Overtone TRS Filter

9/28/08

The crystal in the half lattice circuits is caused to resonate with the incoming signal at an average phase between phases 1 and 2, or at a phase as offset by tuning. This stores energy in the crystal, as in a flywheel, which then forms a vector reference for the detected phase. Vector adding the reference to the incoming signal yields the transient input phase change vs output phase change comparison. The stored energy corresponds to the measured envelop group delay, which is hundreds of times the bit period. The observed transient group delay is the transient vector sum, not that of this much larger stored group delay.

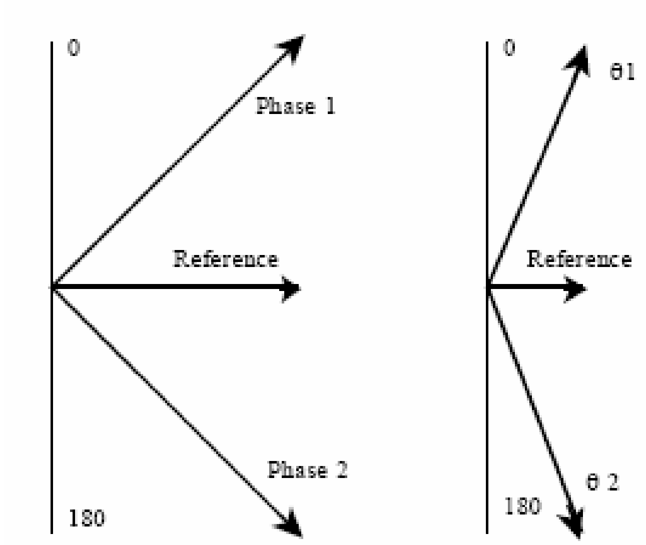

Figure 1/ 7.3. Reference energy is vector added to the incoming signal to obtain a transient response equivalent to 1 IF cycle.

At resonance the circuit should function as an RC differentiator. However, energy is stored in the crystal, which adds to the incoming signal to produce a vector sum with a consequent phase loss. In the Bridge and Shunt filters with fundamental crystals this reference level is relatively large and the vector sum for a +- 90 degree phase modulated signal suffers a phase loss of approximately 50% as seen on the left in Figure 1.

This assumes the filter is passing a vector sum. If the filter did not store the reference energy, it would function as an RC differentiator with no group delay and no phase loss. This actually occurs in burst testing the filters where there is no stored energy and the crystal represents a very high impedance. This shown in Fig. 7.16 of the textbook.

Assuming that a crystal in the overtone mode stores less energy and the reference level is therefor smaller, third overtone crystals were tried. This appears to be verified. The phase loss was much less in the TRS filter circuit when using third overtone crystals. Cp must be tuned as near balanced as possible to approach the differentiator effect and the frequency near peak tuned.

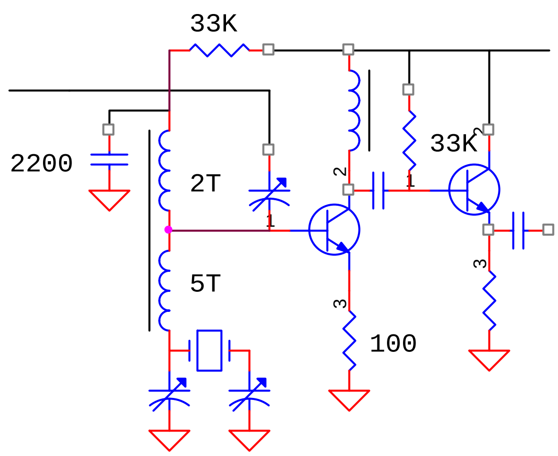

Figure 2. Schematic of the overtone filter. Gain = 1.3

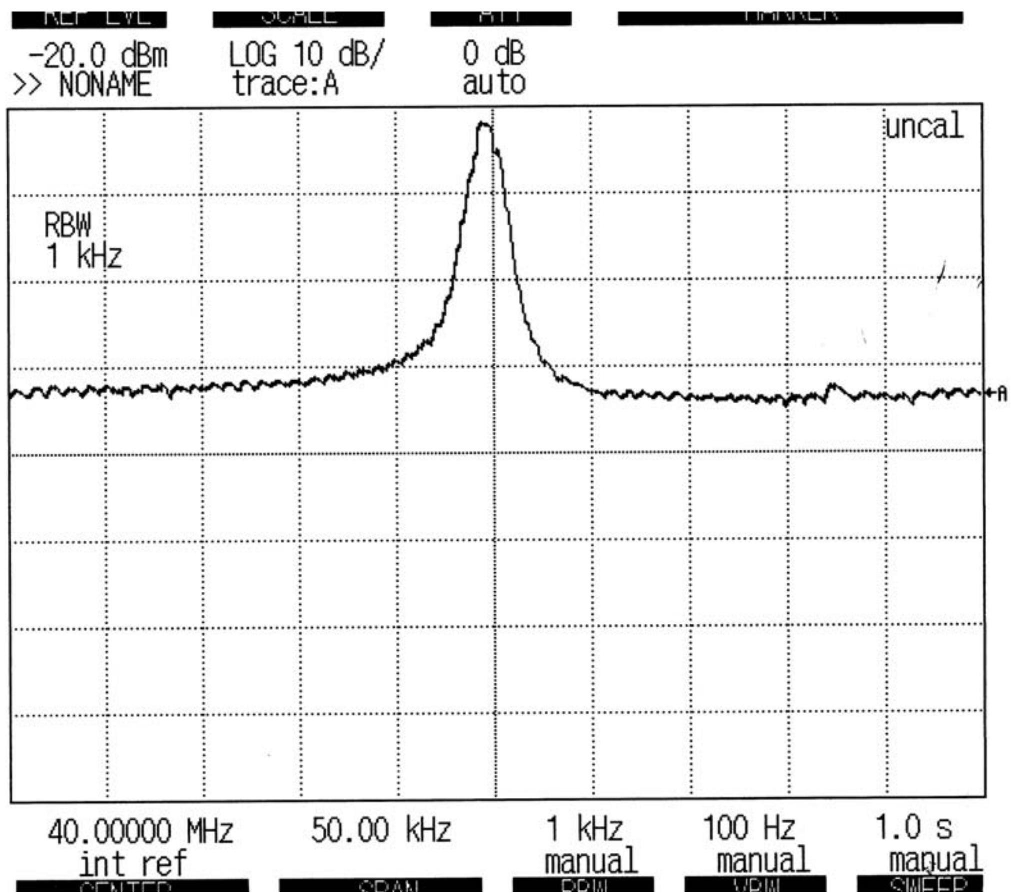

Figure 3. Swept response of the 'Overtone TRS' filter. The shoulders are down approximately 30 dB. The bandpass peak is narrower than that of the filter using the fundamental crystals.

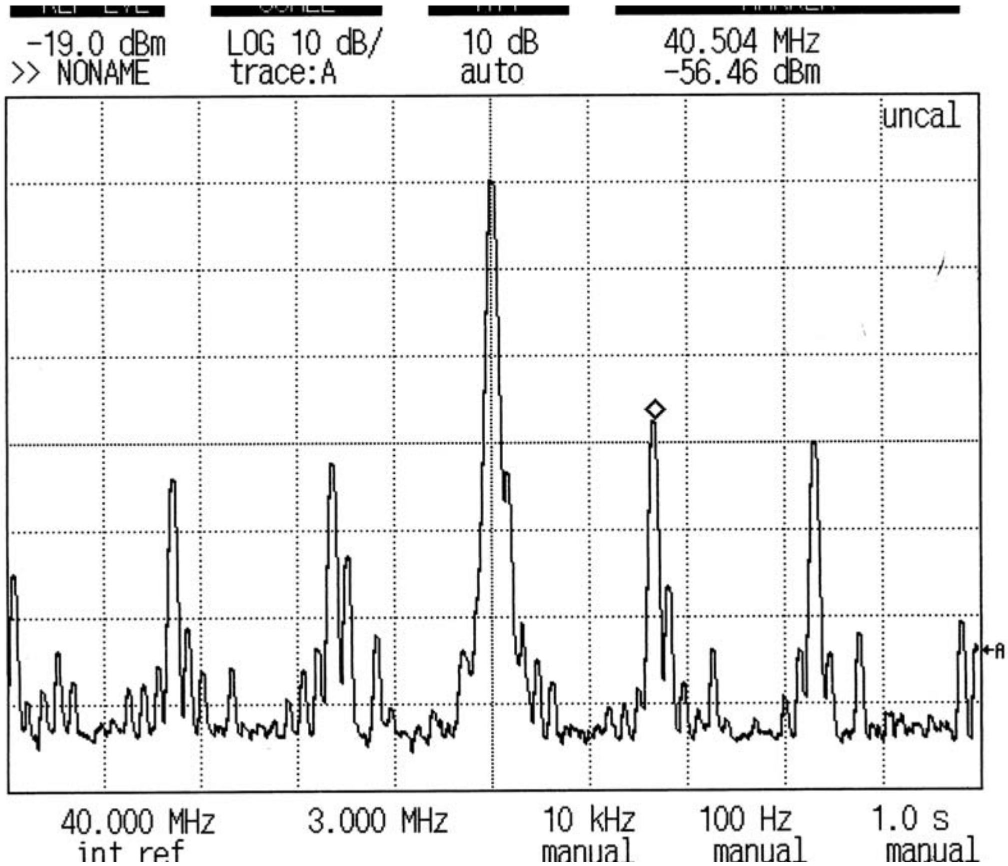

Figure 4. Spectrum of one stage of the filter using the analog modulator with the sidebands at the input approximately equal to the carrier in level. The highest sideband is at -27 dB. Some shoulder reduction is lost when the stages are cascaded.

The phase loss with this single stage was measured at approximately 15 degrees out of 120 degrees at the input.

Referring to Figure 1, the phase loss with a fundamental crystal is typically 50% as shown at the left. If the reference energy can be reduced as shown at the right, the phase change vectors retain more of the original modulation angle.

Until overdriven, there was no level sensitivity. There can be a signal level loss that must be made up for elsewhere unless the component values of the coupling stages is changed. The biplor bias resistors shown as 33K may have to be changed to a value that biases the base to approximately 1.5 V.

When overdriven, an IP3 effect occurs that causes the sidebands to ‘growback’. When this occurs the phase loss can become 100%. Even a phase reversal has been observed. This effect is avoided somewhat by using Op Amps as amplifying and coupling devices, but bipolar circuits, which are not overdriven, work also. It is extremely important when designing systems to make sure this ‘growback’ due to IP3 overload is not present, or is at least at a minimum to prevent level sensitivity.

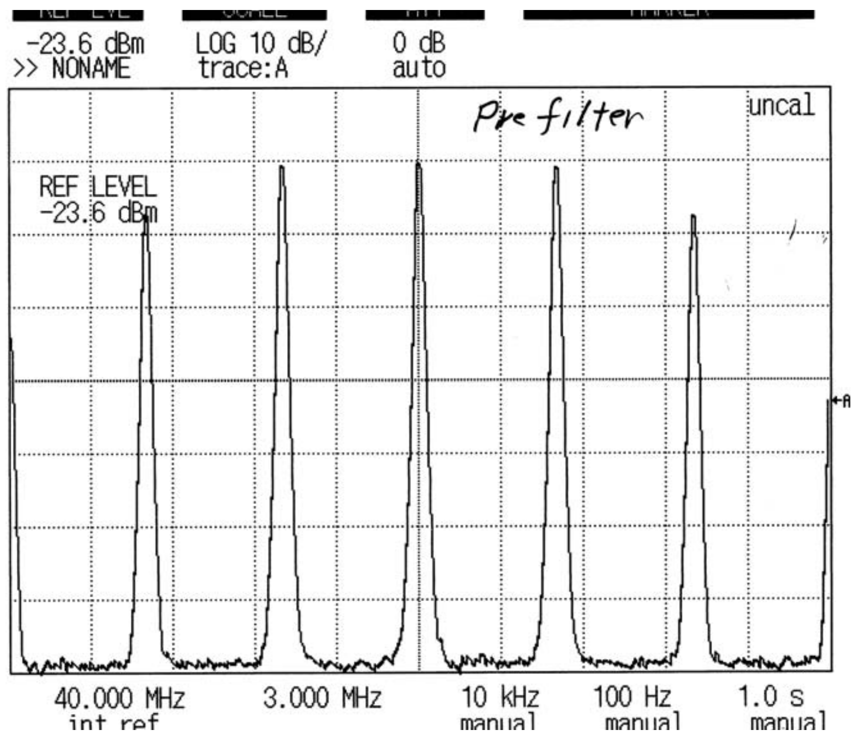

Figure 5. The test signal - prefilter. The shoulders are almost at the same level as the sidebands.

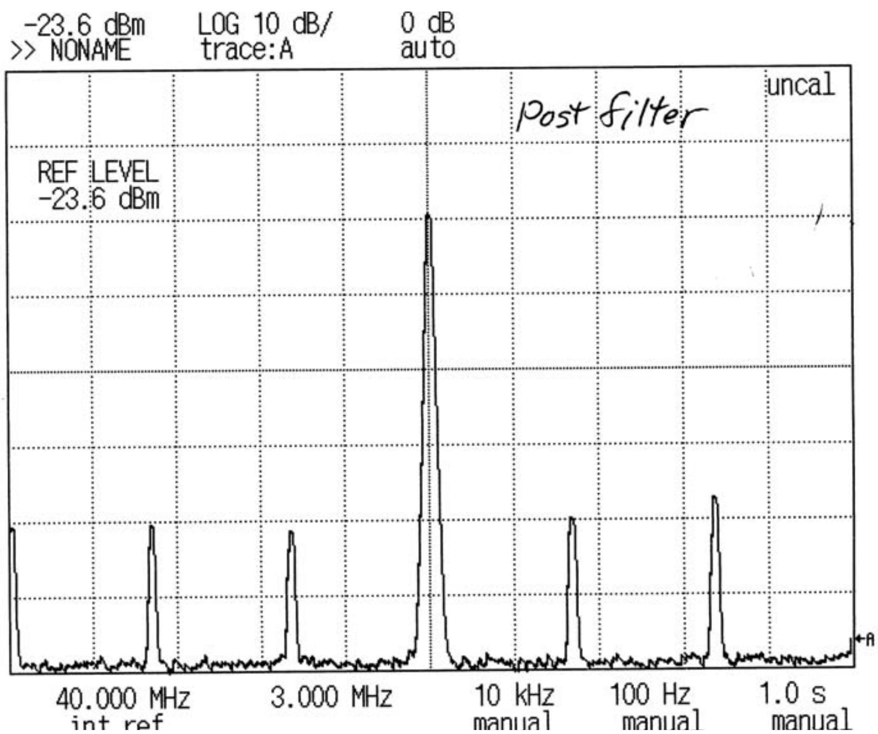

Figure 6. Post bipolar filter with 2 stages. The shoulders are reduced nearly 40 dB. As seen below there is almost zero phase loss.

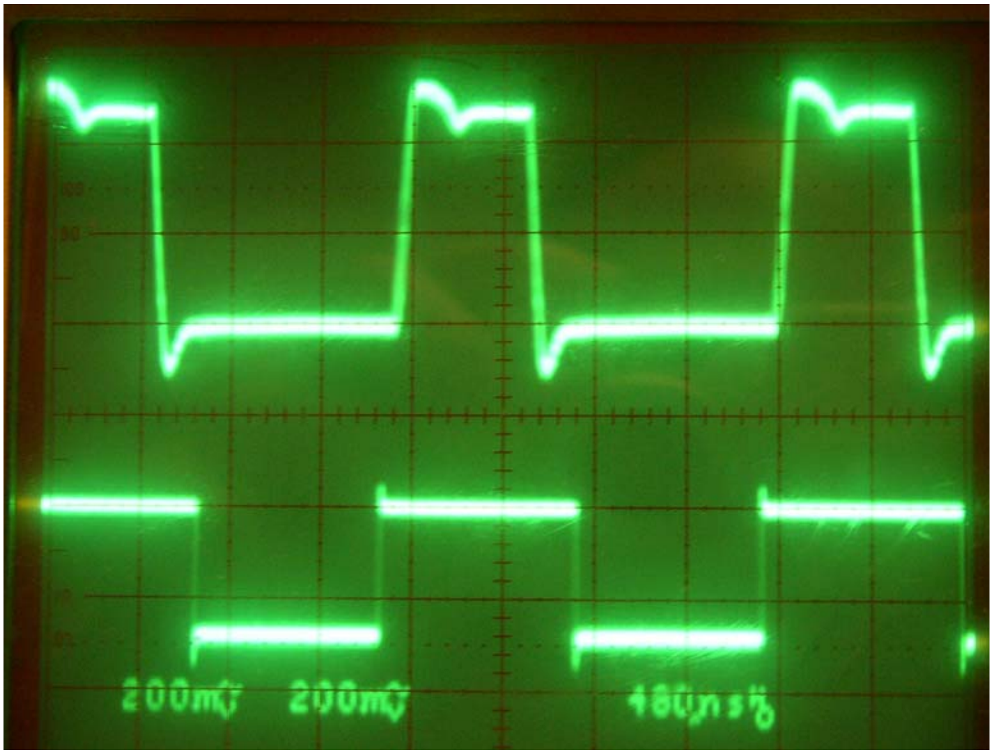

Figure 7. Phase change measured with no filter. The peak to peak voltage is approximately 5.0 Volts.

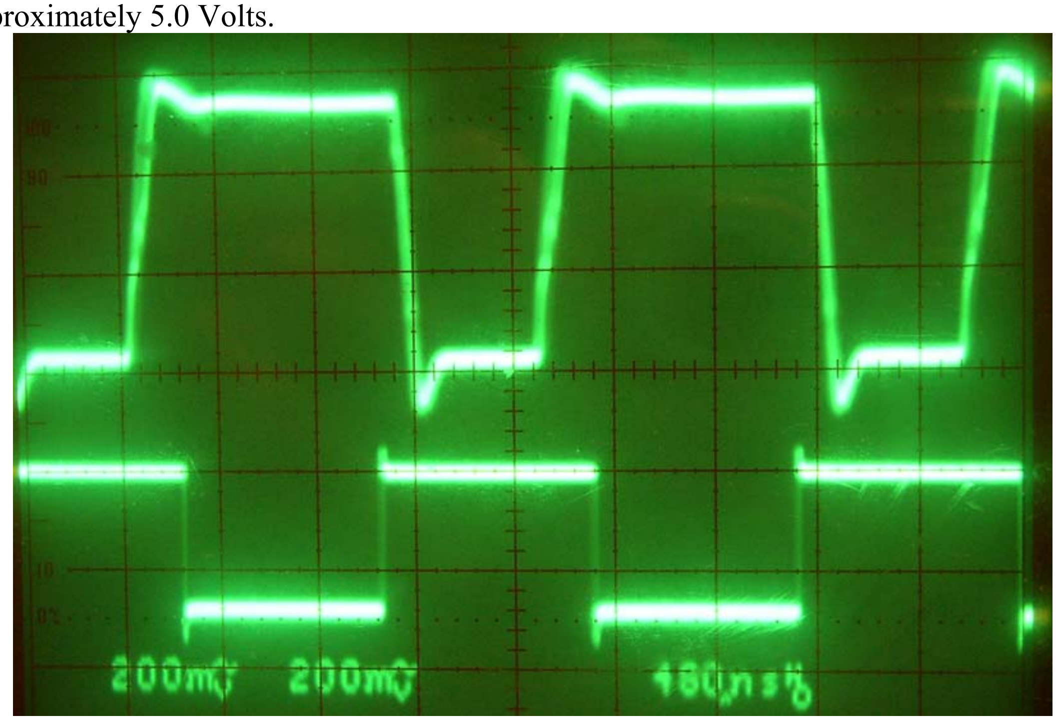

Figure 8. The signal after the filter. The detected peak to peak voltage which indicates phase change is still approximately 5.0 Volts.

The indication here is that the overtone filter has almost no stored reference energy and there is little or no phase loss.

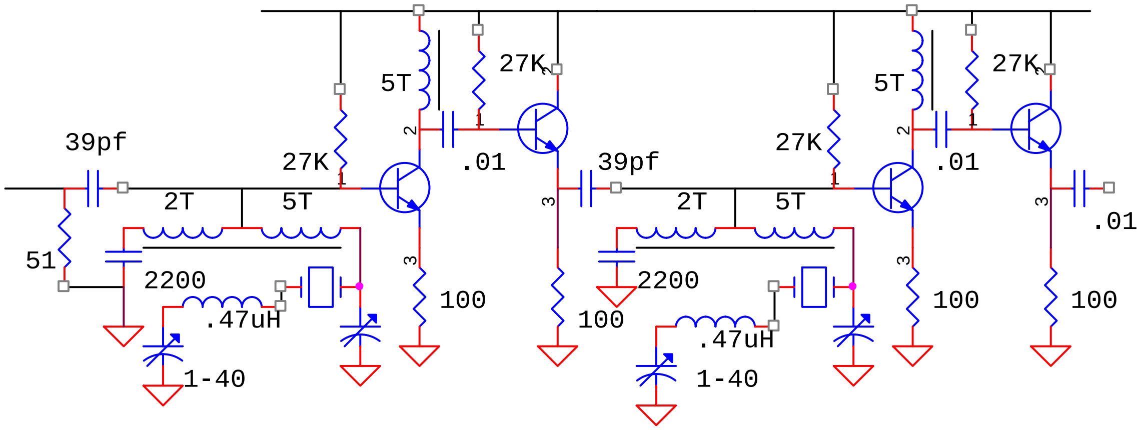

Figure 9. Third overtone circit using bipolar transistors. The circuit has a gain of 0-6 dB with a maximum output level of approximately +10 dBm to a 50 Ohm load with an 8V supply. Tuned for least phase loss the value will be lower.

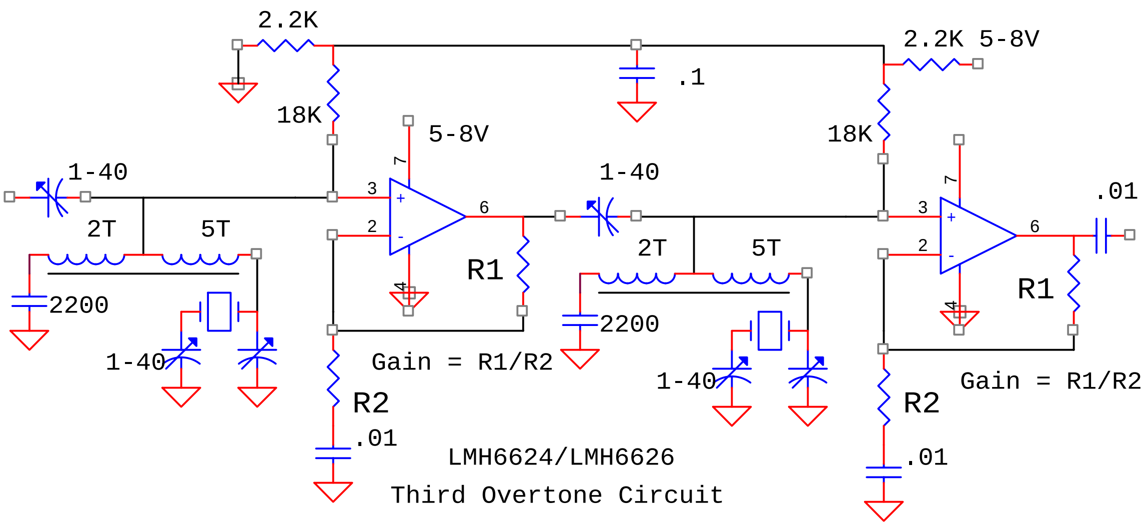

Figure 10. Third overtone circuit using Op Amps. R1 = 680, R2=100. Gain approximately 0 dB.

These tests were made using 3PSK with 120 degree phase shift. The period is approximately 38% on phase one and 62% on phase two. The phase detector has an Op Amp following detection to raise the level to the 5V observed. The detector has a linear voltage output level with phase

These filters would be very effective with NRZ-MSB as well. They are less suitable for use with 3PRK, but certainly could be used with that method.

The least spectral spread for unwanted sidebands would be with NRZ-MSB modulation.

In view of the fact that there is little phase loss, it is probably not desirable to use the harmonic phase multiplication after the limiter scheme (Armstrong method to increase phase shift) prior to detection. The D flip flop detector should function very well with a direct NRZ output using NRZ-MSB as a signal input.

Impedance Matching, Gain, Growback and IP3

The input impedance of the 3rd overtone filters is realtively low, therefor there can be a level loss per stage unless some stage gain is included. Figures 2 and 9 are examples. Figure 2 has a gain of approximately 1.3. The loss at the TRS input is made up in the first bipolar amplifier stage where the gain is approximately ωL/ 100. An emitter follower for impedance matching is used to couple the amplifier high impedance output to the low impedance output load.

Amplifiers, including the emitter followers, are subject to level overload. This overload causes distortion in the linearity, which in turn causes 'cross' and 'intermodulation'. Third order non-linearity causes cross modulation, which causes a 'growback' of the sidebands. As the level is increased, increasing the distortion, the sidebands rise in level above optimum to a point where there may be no sideband rejection at all. As the level rises, the phase loss of the filter increases until at one critical point the signal phase loss is total. Above that point the phase can be seen to reverse. This distortion is related to the IP3 of the amplifier stage.

The near zero phase loss of the overtone filter with maximum sideband reduction is only achieved when there is very minimal distortion in the coupling stages.

In designing amplifiers to couple the TRS crystal components, it is desired to have an amplifier that can accept a very large voltage level change without distortion. The bias on the bipolar transistors should be raised to an optimum value so that there is a minimum or no growback.

Another solution is to keep the levels through the amplifiers low so that this distortion does not occur.

The transformer and load inductances are loose wound on a FairRite .25" bead. The load inductor has 5 turns. Other ferrites may be used but the turns ratio etc. will have to be determined experimentally.

Overtone crystals have much less frequency varying capability (rubbering) than fundamental crystals. It can be difficult to tune exactly to the nominal frequency of the crystal. Adding a small inductor (.27 - .56 uH) in series with the crystal can increase the frequency variable range. Crystals used were Citizen CSA309 cyclindrical.

[1]R.R. Zeigler and David Babcock, Cardinal Components, Electronic Products Magazine, May 1999.