ECE 4670 Lab Report Grading

Lab 5: Frequency Modulation, Demodulation and Phase-Locked Loop

Points	Lab Exercise Number	Laboratory Exercise Description	Check off
	Section 1	**VCO and FM Frequency Deviation Constant**	
0	Part 1, setup	Setup FM modulation on 33600A function generator. Use channel 1 for DC input for external modulation for channel 2. Set Channel 1: to DC and you will vary amplitude from -2 to +2 VDC, using 0.25 VDC steps. (Be sure to accurately measure DC value going into the external modulation input) Set Channel 2: $F_c = 50$ MHz carrier, $f_d = 5$ MHz with external modulation.	
5	Part 1	Collect data.	
5	Part 2	Using Python code, plot and determine slope and offset of data. (As described in lab reader.	
5	Part 2	**State in report the value of f_d you determined in Hz/Volt**	
	Section 2	**FM Modulation Index - β**	
0	Part 1, Setup	Set up 33600A (channel 2) for $f_c = 50$ MHz carrier, f_d=5 MHz and Amplitude = -15 dBm. Set up Spectrum analyzer for 50 MHz center and span of about 200KHz.	
5	Part 2	Setup 33600A channel 1 for vmod input to channel 2. Set channel 1 amplitude to as near to 0 V amplitude and frequency of 10 KHz sine. Observe spectrum analyzer for first, second and third sidebands as modulation amplitude is increased. Reduce modulation amplitude to a value where the 2nd sideband is >20 dB down from first (make it >30 dB down from first sideband). Take appropriate data at this setting and calculate β. Is the β value ≤ 0.5? This is known as narrow-band FM, do you agree?	
5	Part 3	Set channel 2 (FM signal) to internal modulation with message frequency of Fm = 10 KHz. (Note you do not have the ability to adjust message amplitude, i.e. Am is fixed) Now adjust f_d to attain narrow-band results similar to what you did in steps above. Explain why adjusting f_d that you are getting the same results. By the way you should be able to calculate the fixed Am from this experiment.	
5	Part 4	Increase modulation amplitude and observe other sidebands increase and decrease in amplitude, continue to increase amplitude until the carrier "disappears," calculate β for this condition does it equal 2.4048? Note: you should be able to see 5 sidebands	
5	Part 5	Repeat part 4, for $f_m = 5$ KHz, increase f_d to duplicate what you did in part 4. Calculate β. Does this agree with the equation for β?	

5	Part 6	Return to settings in part 2, ($f_m = 10$ kHz and amplitude A_m increase/decrease via external mod, $f_d = 5$ MHz, and $f_c = 50$ MHz) to find second zero of $J_0(\beta)$, note the amplitude and calculate β, does the value agree with the equation for β?	
5	Part 7	Set the FM modulation so that sidebands are out to about 100KHz. $f_d A_m = \Delta f$ where $f_d = 75$ kHz and $f_m = 10$ kHz (internal modulation). Set analyzer to 50 kHz/div linear, centered at 50 MHz. Ensure the power in the outer sideband is no less than 20 dB down from peak power in the bandwidth ($\pm$100 KHz). Note: use this determining factor in the next part.	
5	Part 8	Decrease f_m to 10, 5, and 1 kHz, observe the spectrum at each frequency and take readings of the BW (as noted above). Calculate the relationship between BW and Δf for each f_m, does it agree with Carson's Rule?	
5	Part 9	As a cross-check export corresponding .csv files for the three f_m and Δf combinations. The Jupyter notebook sample contains a helper class for processing the .csv files into spectrum plots and calculates the 98% fractional bandwidth as obtained from the actual measurements.	
	Section 3	**FM with Other than Sinusoidal Signals**	
0	Part 1, setup	Set up 33600A (channel 2) for $f_c = 50$ MHz carrier, $f_d = 20$ kHz and Amplitude = -15 dBm, $f_m = 10$ kHz **SQUAREWAVE**.	
5	Part 2	Observe the spectrum on the analyzer as f_d is increased over the values of 20, 100, 500, and 1000 kHz. Center the spectrum analyzer on 50 MHz and set the span as needed to a clear view of what I call the *suspension bridge spectrum*. Compare your measured results to a Python simulation.	
5	Part 3	Does Carson's rule seem to hold for this signal if you define BW as the -15 dB spectrum width below the peaks?	
5	Part 4	Calculate the BW by exporting the four .csv spectrum captures to the Jupyter notebook and making use of the FieldFox_capture class as you did for the sinusoidal FM case.	
	Section 4	**FM modulation with RF doubler**	
0	Part 1	Setup 33600A channel 2 $f_c = 35$ MHz, $f_d = 100$ KHz, choose a convenient frequency for $f_m =$ TBD kHz to validate the math equation. Do you attain the correct frequencies in the spectrum, show using the equation?	
5	Part 2	Observe the doubler input spectrum at 35 MHz and note the spacing of the spectral lines is indeed $\pm n f_m, n = 1,2,\ldots$. What is the 98% containment bandwidth of the signal?	
5	Part 3	Observe the doubler output spectrum at 70 MHz and note that the spacing of the spectral lines is still $\pm n f_m, n = 1,2,\ldots$. Is this correct? What has changed? Explain. What is the 98% containment bandwidth of the signal? Do you attain the correct frequencies in the spectrum, show using the equation?	
	Section 5	**FM Demodulation**	
		Slope Detection	
0	Setup Part 1	Setup Function generator 33600A as shown in Figure 10. Setup Channel 1 for FM modulation, Fc = 1 MHz, Fd = 50 KHz, Fm = 500 Hz, amplitude -10 dBm.	

		Connect output of FM signal to power splitter, one-side of splitter output to SA and the other to scope. Connect the sync output of function generator to a channel and use this for triggering scope.	
5	Data capture Part 2	Capture data from scope and SA. What do you see in the time-domain scope signal? Define what you see.	
10	Part 3	**Optional for bonus points** create a Python model of the lowpass filter as a 5th-order digital Chebyshev type 1 filter driven by a sinusoidal FM signal source. Observe the output and see a similar AM signal is obtained. The sampling rate will need to be around 10-100 Msps, so the computational burden will be rather high. You will only need, say two cycles of a 500 Hz message sinusoid. At $f_s = 100$ MHz this requires just $2 \times 10^8/500 = 400{,}000$ samples.	
		First-Order Phase-locked loop	
0	Setup	Setup Function generator 33600A as shown in figure 16. Setup Channel 2 for FM modulation, $f_c = 50$ MHz, amplitude -10 dBm. (Note do not produce a modulated signal yet, just carrier) Setup Channel 1 as a VCO (this is the same as an FM source, and will use the filtered signal as control voltage). $f_c = 50$ MHz, $f_d = 500$ kHz, external modulation (5V) with amplitude +6 dBm. Connect output of FM (RF) source to the mixer input RF port. Connect output of VCO generator signal (channel 1) to power splitter, one-side of splitter output to SA and the other to a mixer input LO port (now known as a phase detector). Connect IF port of mixer to 1 MHz LPF on the comm. RF board. Connect output of filter to scope, **at this point do not connect the output of the filter to Modulation input of signal generator**.	
5	Part 1	Observe peak value of K_d (output of phase detector) on scope, record this value. Record here ___________ and capture scope data.	
5	Part 2	Determine K_t (total loop gain). Record here____________. Show calculation in report. (Note Kv has units of Hz/V, as a VCO)	
5	Part 3	Close the loop (i.e., connect Phase detector output to 33600A VCO input). Change frequency of the FM carrier, in small steps, approximately 10 Hz at a time. Ensure the loop is and stays locked. Now measure the lock range. Record the value here:________________Hz and in lab report. Does it agree with the measured value(s) above?	
5	Part 4	Apply FM signal (RF input) from 33600A and verify on scope it is demodulating the tone signal. Document all settings and demod results.	
5	Part 4	Verify that if the FM input to this demodulator is increased lock is lost. Document all settings and demod results.	
5	Part 5	Decrease the gain of the PLL by halving the deviation of the VCO on the 33600A. Verify the track range has halved. Document all settings and demod results.	
115	10 bonus	Total Points	