

REVIEW

from PhD Anna Vladova Stoynova, professor from Technical University of Sofia

of a dissertation for obtaining the educational and scientific degree "**doctor**"

by: field of higher education 5. Technical sciences

professional field 5.3 Communication and computer technology

doctoral program „Automation of fields from the intangible sphere (medicine, education, science, administrative activity, etc.)“

Author: Tihomir Tihomirov Lovchaliev

Topic: Design and automated testing of the parameters of 5G antennas

Scientific supervisor: Assoc. Prof. Nadezhda Miteva Kafadarova, PhD, Plovdiv University "Paisii Hilendarski".

1. General description of the materials submitted

By order No. RD-21-720 dated 02/04/2024 of the Rector of the Paisii Hilendarski University of Plovdiv (PU), I have been appointed as a member of the scientific jury to ensure a procedure for the defense of a dissertation work on the topic " Design and automated testing of the parameters of 5G antennas" for acquiring the educational and scientific degree "doctor" in the field of higher education 5. Technical sciences, professional direction 5.3 Communication and computer technology, doctoral program Automation of areas of the intangible sphere (medicine, education , science, administrative activity, etc.). The author of the dissertation is Tihomir Tikhomirov Lovchaliev - a full-time PhD student at the Department of Electronics, Communications and Information Technologies, supervised by Assoc. Prof. PhD Nadezhda Miteva Kafadarova from Paisii Hilendarski University of Plovdiv.

The set of paper materials presented by Tihomir T Lovchliev is in accordance with Article 36 (1) of the Regulations for the Development of the Academic Staff of the PU and includes the following documents:

- a request to the Rector of Plovdiv University for disclosure of the procedure for the defence of a dissertation;
- CV in European format;
- protocol from the departmental council related to reporting the readiness to open the procedure and preliminary discussion of the dissertation work;

- dissertation work;
- autoabstract;
- a list of scientific publications on the topic of the dissertation;
- copies of scientific publications;
- statement of originality and authenticity of the attached documents.

2. Brief biographical data for the PhD student

Tihomir Lovchaliev was born on April 2, 1992. and completed his secondary education at the Professional High School of Electrical Engineering and Electronics in 2011. In 2015 he acquired the educational qualification of Bachelor in Information Physics and Communications and in 2018. Master's degree in Telematics at Paisii Hilendarski University of Plovdiv. Since 2016 until now, he is the head of the Help Desk - South sector at the National Revenue Agency, Plovdiv, with main activities and responsibilities - organization, administration and optimization of workstations for the whole of southern Bulgaria.

From March 2020 he is enrolled as a full-time PhD student in the Department of Electronics, Communications and Information Technologies (ECIT) of Paisii Hilendarski University of Plovdiv (PU) with scientific supervisor Assoc. Dr. Nadezhda Kafadarova. In March 2023 he is written off the right of defence. On 28.02.2024 a preliminary discussion of the presented dissertation work was held at the ECIT departmental council and a decision was made to open a procedure for the defense of Tihomir Lovchaliev's dissertation work for the acquisition of the educational science degree (ESD) "Doctor". The requirements under the law on the National Tax Service and the rules of the Paisii Hilendarski University of Plovdiv under the procedure for the acquisition of ESD "Doctor" were completed in volume and on time.

3. Relevance of the topic and appropriateness of the objectives and tasks set

The topic of the dissertation is current and socially significant, as it is directly related to the development of wireless technologies providing modern communication services in the next generation 5G network. Today, significant challenges exist to achieve the required performance of 5G generation cellular networks. To ensure the required quality and reliability of coverage and cost redistribution in various deployment scenarios of the base station or 5G devices and communication systems, the adequate design and manufacture of 5G antennas is crucial. For the proper design of antennas for 5G applications, it is very important that engineers are aware of all bandwidth and noise

immunity requirements to reduce microwave signal propagation losses in various environmental conditions. Accurate analysis of the main characteristics of antennas at different operating frequencies and environmental conditions is required to predict and optimize radio coverage.

The aim of the dissertation work is related to the design of antennas for 5G and the development of a system for automated testing of the parameters of their directional action diagrams. In the implementation of the set goal, a sequence of eight specific tasks, which require complex knowledge, are clearly defined and successfully executed. Expectations relate to proof-of-concepts developed to demonstrate the feasibility and effectiveness of proposed innovative techniques and to encourage implementation, through prototyping and experimental research activities.

4. Knowledge of the problem

The literature review on the topic is thorough, analytical and well structured. It shows that the PhD student knows the specific scientific issues very well and is fluent in the specialized terminology. 74 sources in English are cited, of which 17 sites with up-to-date and related information. From the review, it is clear that the PhD student creatively evaluates the literary material, as a result of which he logically substantiates the purpose and tasks for its implementation in his research work. The conclusions drawn in the dissertation work are logical and justified.

5. Research methodology

Modern and efficient methods were used in the development of an innovative system for researching different antennas in laboratory conditions. The chosen research methodology allows achieving the set goal and obtaining an adequate answer to the tasks solved in the dissertation work.

6. Characterization and evaluation of the dissertation work

The dissertation has a total volume of 156 pages, which includes used abbreviations, an introduction, six chapters, conclusions, contributions and cited literature.

In the Introduction, the current need for continuous improvement of both the antenna manufacturing technologies and the system for researching their main characteristics is justified.

The first chapter presents an in-depth critical analysis of current approaches to the study of antenna parameters for mobile applications. As a result, the purpose and tasks of the dissertation are logically derived, to solve existing scientific applied problems in the field.

Chapter two presents the experimental research results of a prototype antenna research system for 5G to perform an accurate analysis of the main characteristics of antennas at different operating frequencies and environmental conditions to predict and optimize radio coverage. A decision on the necessary modules to participate in the construction of the designed system has been

made. A software was specially developed to configure the parameters necessary to rotate the antenna during the measurement.

The third chapter presents innovative solutions in the development of a working system for the study of an antenna directivity pattern. A design solution with reduced dimensions is proposed, which allows the investigated antenna to rotate without causing mechanical tension in the cables. The operation of the measuring system is managed with specialized PC software. A specialized firmware has been developed through which the control of the stepper motor driver and communication with the personal computer is carried out. The TkInter library was used to create the user interface. To eliminate unwanted noise, the measured signal is filtered using the Savitzky–Golay filter.

The fourth chapter presents the methodology developed by the PhD student to study the directional action diagram of antennas for 5G mobile communications using the developed system.

In the Fifth Chapter, the results of the study of different antennas are systematized: a dipole antenna for a frequency of 2.45 GHz, a yagi antenna for a frequency of 2.45 GHz and a logarithmic periodic antenna operating in the frequency range 850 MHz - 6500 MHz. The research was conducted in the "Telecommunications" laboratory at the Faculty of Physics and Technology of PU.

In the Sixth Chapter, the results of the design and measurement of a patch antenna for 5G are presented. The simulated characteristics (with Ansys HFSS) are verified with the developed innovative measuring system. The measurements show that the designed antenna offers good enough efficiency for the chosen resonance frequency of 2.45 GHz and can be used in a wide range of WLAN applications.

7. Contributions and relevance of development to science and practice

I accept the scientific and applied contributions formulated by the PhD student in the development of his dissertation. The set goal and tasks in the dissertation have been fully fulfilled. The results of the conducted research are mainly scientific and applied in nature. The PhD student has carried out a thorough critical analysis of modern approaches to the study of antenna parameters for mobile applications, thus supporting the creation of new classifications. In order to carry out experimental studies of antennas for 5G, a prototype measuring system was created, which was tested and subsequently modernized by means of innovative structural and elemental changes. New design solutions have been proposed to overcome problems with twisting the feeder RF cable of the antenna under study and to create larger torques when studying heavier antennas. As a result, a special high-frequency rotary connector module was designed and manufactured, which prevents twisting of the connecting cable between the rotary antenna and the spectrum analyzer. This leads to the creation of a custom system for unique specifications and applications when researching antennas for mobile

applications. PC software was developed, with a built-in algorithm for filtering the signal, which coordinates the actions of the executive mechanisms of the measuring system. The software has a user interface for managing the measurements and presenting the results in digital and graphical form. Thus, during the measurement, a database of the signal power values is created, depending on the angular position of the antenna. A patch antenna for 5G has been designed and manufactured. Its radiation properties are simulated using the specialized HFSS software and verified with the developed innovative measurement system.

The main results of the dissertation research are presented in 6 (six) publications in specialized publications. The developed modular antenna characterization system for mobile applications is used in the department for ongoing research as well as possible development activities.

8. Assessment of publications on the dissertation

The PhD student is the author and co-author of a total of 6 publications in which the results of the dissertation are reflected. In two of the publications published in a collection of scientific works of the Union of Scientists in Bulgaria-Plovdiv, the PhD student is the sole author. The publications are in Bulgarian, and the editions of the collections are included in the National Reference List of contemporary Bulgarian scientific publications with peer review. The remaining 4 publications are in English, in which the PhD student is a co-author (1 publication with two authors, 2 publications with three authors and 1 publication with four authors) were published in Proceedings of International Conferences. Two of these publications are in publications referenced in SCOPUS (ET 22, Sozopol), and the other two are in publications included in Google Science (ICERI21, online Seville and SOCIOINT22, online Istanbul).

9. Personal participation of the doctoral student

The presented materials show a wide range of experimental work carried out in which the PhD student participated, with the help of specialists in the relevant field from the EKIT department. There is no doubt that the PhD student has familiarized himself with the theory, gained practical experience and acquired skills in the use of methods and techniques from various scientific fields: in the field of design, fabrication and measurement of antennas for 5 G - as a result of which the innovative antenna research system for 5G.

10. Autoabstract

The 32-page abstract is made according to the requirements and presents the content of the dissertation in a concise and informative form. It accurately reflects the goals and tasks of the dissertation work, the main results and analyses, the conclusions, as well as the list of publications

and participation in scientific forums. The attached illustrations such as diagrams and graphics are of high quality.

11. Critical remarks and recommendations

On page 9 there is a repetition of text in two consecutive paragraphs which could have been avoided. In one or two places in the text there are spelling mistakes, probably from careless typesetting. In my view, contributions 2 and 6 could be combined without diminishing the value of the scientific-applied contributions made by the research presented in the dissertation..

12. Personal impressions

The PhD student gives the impression of a motivated, goal-oriented young researcher who managed to successfully complete her dissertation work on time, regardless of the difficult conditions of the COVID-epidemic. From the materials presented, the presence of in-depth knowledge and excellent use of terminology in the field of mobile telecommunications technology is evident. The PhD student convincingly demonstrates skills in solving research problems and working in a team.

13. Recommendations for future use of dissertation contributions and results

The developed innovative system, built on a modular principle, in addition to scientific research of antennas for 5G could be successfully used for the needs of the educational process in the ECIT department. I also recommend that research in the field of 5G, given the accumulated experience and scientific-applied results, continue to develop.

CONCLUSION

The dissertation *contains scientific-applied and applied results that represent an original contribution to science* and **meet all** the requirements(s) of the Law on The Development of The Academic Staff in The Republic Of Bulgaria, Regulations for Implementation of The Law on The Development of The Academic Staff in The Republic of Bulgaria and the relevant Regulations of Plovdiv University "Paisii Hilendarski".

The dissertation work shows that the PhD student Tihomir Tihomir Lovchaliev **has** in-depth theoretical knowledge and professional skills in the scientific specialty "Automation of areas of the non-material sphere (medicine, education, science, administrative activity, etc.)" by **demonstrating** qualities and skills for independent scientific research.

Due to the above, I confidently give my *positive assessment* of the conducted research, presented by the dissertation reviewed, autoabstract, achieved results and contributions, and **I propose to the honorable scientific jury to award the educational and scientific degree "doctor"** to Tihomir Tihomir Lovchaliev in the field of higher education: 5. Technical Sciences,

professional field 5.3. Communication and computer engineering, doctoral program “Automation of areas of the non-material sphere (medicine, education, science, administrative activity, etc.)”.

Sofia, 07.05.2024

Reviewer:

(signature)

(Prof. PhD Anna Stoyanova)

(*ac. d., n. st., name, surname*)