Tampere University of Technology

83950 Telecommunications Laboratory Course

IQ-modulation

You will find the information concerning this lab on the following web site: www.cs.tut.fi/kurssit/83950/

Email: ari.asp@cs.tut.fi

1. Pre-lab assignments

1.1 Explain the following terms in brief and/or using figures:

- BPSK, QPSK, 8-PSK
- Eye diagram
- Constellation

1.2 Present the general expression describing IQ-modulation.

1.3 Present a basic figure for IQ modulator and demodulator. (In-phase/Quadrature modulator/demodulator).

1.4 Present two different methods to generate in-phase and quadrature signals at circuit level. What are the pros and cons of the methods you suggested?

1.5 How does the output of IQ-modulator look like (both in time and frequency domain), if we have the following signals as inputs:

a. I(t)=sin(xt), Q=0 ?
b. I(t)=0, Q(t)=sin(xt) ?
c. I(t)=sin(xt), Q(t)=sin(xt-90°) ?

You can use Matlab for help.

1.6 Explain the following terms (related to IQ-de/modulator), in words or using figures:

- conversion loss
- amplitude unbalance
- phase unbalance
- carrier rejection
- sideband rejection

2. The laboratory work:

We need the following equipment in our measurements:

Several signal generators

Spectral analyzer

IQ-modulator MIQA-70M

IQ-demodulator ZFMIQ-70D

Amplifier ZFL-1000

Splitter ZFRSC-42

2 mixers ZP-5 or HP 10514A

2 lowpass filters BLP-90

2 lowpass filters BLP-1.9

Bandpass filters: BLP-750 + BHP-800 or BLP-750 + BHP-700

2 50ohm loads

Power source

“The brown box” (2*amplifier/adapter circuits & 2*audio amplifiers)

The headphones, MiniDisc-instrument, RCA-cable

+ Some coaxial cable

1. Modulation

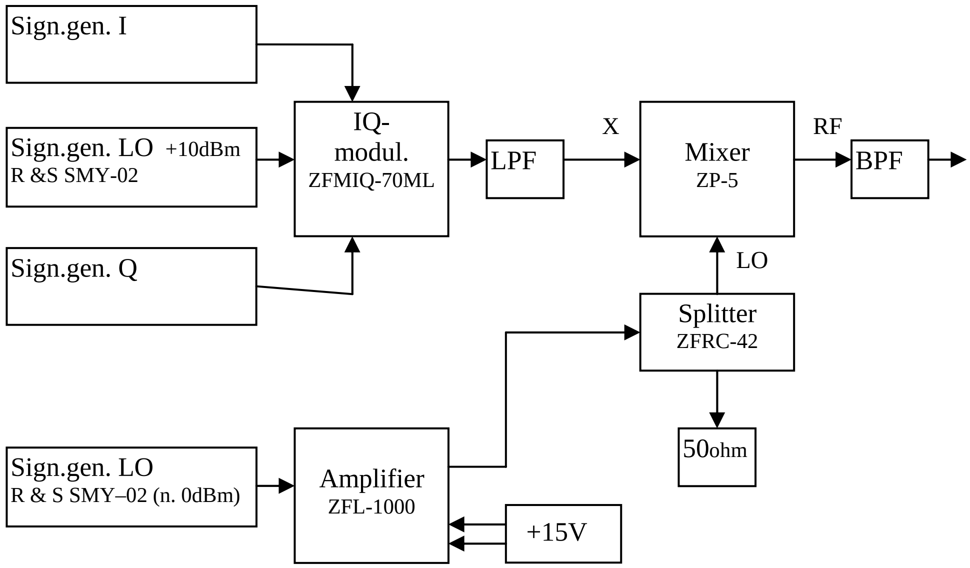
1. Find the optimal LO frequency for the modulator and measure carrier rejection of the modulator at that LO-frequency.

Use Rohde&Schwarz SMY-02 as the source for LO-signal (66…73MHz, +10dBm) and two HP 33120A for the source signal of I/Q-ports (the max. amplitude is –5dBm). Set the frequencies of both generators at e.g. 5MHz and measure the spectrum of the output of the modulator.

Measure the LO-to-IQ- and LO-to-RF-isolation for the modulator at the same LO-frequency. LO-signal level is still +10dBm. Use 50-ohm terminators to match the ports of the modulator, which has been left open.

3. Feed different signals (in frequency) to I/Q-ports (100kHz…5MHz). Find the best levels at I/Q-ports for the signals (max. –5dBm). Draw/print a picture of the spectrum of the modulator at the RF-port, after feeding the above-mentioned input signals. What are the amplitudes of the harmonics?

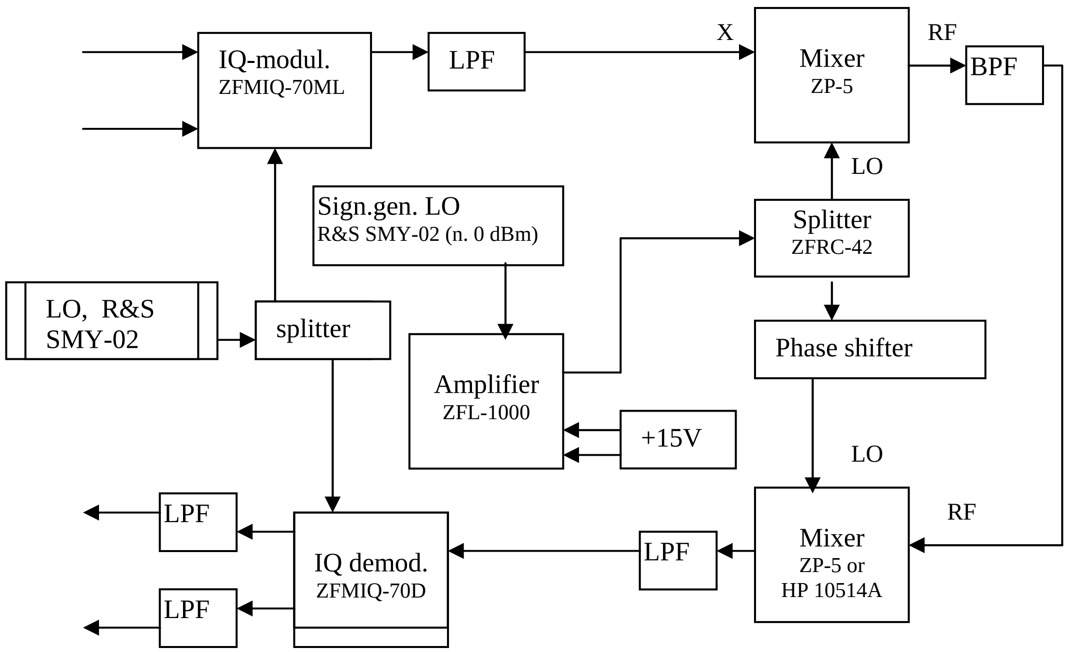
2. Up-converting



Next we mix the IF signal to the real RF-frequency.
Connect the output of the modulator to a suitable lowpass filter and the output of the mixer to a bandpass filter.

The LO signals to the mixers is taken from R&S signal generator, using an amplifier and a splitter (look at the figure above). Check the level the of signal coming out of the splitter (max. +7dBm!) before you connect that to the mixer. Convert the frequency of the signal coming out of the modulator up to the optimum frequency (Optimum frequency is the frequency that, in your opinion, produces the best result). Choose the frequency so that the attenuation of the carrier and the sideband are as good as possible. Take the frequency response of the filters and the amplitudes of the harmonics into consideration. Draw/print a figure from the spectrum of the signal up-converted.

3. Down-converting and demodulation



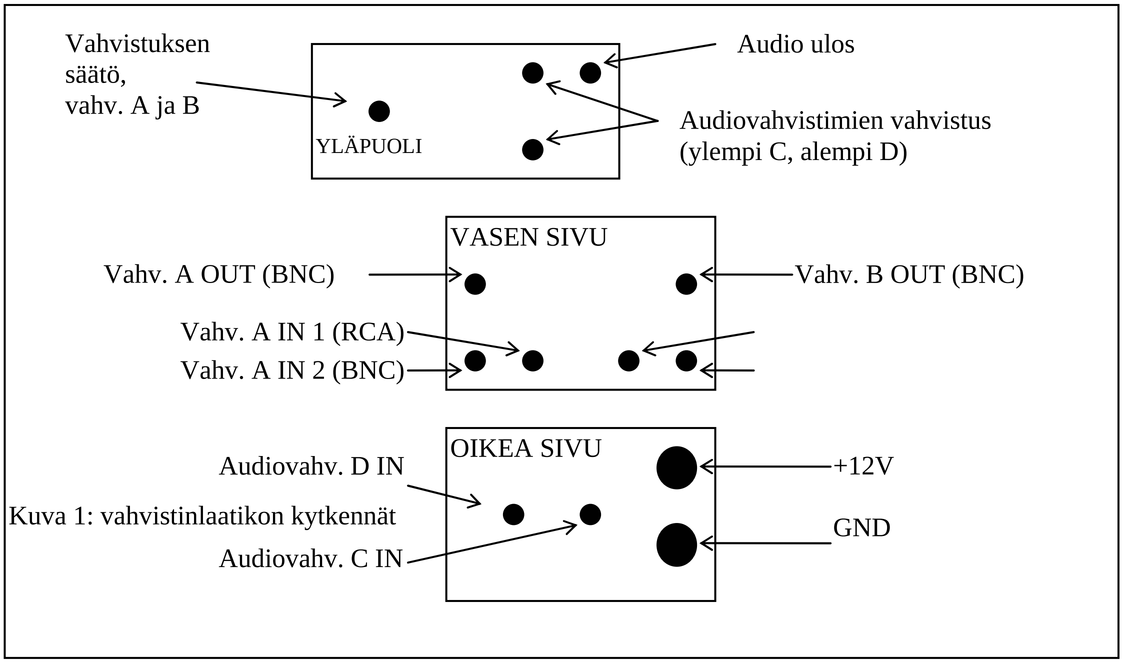
Now we connect the output of the BP filter to another mixer and afterwards to an LP filter. Connect the down-converted signal to the RF port of the demodulator. Note that the LO-signal to the demodulator is taken from the same generator as that of the modulator, using a splitter.

Now the circuit should look like the figure above.

Check the outputs of the modulator, are they what they should be?
If not, think why and adjust the equipment until you get the right signals at the outputs of the demodulator. You can change the phase-difference of the LO signals of the modulator and the demodulator using a phase shifter.

What are the differences in levels between the outputs of the channels (so for example at I-port= I-sign. dB - Q-sign. dB)?

4. Observation of successful tuning



Kuva 1: vahvistinlaatikon kytkennät

Now we check the functionality of the tuned transmission system by transmitting an audio signal.

NOTE: Set the amplification of the audio amplifier to its minimum before you connect the headphone to the audio amplifier. Don’t make any changes to the circuit when the headphone is connected!

Connect +12V..15V to the amplifier box. Set all the amplifiers in the box to their minimum level (the amplifiers are not hi-fi…) and the amplification of the MiniDisc-instrument to position '2'. You can adjust the amplifications of the audio-amplifiers (C,D) by using the red and the blue buttons, by using the white button you can adjust the amplifications of amplifiers A and B.

Connect the output of the MiniDisc (the headphone interface) to the amplifiers A and B (RCA), the outputs of which are connected to the I- and Q-ports of the modulator. Connect the output of the demodulator to the audio amplifiers C and D.

Adjust the level of the input signals using the white button.
Listen. Did the tuning succeed? Change the outputs of the MiniDisc the other way around. What happened? Change the phase difference between the LO signals of the modulator and demodulator. What happened?

3. Post-lab assignments

1. Present the performance of the transmission system you built in frequency domain in the ideal case (So the bandwidth of the signal and its position in frequency domain at different transmission phases, assuming that the input signal is the two channel audio signal from the MiniDisc). How is the performance of your transmission system different from the ideal case?

2. Why at the demodulation stage of this lab, the initial I and Q signals were not those we expected?

3. Why is it important that the LO signal is locked to the received signal? How do we lock the phase of the receiver’s LO to that of the received signal in the practical transmission systems?

4. What are the pros and cons of IQ modulation with regards to AM and FM modulation?

5. Name two transmission systems, in which we use IQ-modulation. Present also the constellation and the bit-rates used by the systems.

6. Why do we usually use the IF signal in modulators and demodulators (IF), and why don’t we modulate/ demodulate the signal directly to/from RF frequency?

7. Can IQ modulator be used for QPSK modulation? How about the other way around?
8. How does QPSK signal look like, when SNR is weak? What if the demodulator is not locked?

9. Any suggestions to improve the lab? What was good and what was bad?

References:

Digital and Analog Communication Systems, Leon W. Couch

RF/IF Designers Handbook, Mini-Circuits

Back to Basics, Hewlett Packard

Microwave & RF circuit design for wireless communications, Chap 4.

Communication Systems, A. Bruce Carlson

More information about QPSK and QAM:
http://www.physics.udel.edu/wwwusers/watson/student_projects/scen167/thosguys/index.html