Wireless Communication Systems Laboratory

Lab #3: Digital modulation techniques

Objective

The objective of this experiment is to understand the various digital modulation techniques and observe the related modulation quality measurements. The students will be familiar with the following items:

- Various modulation types.
- Constant envelope versus higher order modulations.
- Understanding power, spectral efficiency, and data rate trade-offs.
- Comparisons of various modulation types in terms of time envelope, spectral efficiency, EVM performance, constellation, and eye diagrams.
- The tradeoff between higher data rates and higher susceptibility to noise at higher orders of modulation (*e.g.* 64QAM). Investigation of overall capacity change (increase or decrease) at higher modulations.
- Understanding CCDF (Complementary Cumulative Distribution Function).

Pre-lab

- Study and understand the various digital modulations (BPSK, QPSK, QAM, pi/4DQPSK, OQPSK), A brief introduction is available on the website: http://en.wikipedia.org/wiki/Modulation.
- Try to expand your own search, to have better idea about the various digital modulations.
- Also refer to the supplementary documents.
- Study and understand the relationship between symbols and the bit-rate and relation of mapping bits to symbols.
- Calculate PAPR of a BPSK signal. Then, calculate PAPR of another signal that is the summation of two independently modulated BPSK signals. Which one has higher PAPR and, explain why?

Procedure

For the following procedures, each bench transmits an NADC signal at different carrier frequency.

Bench-1 at 913MHz

Bench-2 at 917MHz.

Bench-3 at 920MHz.

Use Digital Modulation analysis at steps I, II, and III. Use Time-Frequency analysis at steps III, IV, V, and VI.

Digital modulation analysis mode: Pick a screen layout of 2x3 and observe the following plots in each window:

a- Polar plot
b- Spectrum
c- EVM versus time
d- Syms/Errs
e- Constellation
f- Eye diagram.

Time-Frequency analysis mode: Use a 2x2 layout and see the following plots in each window:

a- Spectrum (averaged – use peak hold)
b- CCDF
c- Main Time
d- Inst. Spectrum.

I. EFFECT OF TX POWER ON CONSTELLATION AND EVM

Use the following values in signal generator: 10 ksps, RRC with alpha of 0.35, QPSK modulation.

a. Start from -60 dBm amplitude level of signal generator, than increase it with 10 dB steps until -20 dBm. Observe all plots and make comments on them. Record the EVM values and understand the EVM change.

b. Estimate SNR from the spectrum plot and explain how you obtain this value.

c. Calculate SNR from EVM and explain how you obtain this value. (Check (https://www.keysight.com/main/editorial.jspx?ckey=847674&id=847674&nid=-11143.0.00&lc=eng&cc=UG)

II. EFFECT OF CHANGING MODULATION ORDER AND VISUALIZING THE CONSTELLATION

In this part, various orders of modulations will be evaluated and performances will be observed. The following modulations will be generated with the transmit power of -30 dBm. QPSK, 16 QAM, and 64 QAM.

a. Compare EVMs and other analysis plots as in I. Comment on the results. Is the EVM increasing with the modulation order? Why? Make a comment on the EVM change.

b. How many levels do you observe in the eye diagram for each modulation? Explain in detail.

c. Now, increase the power to 10 dBm, and repeat the step a.

III. UNDERSTANDING THE EFFECT OF CROSSING ORIGIN IN IQ PLANE AND IMPACT ON THE SYSTEM

In this step, the following modulations will be tested and evaluated. The modulation types which will be considered in this step are QPSK, OQPSK, pi/4-DQPSK, and MSK.

Generate the type of the signal which you have generated in the previous steps. Set the amplitude and the RRC pulse shaping alpha factor to -30 dBm and 0.95, respectively.

For the modulation types mentioned above,

a. What is the number of the constellation points?

b. Comment on the transitions between symbols.

c. Comment and compare the modulation types in terms of:

- Number of constellation points.
- Number of transitions between symbols.
- Behavior of the transitions.

- EVM.
- Eye diagram pattern.

Note I: In OQPSK, you need to see the eye diagram for both I and Q components. To be able to do so, replace the constellation display window with Q-eye and keep the I-eye. Comment on the eye diagrams and transitions.

Note II: In MSK, you need to pay attention to "reference filter"

- Measurement filter needs to be "off"
- Reference filter needs to be set to RRC

IV. CCDF

In this step, the following modulations will be tested and evaluated:QPSK, pi/4-DQPSK, MSK, and 64 QAM. Please use the signal generated in the previous section.

a. To observe the CCDF, please follow these procedures:

- First of all make sure that your demodulation mode is off.
- For the desired window double click on the window label, and select channel1. And choose CCDF from it. This process will run the display window to the CCDF window mode.

b. For the modulation types mentioned above, comment and compare in terms of:

- CCDF plots.
- Time envelope (log magnitude).
- Spectrum: Bandwidth and side lobes.

V. MATLAB® PART (Optional)

Download one second of the signals (in the fourth step) to MATLAB®, process the signals, and observe similar type of graphs (as in the previous labs).

References

- Lecture notes.
- Supplementary documents posted on the black board.
- Personal search by the student.