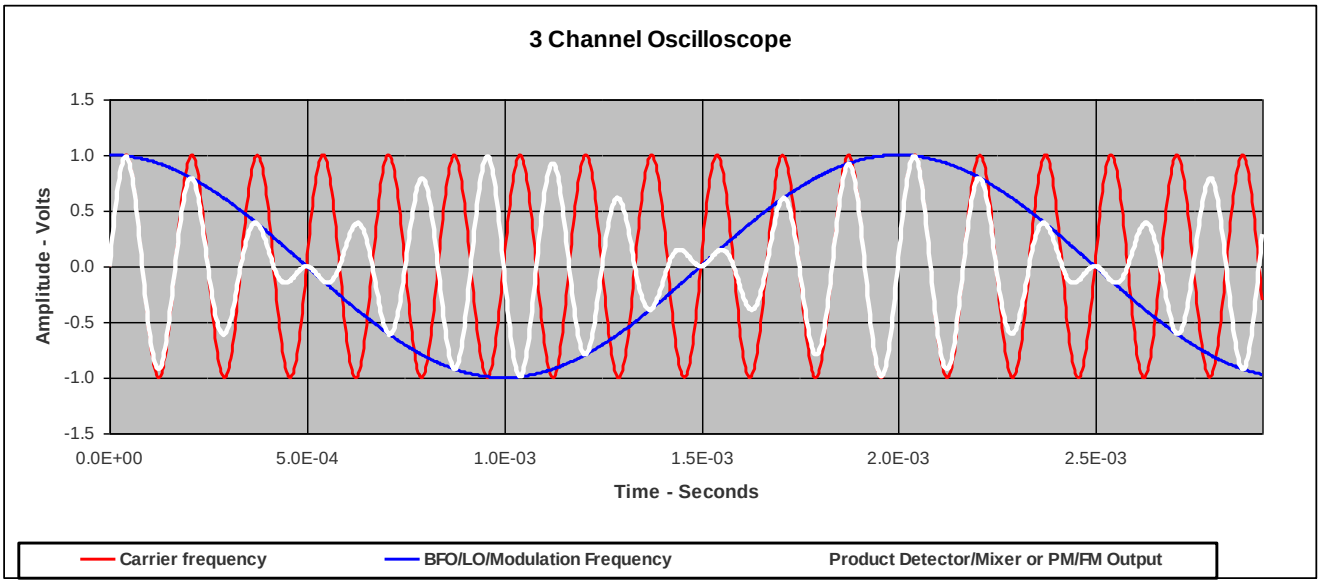
W9PE's Excel Based Virtual Labs

Carrier frequency	0 to 40 KHz in 100 Hz steps	6,000	Hz	***W9PE's Virtual Lab***
BFO/LO/Modulation Frequency	0 to 40 KHz in 100 Hz steps	500	Hz	FFT input range Sheet2!$F$2:$F$4097
Product Detector/Mixer or PM/FM Output	Product = 0, Mod. Freq. DC offset =1	0	0 or ≠0	FFT output range Sheet2!$I$2:$I$4097
Carrier amplitude, clips over 1		1	1 nominal >1 for clipping	
BFO or modulation amplitude, clips over 1		1	1 nominal >1 for clipping	
Carrier Phase/Frequency Modulation	0 = PM/FM OFF, >0 = ON	0	0 or >0 (larger increases deviation)	

Spectrum Analysis: Enter user data, **left click each, H5, Tools, Data Analysis, first time only Fourier Analysis, OK, OK, OK.**



The original virtual lab has both a three channel oscilloscope, shown above and a spectrum analyzer, shown on the next page. They display time domain and frequency domain signals from:

2 sine wave signal generators

Both operate from 1 Hz to over 40 kHz and are fully amplitude adjustable however they clip (or limit) at 2 V peak to peak (PTP) to allow adjustable distortion through square waves. One generator has an on-off DC offset of plus 1 volt. When set to the same frequency they are quadrature (90°) phase locked.

1 multiplier

Used as a product detector and/or mixer.

1 phase modulator

Provides sine wave phase modulation (PM) using one signal generator to modulate the other. With this set up PM is equal to frequency modulation (FM). A fully adjustable modulation index controls the deviation.

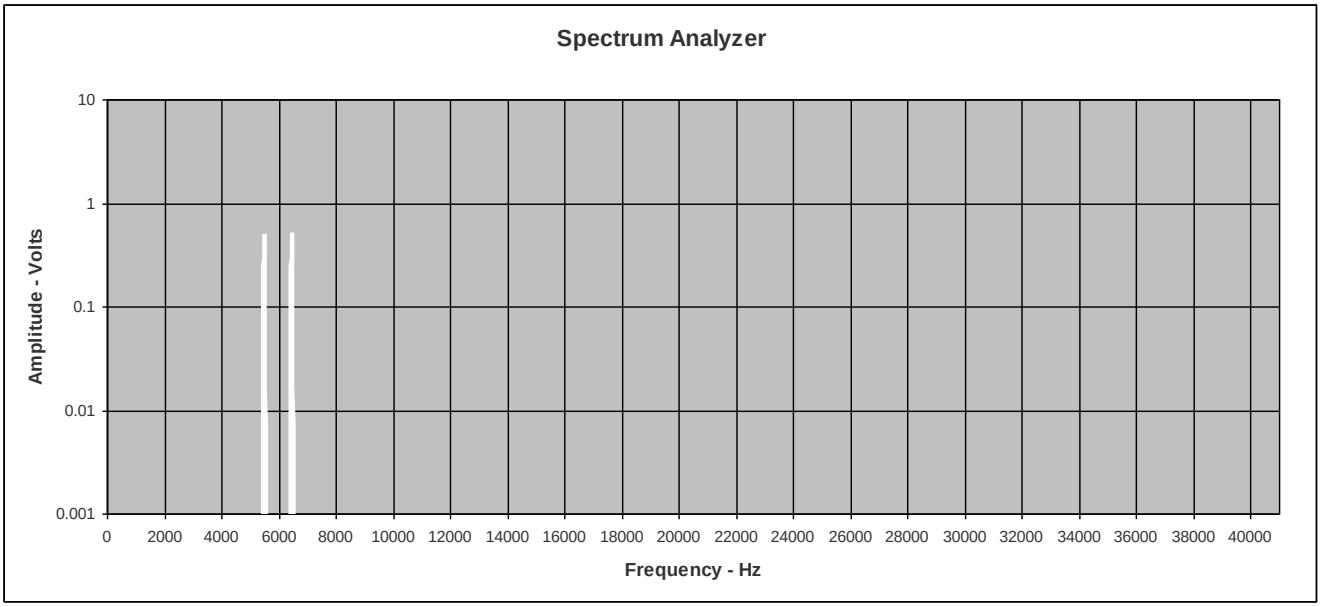
A three channel oscilloscope:

Displays the output of each signal generator and the multiplier or the phase modulator. The scope's horizontal sweep is preset to best display signals in the range of 100Hz to 40 kHz, but it can be manually adjusted. The vertical scale automatically adjusts to display the amplitude of the largest signal.

A spectrum analyzer:

With both linear and logarithmic amplitude displays of the multiplier's output or the phase modulator's output. Switching is automatic between the multiplier output and the phase modulator output. The spectrum analyzer is set to display frequencies up to 40kHz with frequency resolution bin width of 100 Hz. The frequency range can be extended higher however the frequency bins will remain at 100 Hz.

All common adjustments are made by changing the values in six Excel cells and these cells are in red at the top of the spreadsheet, (Sheet One), to clue you. The scope is also located on Sheet One, with the data hidden on Sheet Two and the spectrum analyzers linear display on Sheet Three and its logarithmic display, shown below, on Sheet Four.



If you are using Excel you already have what is needed for the virtual laboratory. The lab can demonstrates a large number of radio circuit functions, those based upon trigonometric products. If you teach or you would like to provide demonstrations but lack the laboratory equipment, this virtual lab will eliminate the hardware need and the requirement to lug and set up a lot of test equipment. It also will allow a bigger display just use your laptop or any PC with an unlimited size auxiliary video display.

The spectrum analyses uses Excel's fast Fourier transforms (FFT). Open Office and Liber Office at present do not have this capability. Excel's FFT capability is built-in, however it is not activated when Excel is installed. You must activate it, one time only. Typical activation using Windows and, Excel 2003 is as follows: Left click on Excel's "Tools" tab, and then left click on the "Add-Ins..." sub menu. Check the "Analysis ToolPac" box, and then left click "OK". Check Excel's Help if required for your version/s.

Excel's data analysis FFTs have a few idiosyncrasies.

1) The FFT is not automatically recalculated after data changes.
   I have added the simple manual recalculate sequence in blue at the top of sheet one, but once you do it a few times no cuing will be required. Macro security is not disabled.
2) It does not save the range of cells to use as input/output data when the program is saved. It does retain them while Excel is open.
   I have added the I/O ranges in blue to the clue section. They have to be copied once each time you load the virtual lab from memory. Follow the above manual sequence & click the output data button. I copy (Windows Ctrl C) the blue output data from the toolbar and paste it (Windows Ctrl V) to both input and output then change (two places) F to I at the input.
3) The display jumped from Sheet One to the data on Sheet Two when recalculating FFTs.
   I solved that problem by hiding the data sheet. Warning, the cursor must not be left on a data cell when recalculating FFTs. Place it on H5 the yellow cell before recalculating. A good habit is to place it on the H5 cell every time you change the red cell demonstration parameters, the yellow may disappear but use H5 as a parking space.

Download the program from: www.w9pe.us/sincosv1.02.xls. Copying this and the SSB (see below) program for Ham and/or educational use is approved, but my credits must remain.

Sine and waveform demonstrations (FFT recalc. Y/N)

D1	D2	D3	D4	D5	D6	FFT	Result
500	1	0	1	1	0	N	500 Hz sine, 2ms
1000	1	0	1	1	0	N	1 KHz sine, shorter λ
2000	1	0	1.1	1	0	Y	clipped sine
2000	1	0	10	1	0	Y	Square wave
Multiplier, mixer and product detector demonstrations							
25000	15000	0	1	1	0	Y	heterodyne>10&40KHz
25000	35000	0	1	1	0	Y	heterodyne>10&60KHz
Note: An image 60KHz is easier to filter out than at 40KHz							
34000	1000	1	1	1	0	Y	100% AM
34000	1000	1	1	.5	0	Y	50% AM
34000	1000	1	1	1.1	0	Y	AM audio overdrive
34000	1000	1	1.1	1.1	0	Y	AM over modulation
34000	1000	0	1	1	0	Y	DSB suppressed carrier
Note: If one sideband is filtered out it would be SSB SC							
40000	40800	0	1	1	0	Y	BFO high side = 800Hz
40000	39200	0	1	1	0	Y	BFO low side = 800 Hz
Frequency multiplier demonstration							
5000	5000	0	1	1	0	Y	frequency doubler
Phase modulation by a sine wave demonstrations							
3000	500	0	1	1	1	N	Frequency shifting
30000	500	0	1	1	1	Y	spectrum spreading
30000	500	0	1	1	2.405	Y	wider and no carrier
Note: The carrier power goes to zero at this first Bessel null.							

When modulation is by a single sine wave, PM equals FM. For a fixed amplitude modulating signal, PM deviation is proportional to the modulating frequency and FM deviation is constant with a changing modulating frequency.

A second virtual lab has been added, it provides a single sideband version of the virtual Lab. A full I/Q phasing method single sideband generator with two tone modulation has been implemented. Again almost all parameters are user adjustable, including phase error, clipping etc. The input and output data ranges required for FFT are not the same but they are in blue as in the original virtual lab. It is downloaded free from: www.w9pe.us/SSBv1.01.xls.

Richard F. Gillette P.E. W9PE 22 Oct. 2018