDMOS pair in push-pull. The RF2K5 employs 2 x BLF188XR in which each of the single substrate pairs are connected in parallel with the two independent devices then connected push-pull. Balanced push-pull provides good inherent rejection of even harmonics. Two devices on a common substrate in W6PQL's amplifier yield far better push-pull balance than can be expected from two independent unmatched devices such as those in the RF2K5. The graphic below shows the raw output spectrum from the W6PQL amp driven at 7.150MHz. The 2nd harmonic can be seen at -44dBc and the 4th at -49dBc. Comparable figures for the RF2K5 are -33dBc and -31dBc respectively. This difference in architecture is primarily responsible for rendering the W6PQL LPF incompatible with the RF2K5.



To achieve adequate rejection of 2nd harmonic and beyond 7 pole Chebyshev topology is recommended for all filters except 6m. Measurement of my own unit suggests the raw output on 6m is adequately clean for use without further filtering. Nonetheless I recommend a filter with at least 3 poles be employed in case of unit to unit variation and/or modification of output stage to increase 6m power.

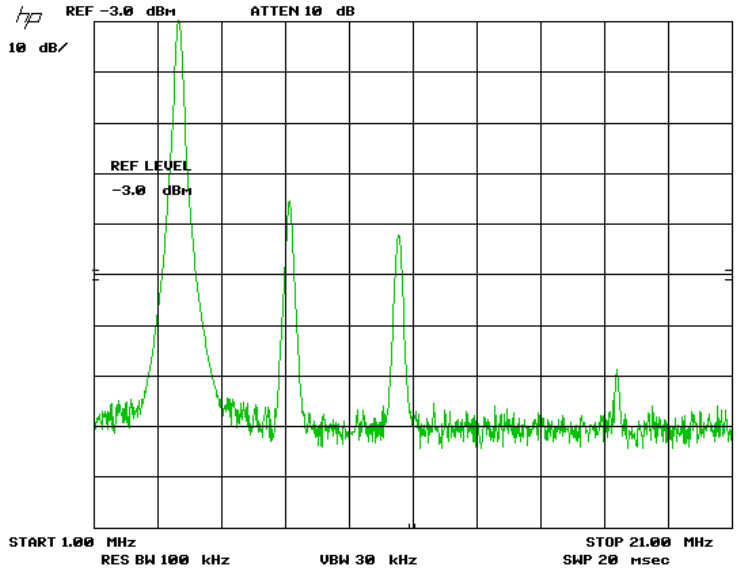
4. Measured performance of W6PQL LPF with RF2K5 at 1500W

160m



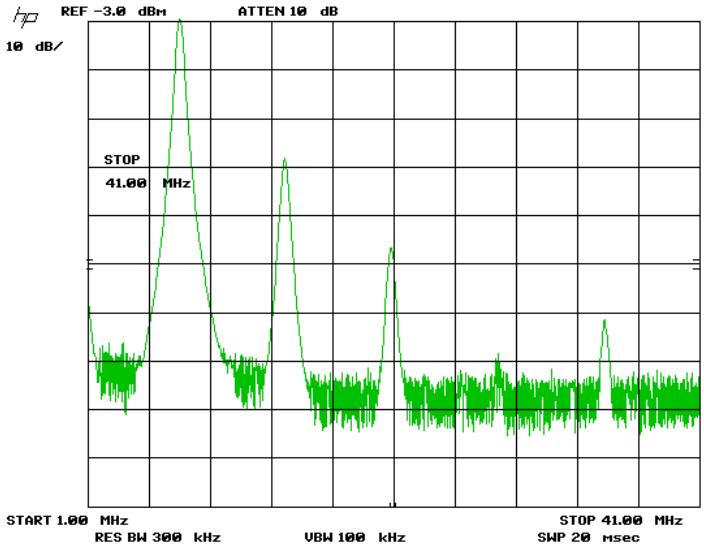
With 2nd harmonic at -34dBc and 3rd at -41dBc this LPF fails to achieve regulatory compliance by 12dB and 5dB respectively.

80m



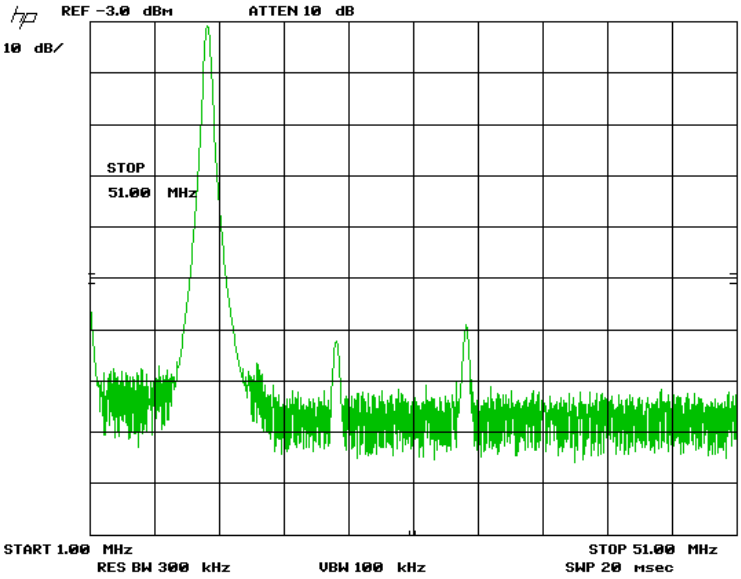
With 2nd harmonic at –36dBc and 3rd at -42dBc this LPF fails to achieve regulatory compliance by 10dB and 4dB respectively.

40m



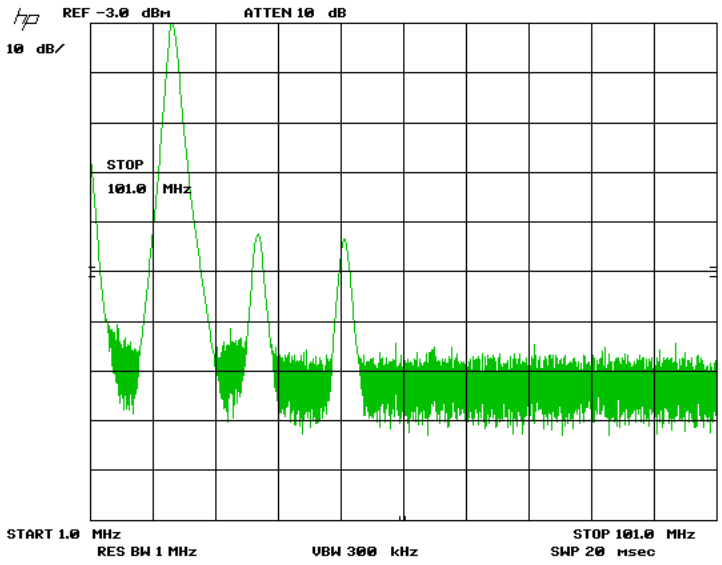
With 2nd harmonic at -28dBc and 3rd at -46dB the 40/30m LPF fails to meet regulatory compliance on 40m by 18dB at the 2nd harmonic. At the 3rd harmonic it is just compliant.

30m



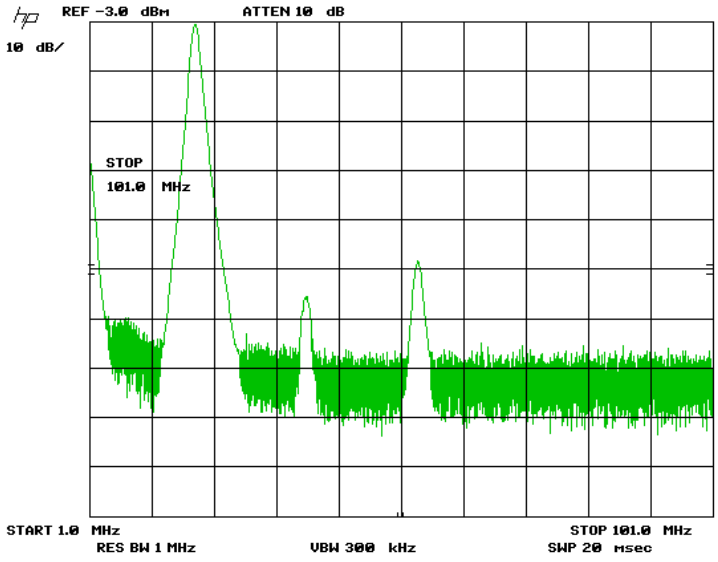
With 2nd and 3rd harmonics both around -60dBc the 40/30m LPF is fully compliant for use on 30m.

20m



With 2nd and 3rd harmonics around -43dBc the 20/17m LPF is 3dB short of compliance.

17m



With 2nd harmonic at -55dBc and 3rd at -48dBc the 20/17m LPF is compliant on this band.

W6PQL LPF + RF2K5 Measurement Summary

There are differences between the arithmetic determination of performance based upon the N2PK VNA evaluation of the W6PQL LPF and the actual performance measured with the LPF connected to the output of the RF2K5 pallet. In some cases these differences are favourable while in others they are adverse. The disparity can most likely be explained by the phase relationship of the reflected harmonic wave to its source.

Despite the differences between calculated and measured performance the conclusion remains the same. Suppression of harmonics from 160, 80 & 40m is woefully inadequate. On the higher bands harmonic levels at the raw output are lower making the filtering adequate, albeit still 3dB short on 20m.

Frequency MHz	Calculated 2nd	Measured 2nd	Calculated 3rd	Measured 3rd
1.83	-32.5dBc	-34dBc	-39.5dBc	-41dBc
3.5	-33.5dBc	-36dBc	-39.5dBc	-42dBc
7.0	-41dBc	-28dBc	-43dBc	-45dBc
10.1	-65dBc	-62dBc	-59dBc	-59dBc
14.0	-32dBc	-43dBc	-42dBc	-43dBc
18.1	-46dBc	-55dBc	-54dBc	-48dBc