Lab 10: Carrier Frequency and Phase Synchronisation in Communication Links

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Legends

- Question/Observation: Show it to the TA and explain (carries marks)
- Recall/think about something
- Caution
- Additional information - weblink

Aim of the experiment

1. To study carrier frequency and phase offset problem in communication links.
2. To design a Costas loop for achieving carrier frequency/phase synchronisation for QPSK signals.
3. Implementing a Viterbi-Viterbi algorithm to remove frequency offsets from 8-psk signals.
4. To get familiar with the dynamics of a phase-locked loop using the Costas loop (which is also a PLL).

Pre-lab Work

- Go through the prelab study material.
- Revise your concepts of control systems – Bode plots, stability criterion (gain margin, phase margin), pole zero compensation for stability. uploaded along with this document.
- Dynamics of a second order system: calculation of the natural frequency of oscillation of the feedback loop, damping factor and settling time.

PART1: Basic Template

- **This part will form the base for the next 3 parts of this lab, in this part you have to transmit the text file as a message and receive it correctly as done in experiment 8. You may use also constellation decoder in this lab.**
- Generate QPSK signals and transmit it as done in Lab 8.
- The following specs are used for respective blocks in transmitter :
  - sps=8 , Gain =3 ,Num_taps=11*sps
  - Symbol rate = 50k , Sample rate=sps$\times$symbol rate
  - alpha = 1
- Modulate the signal with carrier of 500kHz with a sample rate of 8×10^6 samples/sec.
- Add the Noise source to the transmitted signal with Guassian noise=0.1.
- Implement the receiver as done in lab 8.
- Implement QPSK decoder and observe the file.
- **Note**: Try using skip head after constellation decoding.

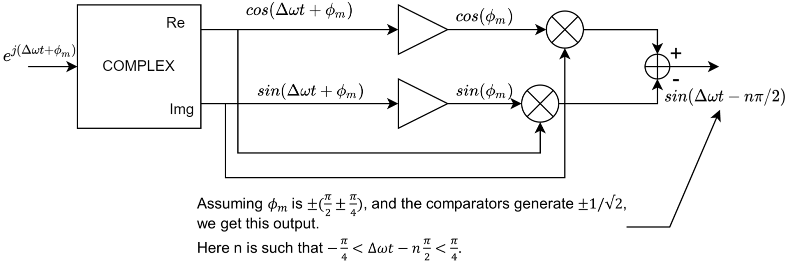
You will observe a perfect constellation and correct file output

- Save the grc file.

Part 2a: Introduction of Carrier offset at Reciever

- Use a copy of the grc file created in previous part.
- At the receiver add the frequency offset to the carrier sources.
- Use a slider to vary frequency from 0 to 10 in steps of 0.1 Hz.
- Observe the Constellation plot is rotating(Why?)
- In the text file you are periodically recieving correct output and garbage values.

Part 2b: Make a QPSK carrier phase detector



- Make the above Phase Detector. The above phase detector will have phase ambiguity of $\pm n\pi/2$
- Use Threshold Detector blocks for the above comparators (threshold levels +0.001,-0.001), followed by subtraction and multiplication to get $1\sqrt{2}$ (Why?)
- Use a low pass IIR filter to suppress noise (*FF coefficients*: 0.01; *FB coefficients*: [-1,0.99]; *Old style of taps*: True)
- A saw-tooth wave will be observed after phase detector(Why?)

PART3: Feedback signal

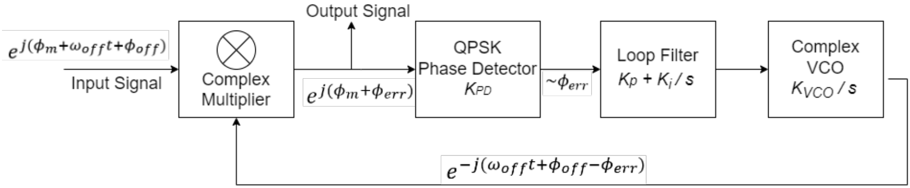
- GNU-Radio software doesn't allow blocks connected together in a feedback loop (however, a Python or C++ code canbe written to have feedback within the block).
- However, Costas loop requires a feedback. To overcome this imitation, we will give our phase detector output to a ZMQ push sink port and get it back through a ZMQ pull source port.
  The address of both the sink and source is tcp://127.0.0.1:50001 respectively. Let the rest of the options remain in their default state.

⚠ However, there can be a problem that the ZMQ source sends more number of packets leading to dropping of packets. To avoid this we introduce a delay of 100 samples after the ZMQ source block.

⚠ Make sure that the output from the ZMQ source block was not saturating, by multiplying with an appropriate constant.

PART4: Complete the Costas Loop

- Now give the resulting signal to the Loop filter (discussed in the prelab material) implemented using an IIR filter with the following parameters: FF taps: [1.0001,-1]; FB taps: [-1,1]; Old Style of taps: True
- Give this output to a Complex VCO with sensitivity of about -5 (why negative sign?).Multiply the VCO output to the signal with carrier offset that was generated in Part 1.
- ✓ Now observe the constellation of the output(make sure to increase carrier offset in steps of 0.1 Hz or less). It should stop rotating and settle to the desired constellation diagram.
- ✓ You Should receive a transmitted message correctly.
- Start increasing step size of frequency offset and observe it won't be able to stablize.



PART 5 (a): 8-PSK signal with frequency offset

- **Here also the template created in part 1 will be used but instead of a QPSK, generate an 8-PSK signal, make sure you are able to transmit a text file as a message and receive it.**
- Keep the similar parameters of pulse shaping and match filtering as in the Qpsk (part 1).
- Introduce a frequency offset at receiver demodulation of 100 Hz as done in Part 3, observe the Constellation plot of the received signal.

Part 5 (b): Viterbi-Viterbi Phase detector

- Implement the Viterbi-Viterbi algorithm before the 8-psk decoding.
- First the signal needs to be raised to its 8th power.
- As we have to estimate the frequency offset we have to use differential decoding of the argument(arg(s[n]s*[n-1]) as done in the FM demodulation).
- Multiply the signal with a suitable constant to obtain the correct frequency offset value.
- The argument is to be given to a VCO(complex) block to generate the appropriate error signal.
- The sample rate and sensitivity will be equal to Symbol rate.

✓ Observe the frequency generated by VCO.Is it equal to the offset given ?

✓ Multiply the output of the VCO with the original signal on which you have applied viterbi-viterbi to get the output and show it to your TA. Are you getting back your original 8-PSK constellation? If not, why??

PART 6: Correcting the phase offset

- Now we need to correct for the phase offset obtained in Part 5 (b). Just by replacing the phase detector used in QPSK, we can use the same costas loop setup to achieve this.
- Implement the phase detector for the 8-PSK signals using the Viterbi-Viterbi algorithm and give the output of Part 5(b) as the input to the phase detector.
- Complete the costas loop as done in part 3 and part 4.

✓ Observe the output and show it to your TA. Are you getting back your original constellation and correct output message?