

Lab 8: Carrier Frequency and Phase Synchronisation in Communication Links

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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).

- 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.

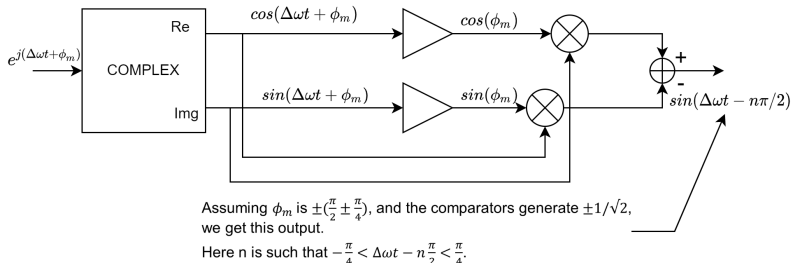
PART1: Basic Template

- **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 :
 - $\text{sps}=8$, $\text{Gain}=3$, $\text{Num_taps}=11*\text{sps}$
 - Symbol rate = 50k , Sample rate= $\text{sps} \times \text{symbol rate}$
 - $\alpha = 1$
 - 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 Receiver

- 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 receiving 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 can be written to have feedback within the block).
- However, Costas loop requires a feedback. To overcome this limitation, 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.

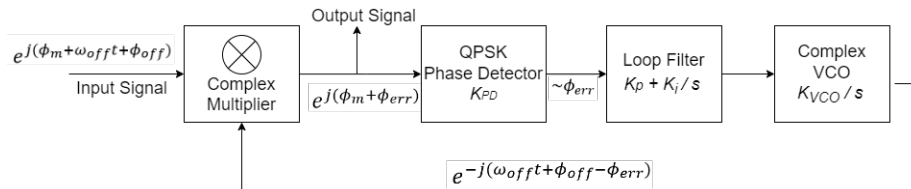


Now observe the constellation of the output (make sure to increase carrier offset in steps of 0.1 Hz or less). It should stop rotating and settle to the desired constellation diagram.



You Should receive a transmitted message correctly.

- Start increasing step size of frequency offset and observe it won't be able to stabilize.



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?