Lab 3H: Generation of modulated RF signals using the "IQ-Modulator Board" and Jamming

Legends

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

Recall/think about something

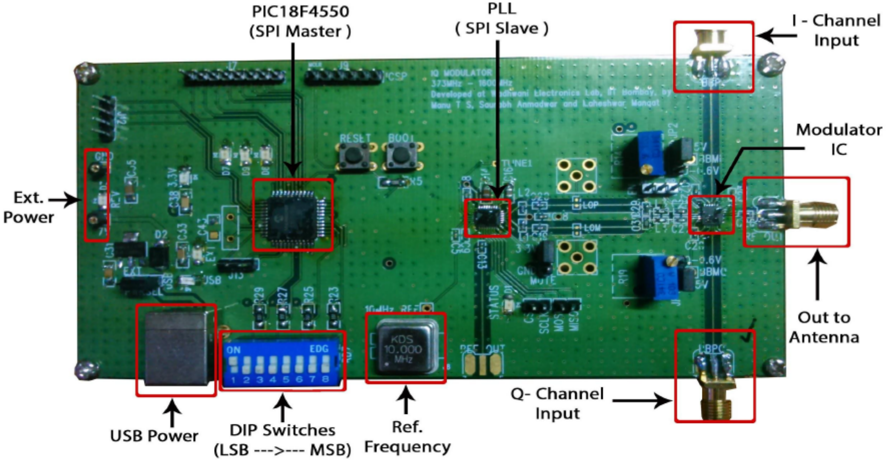
Caution

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
- Perform Jamming Experiment in Hardware using 2 IQ-Modulator Boards (Groups of 2)

IQ Modulator Board



Set Output mode of AFG (Arbitrary 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
- Revise concepts of Desensitization of Software and Prelab related to that.

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 "utility" $->$ select "output setup" $->$ select "High Z"
- In the AFG, set channel 1 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 "Arb" -> Select "Other" -> Select "Built-in" -> Select "Others" -> Select "DC"
  - Set Offset to '480mV'.
- 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 $= 2 \times <$ Your GroupNo. $>$).
- Actual RF carrier frequency for the DIP switch is
  fc=1120.002MHz + 1.25MHz $\times <$ DIP_switch_value $>$.
  (NOTE: 1120.002MHz is the f_{ref} and it varies from board to board. So change the equation accordingly if required.)
- 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”

Part 1: Narrowband IQ Transmisson(DSB)-Continued

- 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 itteratively 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).

PART 3: Side Band Suppression(SSB)

- Single Side Band Modulation is a special case of modulation, which is used to suppress 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) on the Q channel also, but the phase should be shifted by 90°.

PART 3: Side Band Suppression(SSB) - continued

- ☑ 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 suppression for different quadrature phase offsets i.e. difference in the average power levels of two tones.

- ⚠ If you are not getting complete suppression at phases of 0° for I_signal and 90° for Q_signal, press "Phase Align" option in AFG. This has to be done every time 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.

$$\text{Chirp Wave} = cos(\omega * n * n)$$

PART 4: Wide Band Spectrum (DSB)- Continued

- Loading .tfw file in AFG:
    - Keep both channels of AFG in "Arb" mode.
    - Press Arb button => Select "Others"
    - Select "File Browse" => Select "INTER" memory
    - Select "USER0" or "USER1" and select "Call out" to load the chirp signal
    - 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.
- ☑Observe the received signal in GnuRadio in time and frequency domain.

Part 5: Desensitization(h/w)

This part requires two IQ modulator boards and two AFGs and thus, two groups will work together. One group will transmit the interferer tone and the other group will transmit a DSB-FC signal (AM signal) as the message signal.

- Odd numbered group transmits the message signal and even numbered group transmits the interferer signal.
- Odd numbered group: message transmitting group

  <DIP Switch odd> = 2 x <Odd Numbered Group>
- Even numbered: interferer transmitting group

  <DIP Switch even> = 1 + 2 x <Odd Numbered Group>
- Reception has to be done by different groups by tuning the dongle to their frequencies

  f_C =1120.002MHz + 1.25MHz x <DIP Switch>

  (NOTE: 1120.002MHz is the f_{ref} and it varies from board to board. So change the equation accordingly if required.)

Make sure that the AFG output is set to HIGH IMPEDANCE mode.

...cont.: Desensitization(h/w)

- Odd numbered group can generate DSB-FC signal with 5kHz sinusoid by
  - Setting proper DC biases (around $500mV$) at both I and Q channels of AFG.
  - Add a 5kHz AC of amplitude say $20mV_{pp}$ at only one of the channels.
  - Compensating for input DC offsets so that the carrier is not suppressed.
  - This part is the same as what you have done in Lab 5.
- Even numbered group i.e. interferer group should only apply certain DC offset on I and Q input to initially keep interferer minimum. Ultimately, you have to increase the interferer power by EITHER
  - increasing interferer's power (by changing DC offset) OR
  - by reducing the distance between the interferer transmitter and receiver antenna.
- Observe message amplitude decreases as interference becomes stronger.
- Also observe that when the interferer channel number is increased to <DIP Switch even> = 2 + 2 x <Odd Numbered Group>

✓How does separation of interferer frequency away from the signal