COMPARING "RMS" AND "ENVELOPE" AM DEMODULATORS

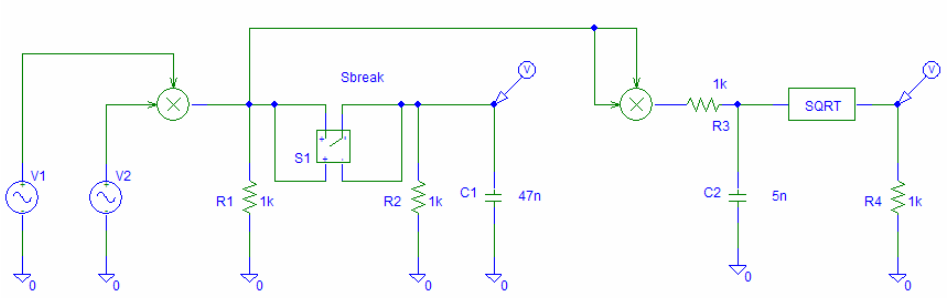
IN3IEX – Giorgio Fontana - University of Trento - Italy October 2011

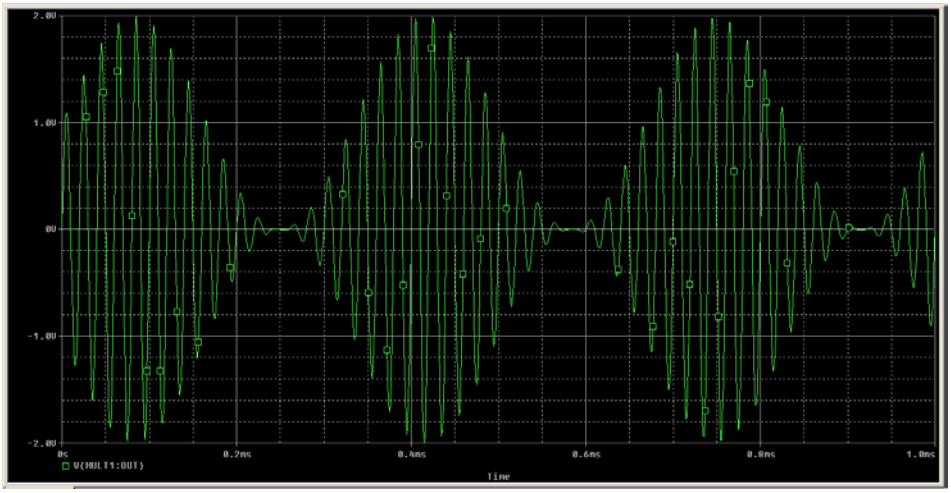
The recent availability of low cost True RMS demodulators for AM signals (for instance the AD8361) has prompted the quest for more information about the performances of RMS AM demodulators compared to ENVELOPE AM demodulators. Both are non-linear circuits, therefore the answer may come from SPICE simulations. We recall that other AM demodulation options, like product or synchronous demodulators, are spectrum shifting demodulators and if some spectral non-overlapping conditions are satisfied, they can easily offer negligible distortion, both linear and non linear. They are more complex and expensive and are not discussed here.

To gain a basic understanding we now use PSPICE to compare IDEAL RMS and IDEAL ENVELOPE demodulators. Specifically the envelope demodulator adopts an ideal diode (a controlled ideal switch), one with zero voltage "knee" and ideal rectangular I/V characteristics. Because of the voltage "knee" of real diodes, real envelope demodulators are worse, and elementary ones are quite worse than the ideal envelope demodulator of this simulation. Real modern RMS demodulators have performances in good agreement with this simulation.

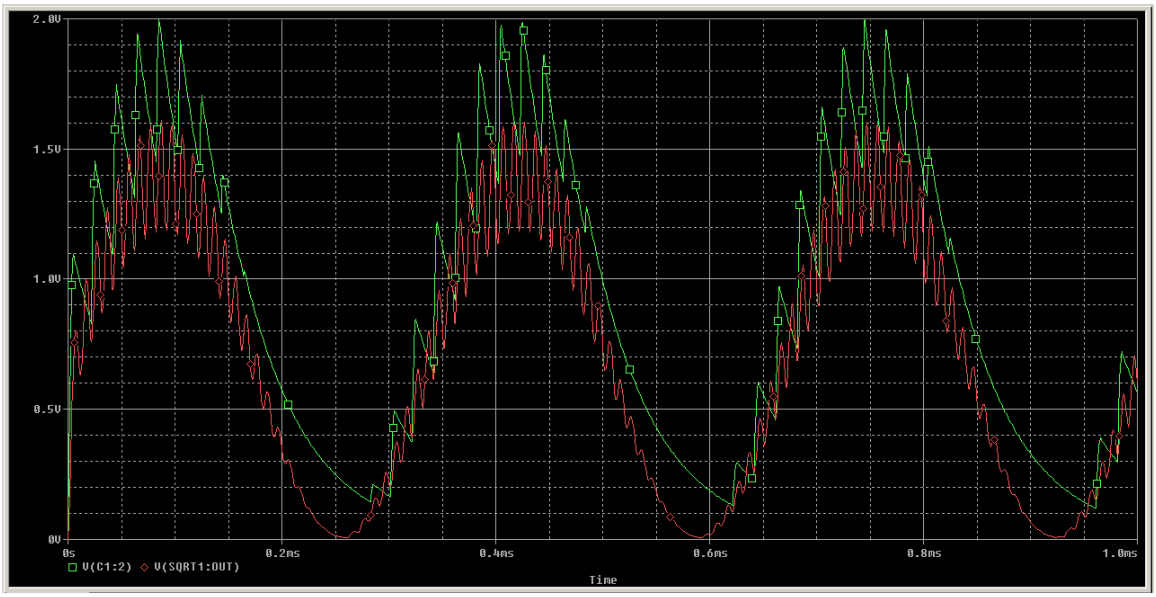
The following simulations adopts 50 kHz carrier, 3 kHz sine 100% modulation and RC filters intended to produce almost the same carrier ripple on both demodulators.

The schematic and the output of the left multiplier are the following:

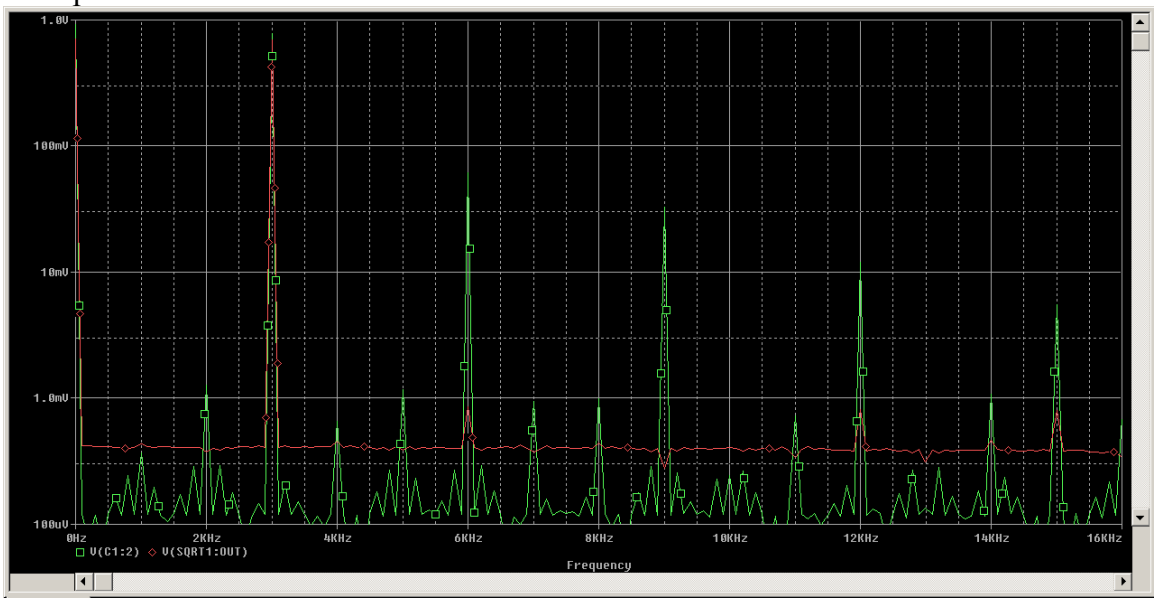




The outputs of the two ideal demodulators are:



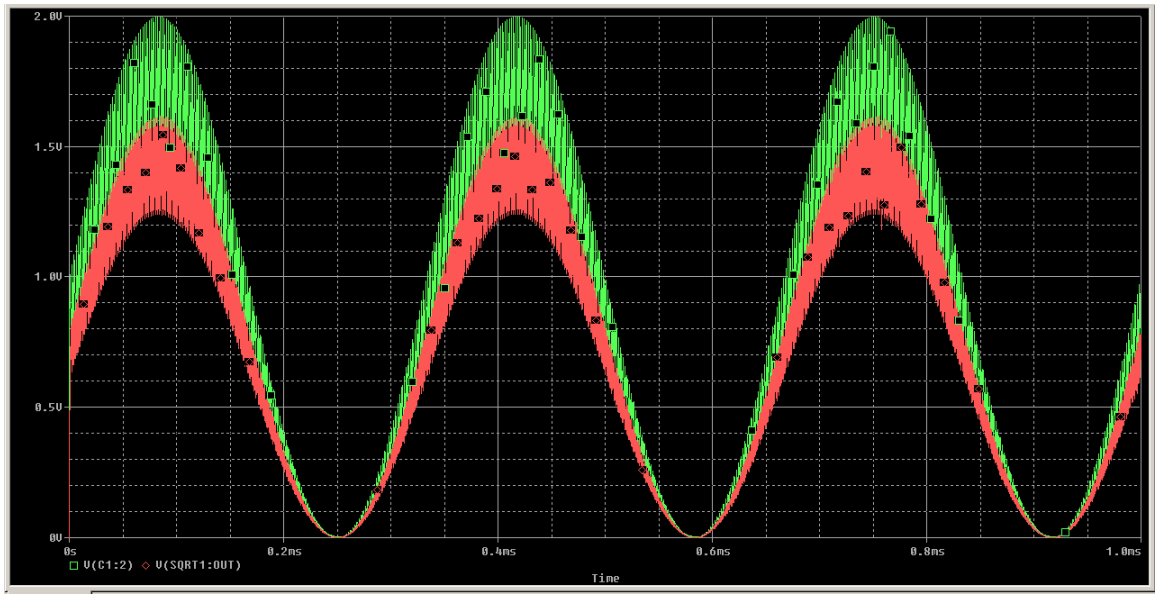
The spectrum is:

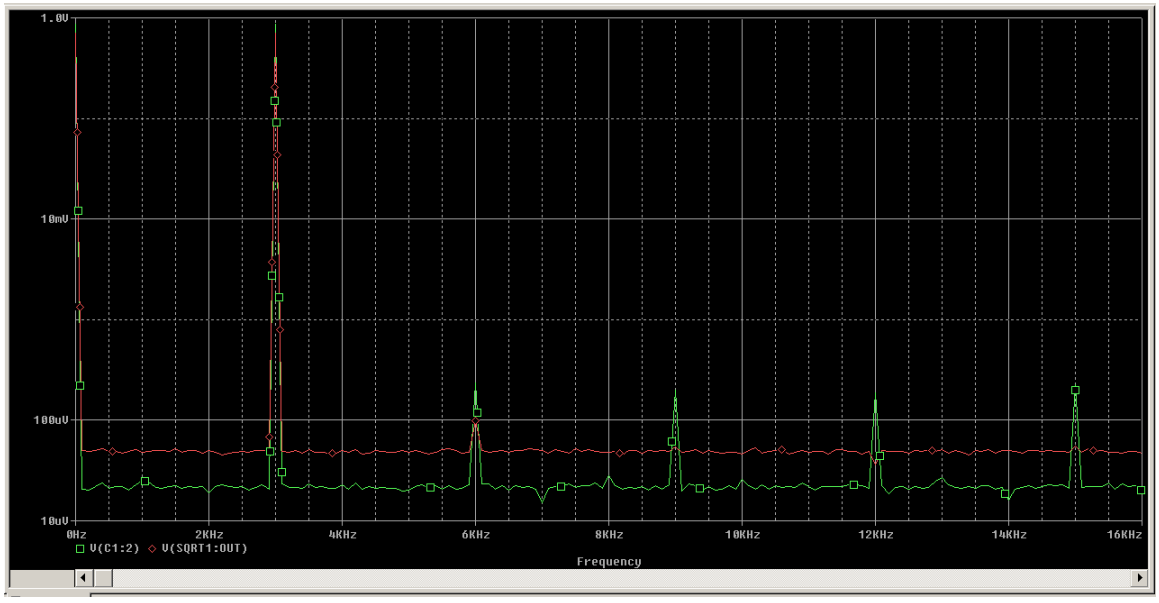


The RMS demodulator is superior to the envelope demodulator. In fact the second harmonic at 6 kHz is less than 20 dB down in the envelope demodulator (green), it is almost negligible in the RMS demodulator (red).

Obviously the difference in performances should be reduced at higher carrier frequency.

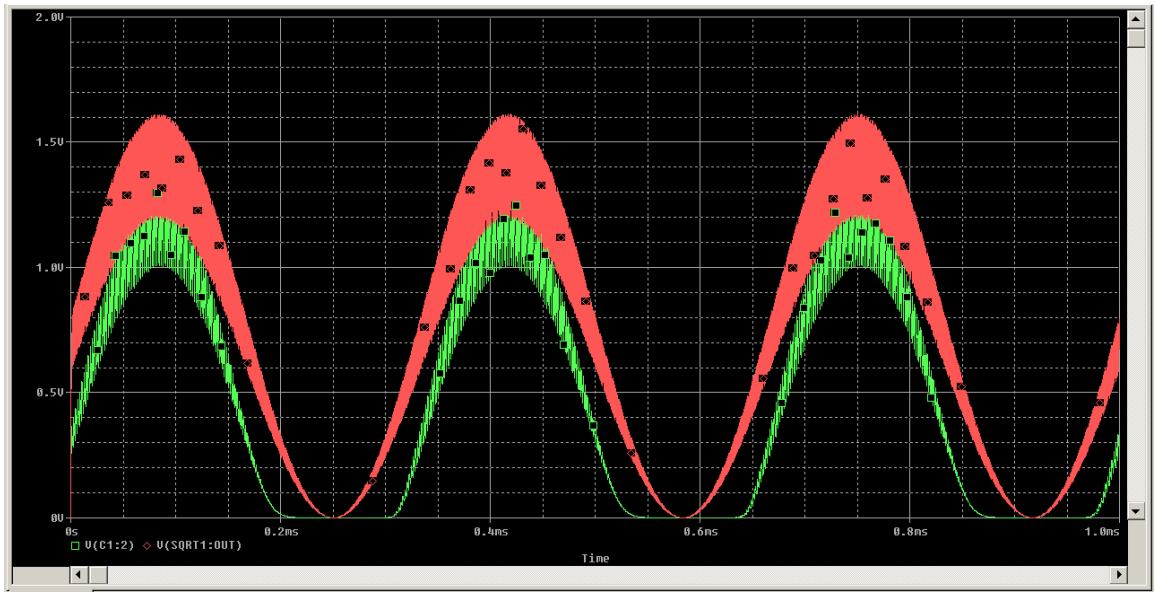
To verify the hypothesis we now increase the carrier frequency by a factor of ten and reduce the capacitances by a factor of ten to keep the ripple amplitude as before (and improve the “fidelity” of the envelope demodulator):

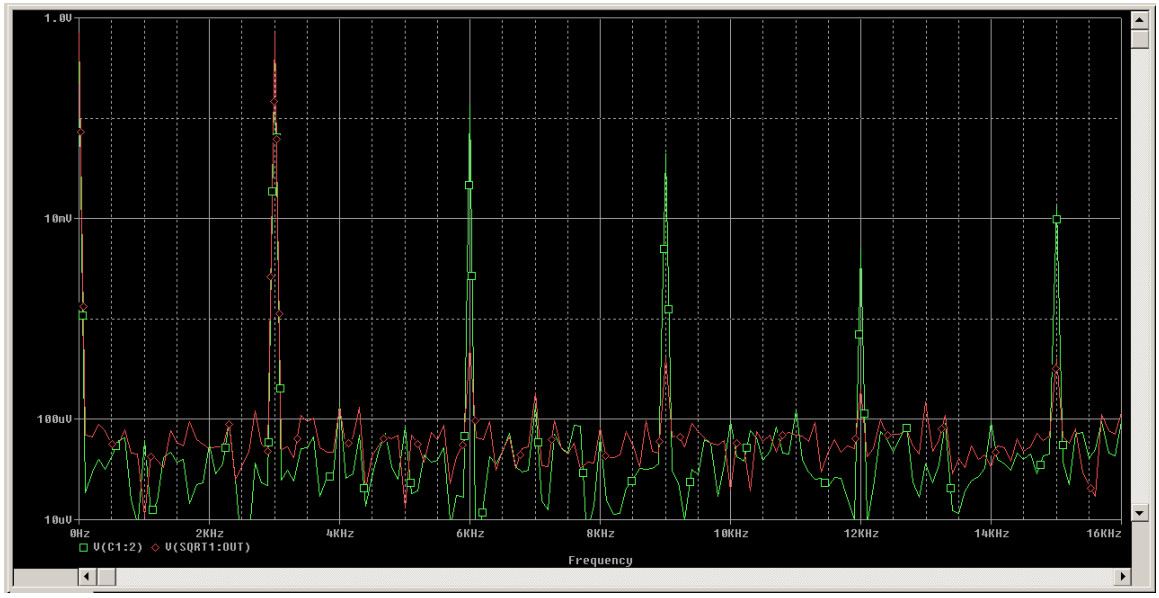




We still have better harmonic distortion performances from the RMS demodulator, but now the difference is small.

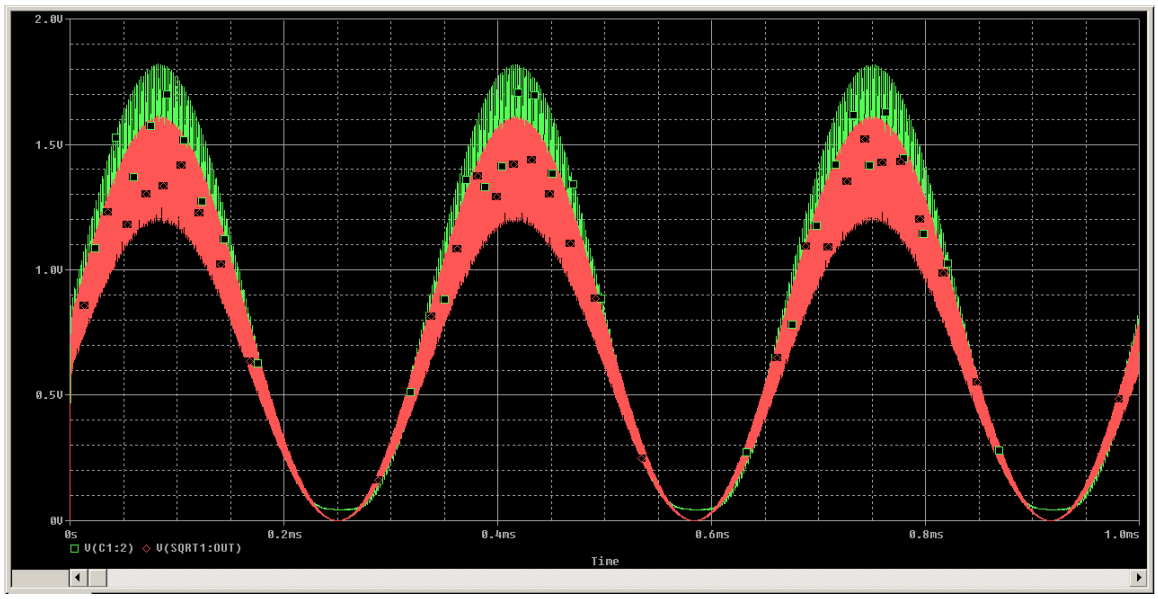
Substituting the ideal diode with the 1N4148 and keeping the carrier at 500 kHz as in the previous simulation we have:

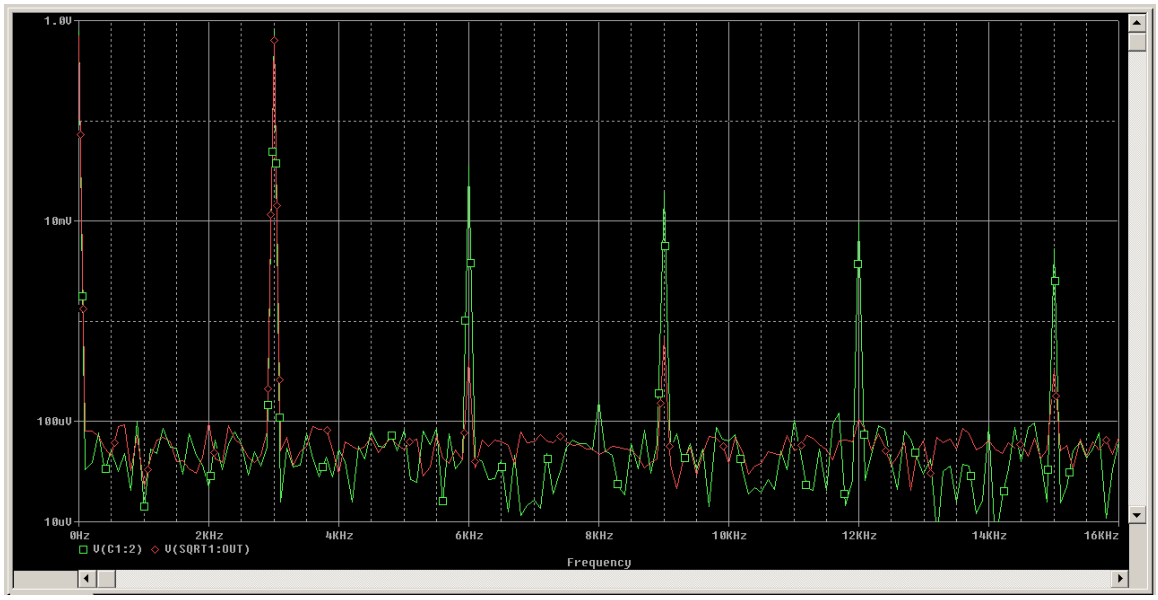




Harmonic distortion is again very high for the elementary "real" ENVELOPE demodulator (green).

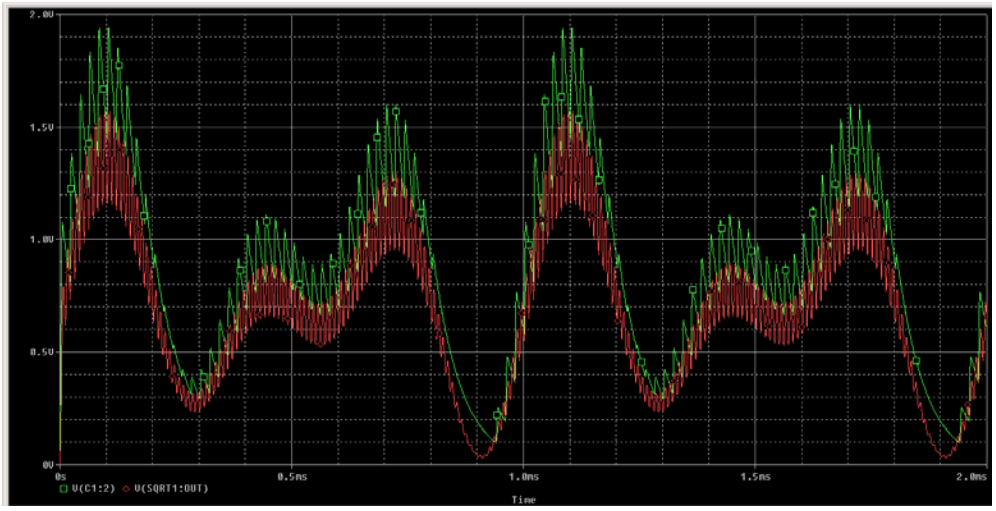
To reduce the distortion caused by the voltage "knee" of the diode, a .5V bias is applied to the diode:

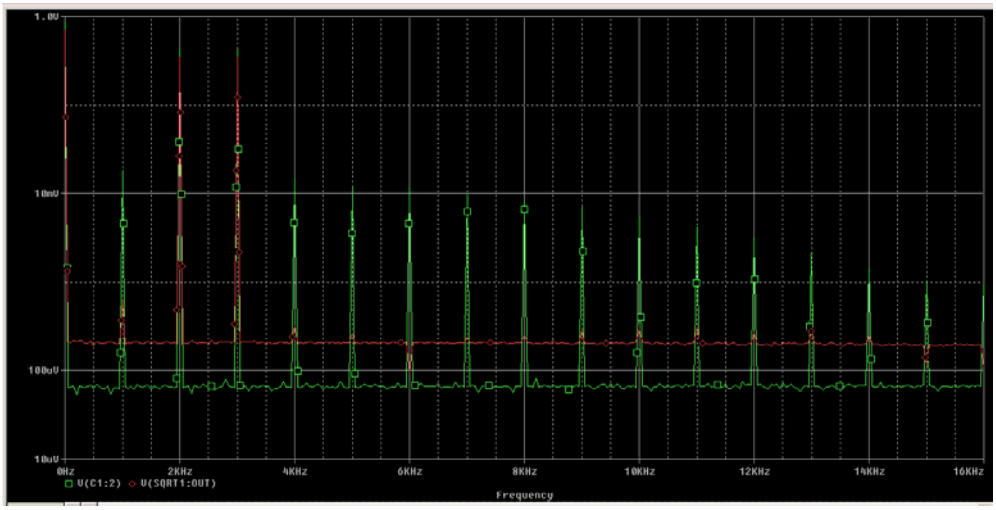




With improved performances for the real ENVELOPE demodulator (green).

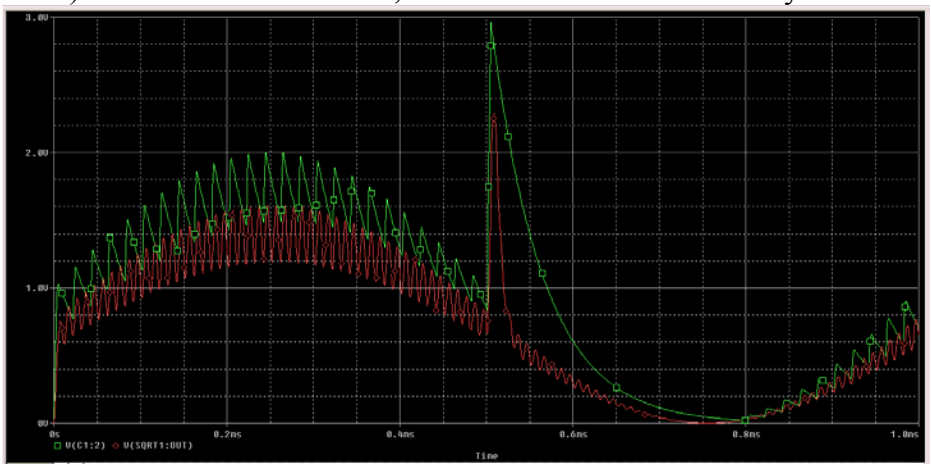
Next simulation is identical to the first one, with the difference that we modulate with a two tone signal 2kHz and 3kHz with equal amplitude and 100% modulation depth.





The RMS demodulator (red) is still a low distortion one, the ideal ENVELOPE demodulator maintains its distortion prone behavior.

Recalling again the first simulation and adding a short pulse (similar to a spark discharge noise) after the AM modulator, we observe the faster recovery of the RMS demodulator:



At the end of this short comparison it is worthwhile to describe the complex signal envelope demodulator. In fact an AM signal is described by:

$v(t) = A(t)\sin(\omega t)$; *A(t)* is the "voice" signal plus offset, *A(t)≥0*, and *sin(ωt)* is the carrier. Using a relatively narrow band phase network we can produce the quadrature signal:

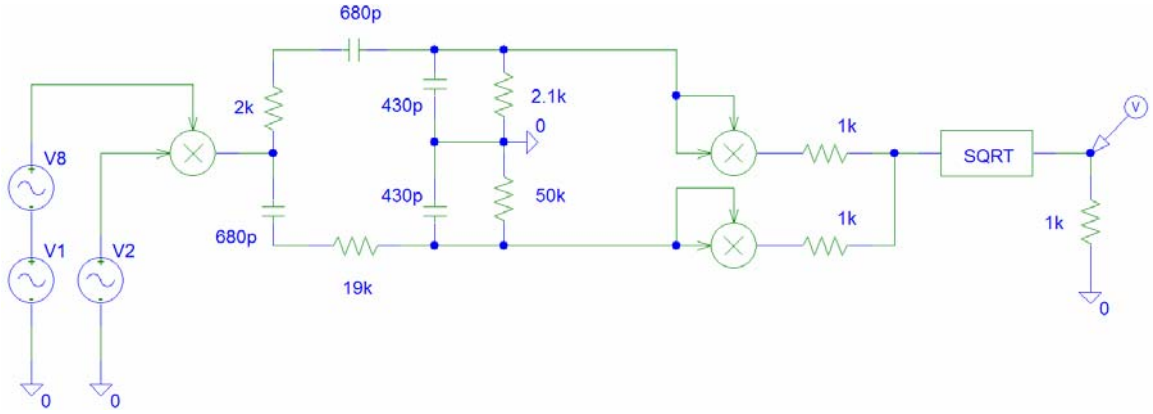
$$v(t) = A(t)\cos(\omega t)$$

We can square both signals, add them and take the square root:

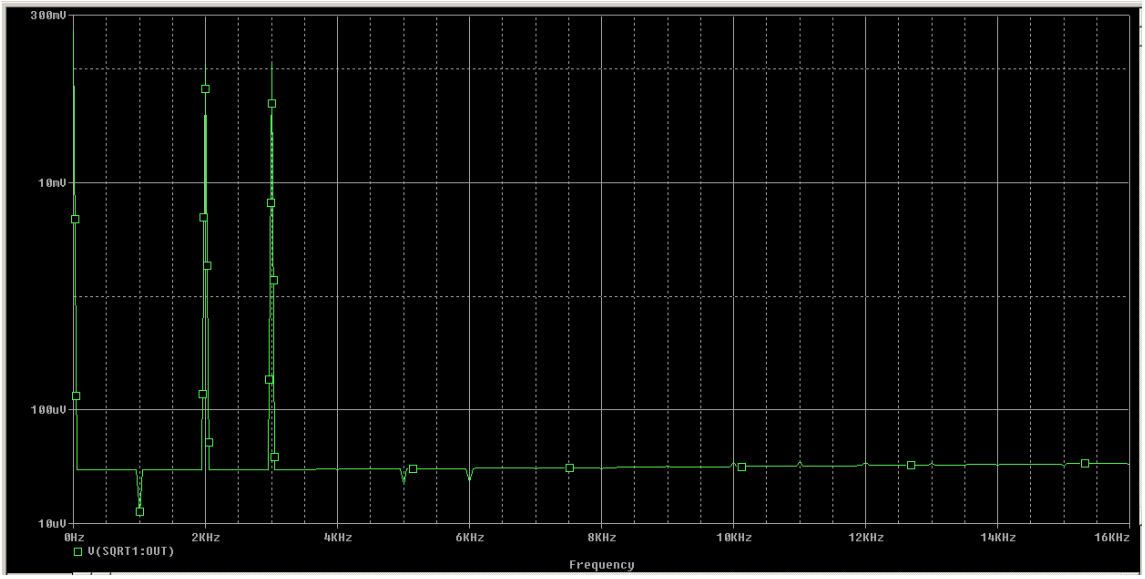
$$\sqrt{\left(A(t)\sin(\omega t)\right)^2+\left(A(t)\cos(\omega t)\right)^2} = \sqrt{\left(A(t)\right)^2}\sqrt{\left(\sin(\omega t)\right)^2+\left(\cos(\omega t)\right)^2} = |A(t)|\sqrt{1} = |A(t)| = A(t) \text{ if } A(t) \geq 0$$

because from trigonometry we know that $\left(\sin(\omega t)\right)^2+\left(\cos(\omega t)\right)^2 = 1$

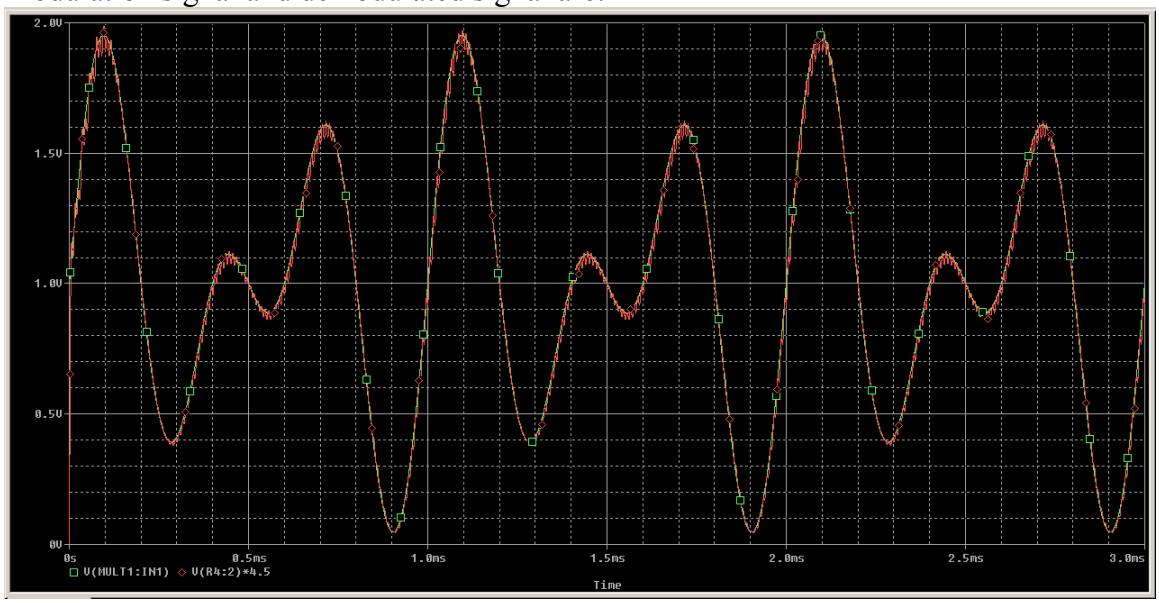
The ideal diagram, with a "real" phasing network for 50 kHz carrier and 2 kHz + 3 kHz sine modulation 100% is:



The demodulated signal spectrum is as ideal as one may expect:



Modulation signal and demodulated signal are:



The superposition is almost perfect if losses of the phasing network are compensated by a scale factor of 4.5. Some residual ripple is caused by imperfections of the phasing network, that has been optimized by successive approximations.
The complex signal envelope demodulator does NOT require any low pass filter at its output.

It is possible to conclude that RMS Detector I.Cs. can be advantageously used as AM demodulators. They offer superior performances if compared to usual diode envelope demodulators. The advantages include: lower harmonic distortion, lower intermodulation distortion and lower susceptibility to impulsive noise.
Near ideal performances can be obtained by using a phase network and a more complex schematic.