

# POSUDEK OPONENTA DISERTAČNÍ PRÁCE

Assessment of the Dissertation

Titul, jméno a příjmení studenta:

Title, name, surname of student

Mr. Haidar Al-Anbagi

Doktorský studijní program:

Doctoral study programme

Electrical engineering

Téma disertační práce:

Topic of the dissertation

Optimization of New Generations  
Communication, Broadcasting, and IoT  
Networks

Školitel:

Supervisor

Ing. Ivo Veřtát, Ph.D.

Oponent:

Opponent

prof. Ing. Roman Maršálek, Ph.D., Ústav  
radioelektroniky, VUT v Brně

## Zhodnocení významu disertační práce pro obor

Evaluation of the importance of the dissertation for the field

The presented dissertation is topical. It is oriented towards the area of satellite signals processing, with particular interests in the diversity combining of signals transmitted by small satellites, such as CubeSats. This is currently a widespread way universities may get experience with satellite communications. The integration of satellites into the earth's communication, so-called Non Terrestrial Networks is one of the envisaged areas for the future of 6G communications.

The thesis of Haidar Al-Anbagi deals with the idea of how to obtain diversity gain by combining the signals from several Ground Stations (GS) to improve the BER performance. The use of such virtual ground stations is then evaluated both by simulation and by the experiment with the real VZLU satellite link. Such an approach can serve as an alternative to other means to improve the signal reception quality (or to reduce outage), such as highly directional, high gain antennas etc.

## Vyjádření k postupu řešení problému, použitým metodám a splnění určeného cíle

Evaluation of the the problem-solving process, the methods used and the goal to be met

The presented thesis includes the design of theoretical concepts and methods, evaluation by simulations, as well as experiments with real data from several ground stations connected to international networks such as SatNOGS.

I have several comments on the methods and results used, such as: The figure 18 shows fundamental results and there is no need to compare erfc and Q functions to get simple BFSK BER (it is evident these need to be exactly the same). The improvement techniques presented in 4.4.2 are rather straightforward but still seem to provide additional robustness.

Objective IV is strange, why not design the system according to objective III directly? The number of objectives could be reduced to improve the cleanliness of the text.

## Stanovisko k výsledkům disertační práce a

## k původnímu konkrétnímu přínosu předkladatele disertační práce

Statement to the results of the dissertation and on the original contribution of the submitter of the dissertation

The main contributions of the presented thesis are as follows:

- Proposal of diversity combining of several ground station signals to improve the BER performance of the downlink satellite link, without need for extensive hardware changes. The method is able to work on simple software defined radio-based ground stations and exists in two variants (post-detection / pre-detection)
- Evaluation of the proposed methods in data from VZLUsat link, with various scenarios investigated (a beacon BER improvement, Sync word re-generation, link outage compensation, packet combining etc.)

### Vyjádření k systematické, přehlednosti, formální úpravě a jazykové úrovni disertační práce

Statement to the systematics, clarity, formal adaptation and language level of the dissertation

The clarity, formal adaptation, and systematics of the presented thesis are rather somehow average. The title is general and could be changed to be more informative. Typography is not nice, the use of a typographic system, such as Latex, would be much more appropriate for such work. There are several minor mistakes, such as "Watt" having a small "w", Figure 7 is not clear to me (where is jamming?), why linear and also logarithmic scales on figures with BER results, etc.? There are no major issues with language.

### Vyjádření k publikacím studenta

Statement to student's publications

The core of the presented thesis has been published at the appropriate level. There have been two journal publications and 4 conference publications. I would only recommend presenting the work at some renowned flagship international conferences, to get immediate feedback on the work.

### Celkové zhodnocení a otázky k obhajobě

Total evaluation and questions for defence

The presented thesis shows the original methods, their evaluation by simulation, but particularly interesting evaluations on the real data from the LEO satellite developed at the workplace. The core of the thesis is adequately published.

The dissertation thus fulfills the conditions of Section 47 (4) Act No. 111/1998 Sb. Higher Education Act. I thus recommend it for the defence, for which I propose some questions, such as:

1. Would there be any effect of varying CFO values on the performance of proposed methods?
2. As far as I understood, "the standardization" process described in section 4.4.3 quantizes the data to either  $(1+0j)$  or  $(0+1j)$ , based on the orthogonal FSK assumption. Is there any performance loss because of this hard decision? Would the soft-decision, in particular in combination with decoding, be possible?
3. The signals from individual ground stations are assumed (p. 28) to be independent. Could you please more elaborate on this assumption?

Doporučuji disertační práci k obhajobě

I recommend the dissertation for the defence

ano yes	x	ne no
------------	---	----------

Datum

Date

14.12.2023

Podpis oponenta:

Signature of opponent





# POSUDEK OPONENTA DISERTAČNÍ PRÁCE

Assessment of the Dissertation

Titul, jméno a příjmení studenta:  
Title, name, surname of student

Haidar Al-Anbagi

Doktorský studijní program:  
Doctoral study programme

Elektrotechnika a informační  
technologie

Téma disertační práce:  
Topic of the dissertation

Cooperative Reception of Small Satellites'  
Signals Based on Diversity Combining

Školitel:  
Supervisor

Ing. Ivo Veřtát, Ph.D.

Oponent:  
Opponent

Ing. Jan Mráz, Ph.D.

## Zhodnocení významu disertační práce pro obor

Evaluation of the importance of the dissertation for the field

In his dissertation, the student provided a novel approach to processing signals available from small satellites by introducing diversity techniques for signals received by several ground stations. As the topic itself emerged recently, there are not other known publications in this field to the opponent. Because goals of the thesis were correctly identified and achieved, the student has delivered an obvious contribution to the field.

## Vyjádření k postupu řešení problému, použitým metodám a splnění určeného cíle

Evaluation of the problem-solving process, the methods used and the goal to be met

The thesis is divided into six parts. In addition to the introduction and conclusion, theoretical analysis is provided, objectives of the thesis are identified, methodology is described and achieved results discussed. The chosen approach is well documented and consistent throughout the thesis, no relevant information for an unambiguous understanding of the problem-solving process is missing. It is well reasoned why combiners conventionally utilized in radio-frequency signal processing are not suitable for being involved.

## Stanovisko k výsledkům disertační práce a

### k původnímu konkrétnímu přínosu předkladatele disertační práce

Statement to the results of the dissertation and on the original contribution of the submitter of the dissertation

The major achievement of the dissertation is providing a means for integrating data from multiple ground stations by a maximum likelihood diversity combiner. The applicability of this major achievement was verified within the thesis as well. Therefore, it corresponds to what is expected to be achieved in doctoral theses, i.e., to provide an original scientific outcome.

## Vyjádření k systematicce, přehlednosti, formální úpravě a jazykové úrovni disertační práce

Statement to the systematics, clarity, formal adaptation and language level of the dissertation

All aspects regarding the formal adaptation are provided with a high standard. The whole document is excellently organized and readable in a very straightforward way. Only the scripts provided via GitFront are not available there, nevertheless, their functionality is implicitly proven by the results achieved.

## Vyjádření k publikacím studenta

Statement to student's publications

The student's publications are adequate to what is specified in the Dean's directive, including the impact factor of particular publishing platforms expected for the key achievements of the thesis.

## Celkové zhodnocení a otázky k obhajobě

Total evaluation and questions for defence

The thesis fulfils the all the criteria for dissertations, therefore I recommend it for the defence.

Questions follow:

1. What recommendations would you provide to the operators of ground stations regarding the form of recorded streams to support more efficient diversity techniques in the future without excessive expenses?
2. Antenna diversity is considered to be synonymous with spatial diversity on page 21, nevertheless, antennas can also provide other types of diversity like angular/pattern or polarisation diversity. Could there be an advantage of introducing polarization diversity reception at ground stations together with statistical combing over conventional circular polarization reception?

Doporučuji disertační práci k obhajobě

I recommend the dissertation for the defence

ano

yes

x

ne

no

Datum

Date

6.12.2023

Podpis oponenta:

Signature of opponent





# POSUDEK OPONENTA DISERTAČNÍ PRÁCE

Assessment of the Dissertation

Titul, jméno a příjmení studenta:

Title, name, surname of student

Haidar Al-Anbagi

Doktorský studijní program:

Doctoral study programme

Elektrotechnika a informační technologie

Téma disertační práce:

Topic of the dissertation

Optimization of New Generations  
Communication, Broadcasting, and IoT  
Networks

Školitel:

Supervisor

Ing. Ivo Veřtát, Ph.D.

Oponent:

Opponent

doc. Ing. Stanislav Vítek, Ph.D.

## Zhodnocení významu disertační práce pro obor

Evaluation of the importance of the dissertation for the field

The main goal of the work is the design and implementation of methods for demodulating a weak radio signal from a small satellite in a low Earth orbit, which is received by ground stations, and exploring the potential integration of small satellites into future 6G communication networks. The thesis introduces a novel solution employing a cooperative reception scheme and diversity combining. The presented research is very timely and important to the current needs of the scientific community, where the research has potential use in the real-world.

## Vyjádření k postupu řešení problému, použitým metodám a splnění určeného cíle

Evaluation of the the problem-solving process, the methods used and the goal to be met

There is good evidence of understanding of research methods, from the literature review stage, identifying research gaps, to designing solution, conducting evaluations, and comparing with the state-of-the-art methods. The methods used in the thesis are appropriate and in good standard. The objective of the thesis was fully met - the candidate proposed a theoretical framework, which was verified both by a series of simulations in Matlab and by a real experiment using the records of VZLUSAT-2 satellite.

## Stanovisko k výsledkům disertační práce a

### k původnímu konkrétnímu přínosu předkladatele disertační práce

Statement to the results of the dissertation and on the original contribution of the submitter of the dissertation

The main result of the work is an algorithm for incoherent diversity combination of signals that are simultaneously detected by several unsynchronized low-cost SDR receivers equipped with low-gain omnidirectional antennas. The algorithm has been verified on an on-board beacon recording during a VZLUSAT-2 nanosatellite flyby. The author performs postprocessing of the parallel captured packets, which consists mainly in temporal alignment of the individual data stream records acquired by SDR receivers in the USA and Canada. For the purpose of diversity combination, Maximum Likelihood combiner has been proposed in the thesis. Then, both the BER reduction and the fault tolerance of the components of the proposed system were verified experimentally.

The main contribution of this work, apart from the proof of concept itself, is the possibility to use multiple satellites for simultaneous tracking using open networks of SDR receivers. The results presented in the thesis are original and the candidate has definitely contributed to the state of the art. I think it was appropriate to perform further experimental confirmation on more records of the VZLUSAT-2 nanosatellite flybys, or on flybys of other satellites.

**Vyjádření k systematicce, přehlednosti, formální úpravě  
a jazykové úrovni disertační práce**

Statement to the systematics, clarity, formal adaptation and language level of the dissertation

The formal quality of this thesis is aligned with a PhD level standard. The thesis is very well organised, well-written and well-described. The presentation of the thesis is sufficiently clear. The candidate has demonstrated in depth understanding of the research domain. The text of the thesis is divided into six main chapters, including the introduction and conclusion. The thesis has a total of 85 pages, which is an adequate length for a PhD thesis. The author works with a total of 80 references that are relevant to the topic of the thesis. The tasks and milestones associated with the objectives were outlined in the thesis and elaborated in the candidate publications. The graphic design of the thesis is of a standard technical standard. The English language used in the text of the thesis is sometimes stilted and deserves more stylistic care, but this does not detract from the quality of the communication of the research results.

**Vyjádření k publikacím studenta**

Statement to student's publications

According to the Scopus database, the candidate is a co-author of a total of 13 publications, of which 7 are affiliated to the Faculty of Electrical Engineering of ZCU and have been produced during the study period. Two publications are published in impacted journals (MDPI Sensors and IEEE Access), in both cases the candidate is the main author. In my opinion, the publication activity is adequate and can be considered sufficient. All publications from the time of the PhD are relevant to the topic of the thesis.

**Celkové zhodnocení a otázky k obhajobě**

Total evaluation and questions for defence

In summary, this thesis has a fine standard and fulfilled a PhD level, given that the candidate has published two journal papers and demonstrated professional development. The creativity element in the thesis is good, from techniques to applications development. The author of the thesis proved to have an ability to perform research and to achieve scientific results. I do recommend the thesis for presentation with the aim of receiving a Ph.D. degree.

Question for defence: in your opinion, what are the limits in terms of the number of data streams to be combined, i.e. for example what is the minimum number of streams to obtain a sufficiently high quality signal and what are the criteria for designing a method of online evaluation of the quality of the stream in terms of benefits in combination?

Doporučuji disertační práci k obhajobě

I recommend the dissertation for the defence

ano yes	x	ne no
------------	---	----------

Datum

Date

12.12.2023

Podpis oponenta:

Signature of opponent

