THESIS REVIEWER'S REPORT

I. IDENTIFICATION DATA

Thesis title:	**Multiconstellation GNSS Receiver, Signal Tracking**
Author's name:	**Anastas Nikolov**
Type of thesis:	bachelor
Faculty/Institute:	Faculty of Electrical Engineering (FEE)
Department:	Department of Radioelectronics
Thesis reviewer:	Tomas Hynek
Reviewer's department:	Pix4D SA

II. EVALUATION OF INDIVIDUAL CRITERIA

Assignment **challenging**

How demanding was the assigned project?

The assignment of this thesis is quite wide spread – starting from theoretical analysis of feedback systems used in GNSS signal processing, over multiple levels of SW and HW simulations, towards even a (though optional) HW implementation. All that in multi-constellation multi-signal conditions. An amount of work that seems to be doomed to fail. I would rather limit the scope of work with focus on theory of feedback systems with particular interest in GNSS signals and their SW simulations. On the other hand the signal tracking of GNSS signals is quite well established area sufficiently covered in literature, such that the topic is quite well accessible to bachelor students.

Fulfillment of assignment **fulfilled with minor objections**

How well does the thesis fulfill the assigned task? Have the primary goals been achieved? Which assigned tasks have been incompletely covered, and which parts of the thesis are overextended? Justify your answer.

The assignment mentions these tasks:

* GNSS signal feedback tracking system analysis – this part was fulfilled, even though I am missing some general theory of feedback systems and presented work is strongly affected by Kaplan & Hegarty's Understanding GPS/GNSS book.
* develop an SDR-like MATLAB simulation – also fulfilled, although I have not understand why it is called SDR, student developed a MATLAB code to generate synthetic GNSS signals, acquire them and track them, with lots of possibilities of feedback loop settings, input signal options, introduction of interfering effects on signal etc. This code is used for numerical simulation of feedback loop behavior and for its comparison against theory.
* compare and debug the existing real HW multi-constellation GNSS receiver – not fulfilled, this task is not at all mentioned in the thesis.
* deploy the simulation environment to receive other signals – fulfilled, student assumes and works with several various GNSS signals, however the biggest emphasis is put on "standard" GPS L1 C/A signal.
* potentially implemented to the HW receiver – not fulfilled, however marked as optional.

Given this summary and given the wide scope of the assignment a big portion of the assignment was done by the student. In the thesis itself a too big portion of the theoretical part is wasted on various, but often only mildly related, aspects of GNSS background theory, signal transmission etc. On the other hand any theory of feedback systems is missing, even quite simple, at a level of bachelor program.

Methodology **correct**

Comment on the correctness of the approach and/or the solution methods.

Chapter 4, the main theoretical chapter, introduces typical feedback systems (FBS) used in a classic GNSS receiver chain – FLL, PLL and DLL. This chapter describes their function in the receiver and their characteristics (order of loop, filter bandwidth, various discriminators), it also mentions erroneous effects that can appear at the FBS inputs. Chapter 5, bit cryptically, describes a signal generation code designed by the student. Chapter 6 describes loops from chapter 4 in a shape suitable for numerical simulation. Finally, chapter 7, presents the results of both numerical simulation of the loops

as well as loops behavior using real GNSS signals. Loops' characteristics are presented in a form of typical FBS responses to more and more complex input signals and the results are discussed against theoretical expectations. This approach seems correct to me.

Technical level **C - good.**

Is the thesis technically sound? How well did the student employ expertise in the field of his/her field of study? Does the student explain clearly what he/she has done?

Student has implemented many of GNSS FBS in a correct way, given the presented results. However, it is not very clear if there is any additional student's work, despite "just" loop implementation and running the numerical simulations. It is pity that HW part of the assignment was not done. The produced simulator code seems to be of a good quality.

Formal and language level, scope of thesis **D - satisfactory.**

Are formalisms and notations used properly? Is the thesis organized in a logical way? Is the thesis sufficiently extensive? Is the thesis well-presented? Is the language clear and understandable? Is the English satisfactory?

Level of English is quite good, I have hardly found any typo or hard to read sentence. However, the style of the thesis is not well on many places, there are plenty of rhetorical questions, lengthy paragraphs explaining motivation of work in the next parts etc. The thesis sometimes (especially in opening chapters) resembles a patchwork of mildly related information, sometimes far from the core of the work. I would reduce the length of the thesis significantly, in the end only chapters 4 and 7 are the important ones.

Presentation of the results is also not very good. Graphs are often too small to be properly readable (luckily they are in vector format in the electronic version), labels, legends and axes labels are missing or no clear. Especially in chapter 7 it is hard to follow the text while jumping among the images. Therein, I am missing a clear schema of a circuit under discussion with accompanying signal charts at various points of interest of the circuit, properly separated from each other. This thesis had a big potential to be a nice illustrative and educative piece of work, unfortunately the opportunity was quite missed.

Selection of sources, citation correctness **E - sufficient.**

Does the thesis make adequate reference to earlier work on the topic? Was the selection of sources adequate? Is the student's original work clearly distinguished from earlier work in the field? Do the bibliographic citations meet the standards?

Reference section contains in total 5 sources. Two are in-house CTU publications, however source [4] seems cited nowhere in the thesis. Other two are quite equivalent, standard books on GNSS topic. Influence of Kaplan & Hegarty on the content of the thesis is striking. The last source [5], also seemingly cited nowhere inside the thesis, is GNSS signal specification wikipedia. Student's work with the bibliography is quite poor. In the end any of the two books would do all the work and rest can be removed. I would expect a better work and richer bibliographic entries if student would have used some of the original papers, for example those referenced in used books. This would also provide him with better understanding of technical writing. On multiple places student uses quite strong statements (especially in chapter 4 claiming that something is typically this or typically that) without any obvious source of this information.

Additional commentary and evaluation (optional)

Comment on the overall quality of the thesis, its novelty and its impact on the field, its strengths and weaknesses, the utility of the solution that is presented, the theoretical/formal level, the student's skillfulness, etc.

None

III. OVERALL EVALUATION, QUESTIONS FOR THE PRESENTATION AND DEFENSE OF THE THESIS, SUGGESTED GRADE

Summarize your opinion on the thesis and explain your final grading. Pose questions that should be answered during the presentation and defense of the student's work.

Scope of the assignment was unnecessarily wide, therefore some parts of the work are missed, but mostly minor or optional. There is quite some technical work on numerical simulations of the GNSS tracking feedback loops analysis. Technical presentation of the results is not good. Big potential for nice educative material was missed. Huge part of the thesis is wasted on mildly relevant theory, on the other hand some basic general theory of feedback systems is completely missing – student explains what is a complex envelope of the signal, but does not explain why the circuit in debate is a feedback one, why do we even measure an error inside the loop etc. I am really missing a consistent "story" of the thesis. What is the output of this thesis? It is also the numerical simulation code? Why it is not described and commented anywhere in the thesis?

There is a huge space for improvement especially in presentation of the outcomes, however there is also indisputable amount of work in numerical simulations of the GNSS tracking loop, which balances out some of the thesis drawbacks.

The grade that I award for the thesis is C - good.

Questions to be discussed during the defense:

- Usage of numerically controlled oscillator (NCO) for local carrier seems natural, we want to generate a numerical replica of a harmonic signal. However the same approach seems bit inatural to generate highly non-harmonic binary code signal. Can you please explain how is NCO used for code generation and how is it influenced within the feedback loop? Also in the section 6.1.2 you mention „the code NCO implemented in software does not have the luxury of over-flowing hardware registers" can you please elaborate a meaning of this sentence?
- On several places the Doppler effect is mentioned, especially its constant/non-constant values. It is also multiple times assumed non-zero. Can you please exemplify some cases when the Doppler induced frequency shift can be zero? What are the other sources of frequency mismatch in real GNSS receivers?
- Under jerk dynamic stress scenario you mentioned that even 3rd order loop suffers from constant error. How can be this error removed, suppressed? In what type of scenarios this kind of stress can occur?

Date: **24.5.2022** Signature: