

## OPINION

by Eng. Dimitar Mihaylov Tokmakov, PhD

Professor at the ECIT department, Faculty of Physics and Technology,

University of Plovdiv "Paisii Hilendarski"

on the dissertation for the award of the educational and scientific degree "PhD"

by: field of higher education: *5 Technical sciences*

Professional field : *5.3. Communication and computer engineering*

Doctoral programme: "*Automation of areas of the intangible sphere (medicine, education, science, administration, etc.)*"

**Author: *Tihomir Tihomirov Lovchaliev***

**Topic:" Design of 5G antennas and automated testing of their parameters"**

**Scientific supervisor: Assoc. prof. Nadezhda Kafadarova, PhD - Paisii Hilendarski  
University of Plovdiv**

### **1. General presentation of the procedure and the PhD student**

By Order No. RD-21-720 of 02.04.2024 of the Rector of Plovdiv University "Paisii Hilendarski" (PU) , I have been appointed as a member of the scientific jury for the procedure for the defense of a dissertation thesis on " Design of 5G antennas and automated testing of their parameters " for the acquisition of the educational and scientific degree "Doctor" in the field of higher education 5. Technical sciences, professional field, 5.3. Communication and computer engineering, doctoral programme Automation of areas of the intangible sphere (medicine, education, science, administrative activity, etc.).

The author of the dissertation is Tihomir Tihomirov Lovchaliev - a PhD student in full-time studies at the Department of ECIT with scientific supervisor : Assoc. prof. Nadezhda Kafadarova, PhD from Plovdiv University "Paisii Hilendarski".

The set of paper materials submitted by Tihomir Tihomirov Lovchaliev, is in accordance with Article 36 (1) of the Regulations for the Development of the Academic Staff of PU and includes the following documents: Application to the Rector of PU for the opening of the dissertation procedure; CV in European format; minutes of the departmental council related to the reporting of the readiness for the opening of the procedure and the preliminary discussion of the dissertation; dissertation; abstract; list of scientific publications on the topic of the dissertation;

copies of scientific publications; declaration of the authenticity and reliability of the attached documents; statement of compliance with the minimum national requirements. The doctoral candidate has attached 6 copies of his publications on the subject of the dissertation.

All necessary and required documents and materials have been submitted, in accordance with Article 36 (1) of the Regulations for the Development of the Academic Staff University of Plovdiv Paisii Hilendarski and the Law on Academic Staff Development of Plovdiv University. All of them have been prepared diligently and correctly.

Mag. Tihomir Lovchaliev has completed his secondary education at the Vocational High School of Electrical Engineering and Electronics in Plovdiv, Bulgaria . He graduated with a degree in Electrical and Electronics in 2011. He completed his higher education in 2015 at Paisii Hilendarski University of Plovdiv, Physics and Communications, Bachelor of Science. From 2016 to 2018, Tihomir Lovchaliyev graduated in Telematics, Master's degree at Paisii Hilenarski University of Plovdiv, Faculty of Physics and Technology - Plovdiv.

Since 2016, he has been working as the Head of the Help Desk Sector - South at the National Revenue Agency – Plovdiv, Bulgaria.

I know Mag. Tihomir Lovchaliyev personally, as my good impressions of his qualifications in the field of information technology are acquired during his training as a PhD student in the Department of ECIT, as well as from the results he has achieved in conducting laboratory exercises with students from the Faculty of Physics and Technology of Paisii Hilendarski University in the disciplines "Computer Networks" and "Microprocessor Technology".

## **2. Topical relevance**

Based on the literature review and the analysis performed, it is evident that the development of new types of antennas and their automated testing for modern 5G communications is an actual and active direction in modern research worldwide.

The tasks set in this dissertation are currently very relevant: 1.To investigate the existing state-of-the-art approaches to study the parameters of antennas for mobile applications. To carry out a critical theoretical analysis of the literature in the field of on-science research; 2. To design and fabricate a working prototype system to investigate the pointing pattern of antennas for 5G. To select appropriate modules for the development of the prototype system; 3. To analyze the measurement results obtained with the developed prototype system. On the basis of the conducted critical analysis to outline the main shortcomings of the prototype; 4.To make a selection of the

main functional nodes, constituting an operating system for automated testing of the parameters of the antenna pointing pattern; 5.To design an operating procedure for the study of the antenna pointing pattern for 5G. To develop an electromechanical functional node for the implementation of rotational motion of the antenna under study. To develop a software for synchronization of the operation of the individual actuators that make up the system, as well as for the study of the main parameters of the antenna radiation pattern; 6.To develop a methodology for conducting the antenna radiation pattern study using the developed system; 7. Using the developed system, to conduct the study of different types of 5G antennas and to construct their radiation patterns; 8.To design, fabricate and study a 5G antenna. The study is to be carried out using the developed system for automated testing of the parameters of the radiation patterns.

### **3. Knowledge of the problem**

The list of cited references contains 74 publications. Most of the cited sources are articles in journals indexed in Scopus and Web of Science.

All publications are in English. Most of the cited sources were published after 2005, which indicates the existence of a thorough analysis of the current state of the art of the problem. In the course of his thesis work, the PhD student evaluated and interpreted the literature creatively, using his own ideas in the development of the antennas, software, hardware and overall systems tested.

### **4. Research methodology**

The main topic of the research is the development of a prototype system to study the antenna radiation pattern for 5G communications. The PhD student has selected suitable modules to build the prototype system. An electro-mechanical functional unit has been developed to perform rotational motion of the antennas under study. A software was developed to synchronize the operation of the individual actuators constituting the system, as well as to study the basic parameters of the antenna radiation pattern. Different antennas with application in 5G telecommunication networks have been measured with the so developed system.

An antenna for the 5G range has been designed using the specialized HFSS software, the radiation pattern has been obtained, and a physical prototype has been developed. The prototype has been tested experimentally for real evaluation of the properties of the designed antenna with and without applied filter.

## **5. Characteristics and evaluation of the thesis and contributions**

In Chapter I, an overview of the state-of-the-art approaches to investigate the parameters of antennas for mobile applications and in particular in the 5G range is presented.

Chapter II describes the design and fabrication of a working prototype of an out-of-the-box antenna tracking system for 5G. The antenna performance measurement procedure is described in detail. In Chapter III, an operational antenna radiation pattern-measurement system is developed, which focuses on the development of an electromechanical functional node and its corresponding control software. In Chapter IV, a "Methodology for conducting the antenna study" is presented. Chapter V presents the results of the study of different types of 5G antennas such as 1. Dipole antenna for 2.45 GHz frequency; 2. Yagi-Uda antenna for 2.45 GHz frequency; 3. Logarithmic periodic antenna operating in the frequency range 850 - 6500 MHz. The radiation pattern diagrams of these antennas for the 5G band are measured using the developed system. Chapter VI presents the Design, fabrication and study of an antenna for 5G using dedicated HFSS software for which the radiation pattern diagram has been measured using the developed measurement system in Chapter III. Conclusions of the dissertation are presented, in which a critical analysis of the weaknesses of the developed system in Chapter III is made by the author, as well as opportunities for improvement of the system. In the Conclusion, the scientific and applied contributions of the dissertation are framed, which I believe are built on reliable data, as the individual chapters of the dissertation show very detailed results of the experiments performed.

## **6. Assessment of publications and personal contribution of the PhD student**

The main content, results and contributions of the thesis are presented in six publications. All are in English. In two of the publications, Mag. Tihomir Lovchaliyev is the only author. Scopus index two of the publications.

The other four publications were presented at international conferences and at conferences of Union of Scientists -Plovdiv, Bulgaria, which are peer-reviewed but not indexed by Scopus or Web of Science.

I believe that the PhD student's publications on the dissertation reflect well the main contributions he claims. My assessment of the PHD student's personal involvement in the dissertation research is that it is unquestionable.

## **7. Abstract**

The abstract has been prepared according to the requirements of the relevant regulations, and reflects the main results achieved in the dissertation.

## **8. Recommendations for future use of the dissertation contributions and results**

It would be good to apply the results obtained in this dissertation in new developed laboratory exercises in Fundamentals of Telecommunications , the effectiveness of which could be evaluated.

## **CONCLUSION**

The dissertation of Tihomir Lovchaliec contains scientific and applied results, which represent an original contribution to science and fully meets the requirements of the Law for the Development of the Academic Staff of the Republic of Bulgaria, the Regulations for its implementation and the Regulations for the Conditions and Procedure for the Acquisition of Scientific Degrees at Paisii Hilendarski University of Plovdiv. The attached abstract reflects the essence of the research and correctly presents the contributions. The dissertation shows that Tihomir Lovchaliev possesses in-depth theoretical knowledge and professional skills in the scientific specialty "Automation of areas of the intangible sphere (medicine, education, science, administrative activity, etc.)", demonstrating qualities and skills for independent scientific research. Taking into account the merits, topicality, significance of submitted dissertation, I give it a positive evaluation and propose to the jury to award to Tihomir Tihomirov Lovchaliev the educational and scientific degree "DOCTOR" in scientific field 5 Technical sciences, 5.3. Communication and computer engineering, doctoral program "Automation of areas of the intangible sphere (medicine, education, science, administrative activity, etc.)".

14.05.2024

Prepared by:.....

/prof. Dr. Dimitar Tokmakov/