EE 340: Communications Laboratory
Autumn 2015

Lab 4: Generation of modulated RF signals using the "IQ-Modulator Board"

Legends

Question/Observation: Show it to the TA and explain (carries marks)

Recall/think about something

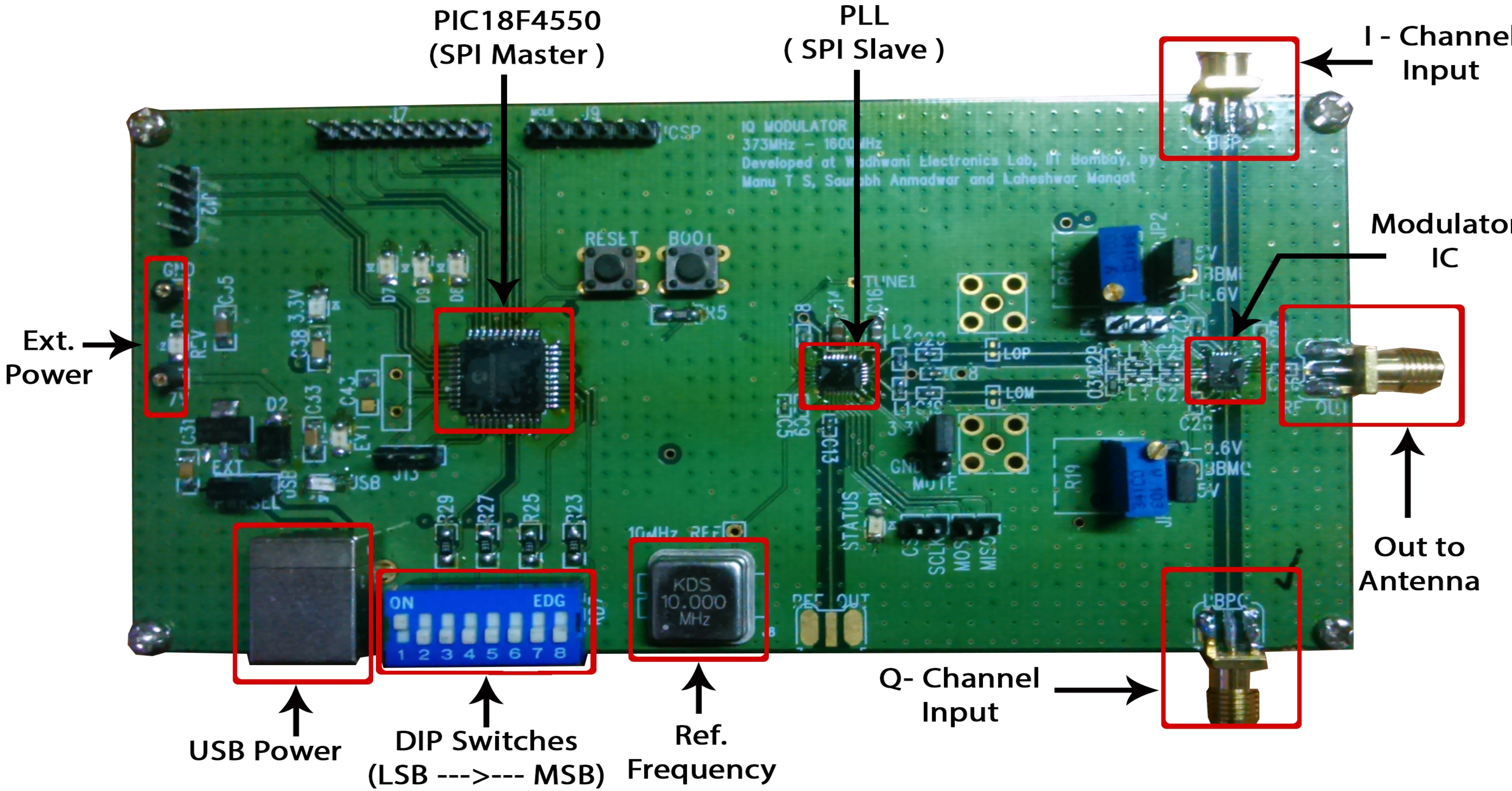
Caution

Additional information - weblink

Aim of the experiment

- The experiment will introduce you to the IQ modulator board.
- You will learn how to carry out DSB, DSB-SC, SSB and SSB-SC modulation, or any arbitrary carrier modulation in a practical system.
- You will learn about the practical issues involved in achieving
  - Good carrier suppression
  - Good side-band suppression
- You will also be trying out your hand at Python programming for generating chirped waveforms.

IQ Modulator Board



Set Output mode of AFG (Arbitary Function Generator) in "High Impedance" load in both channels as soon as AFG is tuned on, without connecting anything to it.

PreLab:

- Go through the Prelab document regarding the IQ modulator board and its practical considerations.
- Revise concepts related to DSB, DSB-SC, and SSB modulation.
- Also go through the document showing steps to load waveforms on AFG.

Part 1: Narrowband IQ Transmisson(DSB)

In this step, you will be upconverting a low frequency narrow band signal (in this case a sinusoid) to an RF frequency using the IQ modulator board.

Before connecting anything to AFG (Arbitary Function generator), switch it on and set it in "High Impedance" output mode as follows:

Press "output mode" => press "Load" => press "High Impedance".

- The input impedance of the IQ board is high — if 50-ohm impedance is used, actual voltage provided by the AFG will be a factor of two higher.

- In the AFG, set channel I in "continuous" and "Sine" mode with the following parameters:
  - DC offset (actually dc bias) of around 480mV
  - Amplitude of ac minimum possible (i.e. 20mV)
  - Frequency < Fs/2, where Fs = Dongle Sampling Frequency (say 2 MHz) to satisfy Nyquist sampling criterion.
- Provide DC bias of 480 mV on the other AFG channel using the following steps:
  - Press "More" button on the AFG.
  - Select "DC" from the waveform options.
- Connect the antenna to the IQ Modulator board RF output port and apply the waveforms from the two channels of the AFG to the I and Q inputs.

Part 1: Narrowband IQ Transmisson(DSB)-Continued

- Now you can power the board through USB. As soon as board is powered, some LEDs will blink initially and then stop blinking. After some time, the red LED near the PLL named “STATUS” should turn on, indicating that the PLL is locked.
- Switch on the AFG channels.
- Set the frequency of transmission using DIP switches which should be different for different groups (DIP Switch Value should be = 2 × <Your GroupNo.>).
- Actual RF carrier frequency for the DIP switch is

  fc=1120.002MHz + 1.25MHz × <DIP_switch_value>.
- RESET the board after setting the DIP switch values correctly, according to your group number.
- The LSB of DIP switch input is the bit closest to USB connector; Switch “On” => bit is “0”.
- Keeping the dongle sampling rate highest possible i.e 2 MHz in GNU-radio, set the dongle to frequency of fc-Δf (where fc is the center frequency and Δf is the frequency offset) and observe the received spectrum in GNUradio. Some fine tuning is also required to remove any frequency offset (use a slider for this purpose).
- Tune it such that, the received spectrum is symmetric along y axis i.e. only 3 impulses in FFT are seen i.e at {+fm, 0, -fm}, where fm is the signal frequency generated by the AFG on I channel.
- Why and where is this DC coming from?
- Show it to your TA. Observe the received spectrum and the dc value. They keep changing, why?

PART 2: Carrier Feedthrough Reduction(DSBSC)

- As discussed in prelab sheets, carrier feed-through is unwanted leakage of carrier from the input of the mixer (i.e. IQ modulator IC) to its RF output port. Thus we get DSB instead of DSB-SC transmission.
- Carrier feed-through to a large extent depends on DC bias offsets and mismatches in the differential circuitry of the mixer which can be minimized by appropriately introducing “offset” between DC-bias of I and Q input channels of the board.
- Carrier feed-though results in zero-frequency component at the receiver output, which can be seen in spectrum. Adjust the DC voltages on the I and Q channels iteratively on the AFG to suppress the carrier as much as possible.

DC should not exceed 580mV on either of inputs (higher voltage may damage the IQ modulator IC on the board).

Note these DC bias voltages and show them to your TA.

PART 3: SideBand Suppression(SSB)

- Single Sideband Modulation is a special case of modulation, which is used to supress one of the side bands where Q signal is 90° phase shifted version of I_signal i.e. Q_signal = Hilbert(I_signal).
- Perfect side band suppression occurs if amplitude of I_signal and Q_signal are exactly equal as well as they have perfect 90° phase shift between them.
- To verify this, apply the same frequency and amplitude signal (as applied on the I channel in part 1) on the Q channel also, but the phase should be shifted by 90° (use the same DC bias obtained in part 2).

Verify the effects of amplitude and phase imbalances:

- Case 1: Effect of amplitude offset
  - Keeping Phase between I and Q 90° exactly, fix the amplitude of I_signal to 20mV and slowly increase the Q_signal from 20mV to 30mV.
  - Take down values of suppression for different amplitude offsets i.e. difference in the average power levels of two tones.
- Case 2: Effect of phase offset
  - Now keep constant amplitude of 20mV for both I_signal and Q_signal, and fix phase of I_signal 0° and slowly change the phase of Q_signal from 70° to 110° in steps of 5°.
  - Take down values of supression for different quadrature phase offsets i.e. difference in the average power levels of two tones.

If you are not getting complete supression at phases of 0° for I_signal and 90° for Q_signal, press "Phase Align" option in AFG. This has to be done everytime you change frequency of message I_signal and Q_signal.

PART 4: Wide Band Spectrum (DSB)

- First, remove USB power from the board. This part is on the same lines of whatever has been done so far, only difference is we will do the same things with wideband signals.
- Wideband signal can be generated by using AFG in “arbitary” mode. In this mode AFG takes samples from the flash drive that can be generated using Python or Matlab.
- For simplicity purpose we will make use of a CHIRPED signal as described in the prelab sheets.

Chirp Wave <= Cos(ω*n*n)

- Procedure for getting samples in flash drive:
  - ➔ PYTHON: Write the code using given template. Python code outputs samples in “.csv” format.

    ⚠ The arbitrary waveforms provided to the AFG are repeated by the AFG with the period. Therefore, the samples of the waveform should start and end in the same values – otherwise there will be discontinuity in the waveform generated by the AFG, which gives undesired spectrum (sometimes a windowing function or waveshaping filter is used to ensure this).
  - ➔ ArbExpress is the software (unfortunately only for windows) for converting this “.csv” to “.tfw” - format compatible to AFG. Convert your file as follows:
  - ➔ Open csv in Arbexpress. Then click ok.
  - ➔ Save As in “.tfw” format in the flash drive.

PART 4: Wide Band Spectrum (DSB)- Continued

- Loading .tfw file in AFG:
  - Keep both channels of AFG in “Arb” mode.
  - Select Arbitrary menu on screen.
  - Then select usb as source memory (by default it is “internal” memory)
  - Browse to the desired “.tfw” file and select it.
  - Keep the time period of the loaded waveform such that all instantaneous frequencies generated in chirp should satisfy Nyquist criterion when sampled in gnuradio.
- The other channel can provide DC (as in case of the DSB modulation earlier).
- You can verify the waveform loaded into the AFG screen.
- Connect the USB power to the board and switch ON the AFG channels.

✓ Show the output to the TA and get it verified.

⚠ Do not remove pendrive unless you reset back the source memory from USB to “internal” memory and bring AFG out of “Arb” mode. Otherwise you have to restart AFG and again output mode has to be set back to “High Impedance” Load.

PART 5: Wide Band Spectrum (SSB)

- The only thing required for this is the 90° phase shifted version (i.e. Quadrature) of the above wideband signal you used in above part (which is referred to as I_signal). 3rd ordered nonlinearity leads to Desentization of receiver. So, we need to use differential model for this part of experiment.

- Quadrature form of it can be obtained from the Hilbert Transform of the I_signal. However, as you know that the wideband signal is a chirped signal, you can generate the 90° shifted version also using trigonometric functions (how?).

- So applying I_signal and Q_signal from two channels of AFG we can get SSB and connect USB power. In this case of wideband signals, suppression won't be as good as in Part 3, because the IQ imbalances change with frequency.

- Finally try to reduce carrier feed-through by changing DC biases (may not be required if you had done it already).

PART 6: Mixed Spectrum of Complex signals (Bonus problem)

- Based upon the understanding you have got so far can u generate the spectrum of the following type?
- Shapes need not be exactly as shown below should be asymmetric wrt. the y-axis.