RESEARCH OF ANTENNAS FOR THE 5G FIRST FREQUENCY RANGE WITH APPLICATION IN EDUCATION OF ENGINEERING STUDENSTS

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Abstract

The in-depth study of fifth generation (5G) technology is dictated by the need to meet the increasing demand for high-speed communication. This article describes our experience in training engineering students at Plovdiv University to design and analyse the basic characteristics of antennas operating in the 5G first frequency range. The training is carried out within the course “Mobile Information Systems”, and a module consisting of three assignments has been developed. The experiments are performed through a specially developed experimental setup for radiation pattern measurements of antennas in the telecommunications laboratory. This experimental setup has been developed during the training of students in the course “Electrical Engineering”, conducted in a pandemic. It consists of a stepper motor for rotation of 5G antennas of different types, like dipole, Yagi, and patch. The measurements of the signal level are carried out by a spectral analyser. Data obtained from spectral analyser are processed by a specially developed software which also visualize the radiation pattern of the antennas. For the purpose of the training and the study two commercially available antennas PN: SW19008IB77 and PN: SW19001IG97 are used to make a preliminary comparative analysis of their characteristics. The experiments are included in the first assignment of the module. The next assignment aims to acquaint students with the process of designing and manufacturing antennas for 5G. In the third assignment a comparative analysis of the characteristics of the factory antennas and students a good opportunity to master the study material for the design and manufacture of antennas for applications in the first frequency range of 5G.

Keywords: 5G, antenna, training, engineering students.

1 INTRODUCTION

To meet the need for higher data rates, lower latency and higher reliability in times of continuous development of information and communication technologies, mobile operators must quickly deploy and expand the range of 5G cellular networks. 5G networks are crucial for the economy and are the basis for the implementation of more efficient and profitable business models and solutions for the development of many new industries (https://www.digi.com/blog/post/solving-5g-antenna-design-challenges).

Building 5G networks is significantly more complicated than the previous generations of networks because they work in the microwave range and their 5G antennas, although more powerful, cover significantly less space. Therefore, good coverage requires more 5G equipment and software, which, however, significantly increases the operating costs of construction and maintenance (https://www.electronicspecifier.com/products/5g/exploring-the-biggest-challenges-for-5g-deployment).

A number of challenges need to be addressed to achieve the required performance of 5G generation cellular networks. One of the biggest challenges is related to the operating frequencies of the radio channel (the used radio frequencies) on which the performance of the network depends. Accurate analysis of the main characteristics of the antennas at different operating frequencies and environmental conditions is needed to predict and optimize the radio coverage. Adequate design and fabrication of 5G antennas is crucial to ensure the necessary quality and reliability of coverage and redistribution of costs in different scenarios of implementation of the base station or 5G devices and communication systems (https://www.altair.com/newsroom/articles/meeting-the-challenges-of-5g-antenna-design-and-radio-coverage/).

When developing suitable antennas for 5G communications, various techniques are used to improve their coverage. For example, (Ojaroudi Parchin and ect., 2019, p.2) demonstrated the design and testing of a multiple-input multiple-output (MIMO) antenna designed for the new generation of 5G / 4G smartphones. The radiation simulation model of the designed antenna shows good radiation characteristics and efficiency in all operating frequency bands, which are confirmed by physical measurements of the realized prototype. Other researchers in (Rusmono and ect., 2020, p.4) have proposed another approach to improve the performance of MIMO antennas by modifying its shape so that it can operate at different frequency bands in the millimeter range. The results of the simulations show that the designed antennas have good performance for several frequency bands in the millimeter bands of 24 GHz, 28 GHz and 38 GHz. The simulation results are verified by radiation pattern measurement of prototype antennas and show good enough results for 5G needs. In (Lak and ect., 2021, p.3) the study of structures with three different antenna arrays consisting of eight single elements is presented. The results of the analysis show that the performance of the designed antennas is quite good and safe for human health, although their work in the millimeter range.

The above studies show that for the proper design of antennas for 5G applications, it is very important that engineers are aware of all the requirements in terms of bandwidth, and noise immunity to reduce losses by spreading the microwave signal in different environmental conditions. Usually, this requires complex knowledge - from the basic concentrations for designing antennas and testing them to solving problems related to energy efficiency. To solve these problems in the telecommunications industry, specialists with sufficient knowledge and competencies in the field of 5G technologies are needed.

This article describes the experience of professors from Plovdiv University "Paisii Hilendarski" in training engineering students in the field of 5G. The training is carried out within the course "Mobile Information Systems". The training includes the design and analysis of the main characteristics of antennas operating in the first frequency range of 5G - from 410 MHz to 7125 GHz. For the purposes of the training, an experimental setup based on the Arduino Uno development board was created for research and visualization of the radiation pattern of antennas. In the course, students designed their own antenna for the first 5G frequency band using Ansys HFSS software. An additional training module is focused entirely on the verification of radiation pattern of prototype antennas made by students through a comparative analysis of the radiation pattern of commercially available 5G antennas operating in the same radio frequency range.

2 EXPERIMENTAL SETUP FOR INVESTIGATION OF 5G ANTENNA

The experimental setup for studying the radiation pattern of antennas was created by the team responsible for the training of engineering students at Plovdiv University. The scheme of the experimental setup is shown in fig. 1. It consists of the following elements: 1-personal computer, 2-spectrum analyzer GWINSTEK GSP-9300, 3-microcontroller Arduino UNO, 4-stepper motor driver A4988, 5-stepper motor, 6-stationary (transmitting) antenna, 7-tested (receiving) antenna, 8-high frequency generator, 9-power supply.

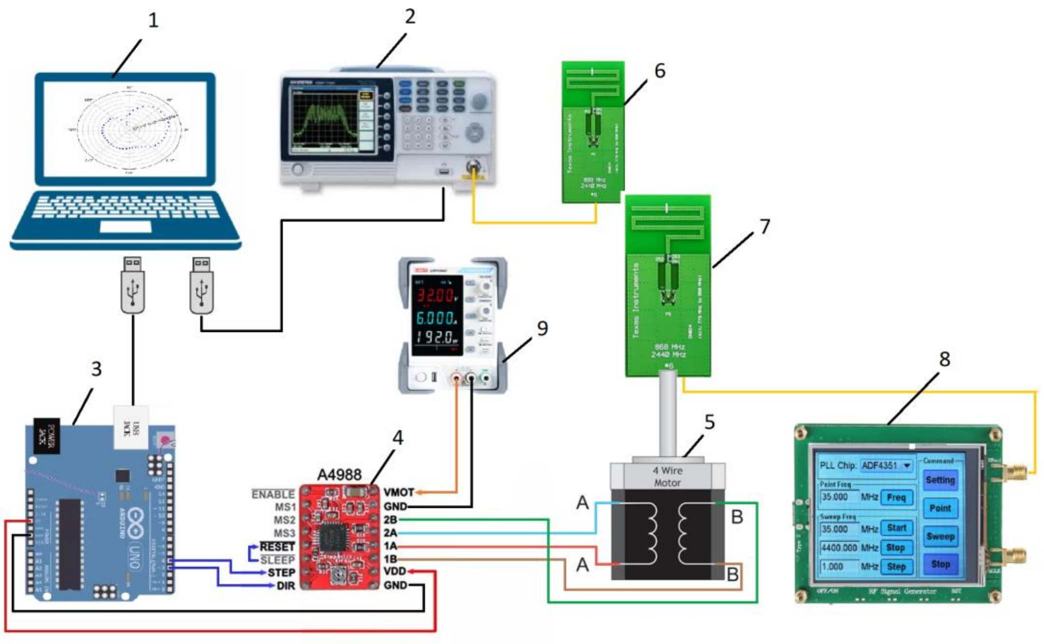

Fig.1 Experimental setup for investigation of 5G antenna

Specialized firmware for the Arduino UNO has been developed to control the stepper motor. The A4988 integrated circuit, which is a specialized driver for controlling stepper motors, is connected to the Arduino UNO development board. The Arduino UNO microcontroller is connected via a USB cable to a personal computer in series via RS232. Other specialized user software based on the Python programming language has been developed to control the operation of the stepper motor. The user interface sets the number of steps and the pause between them, which determines the speed of rotation of the motor. The GWINSTEK GSP-9300 spectrum analyzer is used to measure the signal strength. This spectrum analyzer is also connected to and controlled by a USB cable. The software synchronizes the measurements performed by the spectrum analyzer with the movement of the motor. After turning the motor one step, the strength of the signal received at the input of the spectrum analyzer is measured. This value is stored in an array (database) and is displayed as a point in the graph with polar coordinates. The tested antenna is attached to the motor. When the motor is rotated from 0 to 360 degrees, the graph writes the radiation pattern of the studied antenna operating in the first frequency range of 5G. The tested antennas can be of different types: dipole, yagi, logarithmic, and patch. The signal coming to the test antenna is generated by a fixed antenna operating in the same frequency range.

3 STUDY OF 5G ANTENNAS

Experiments were performed by engineering students in the “Mobile Information Systems” course using the created experimental setup and software. These experiments are included in the first assignment of a developed module for the course entitled "Study of 5G antennas". The radiation pattern of the studied antenna is taken in the E and H planes of the electromagnetic wave. For the purpose of the training and the study two commercially available antennas PN: SW19008IB77 and PN: SW19001IG97 have been measured. Fig.2a shows the radiation pattern of PN: SW19008IB77 in the E plane, obtained by means of the created experimental setup.

The next assignment of the module aims to acquaint students with the design and manufacture of antennas for the first frequency range of 5G. A dipole antenna has been designed and manufactured. Fig.2b shows its radiative pattern in the E plane.

In the third task, students perform a comparative analysis of the characteristics of factory antennas and antennas made and designed by them for the first frequency range of 5G.

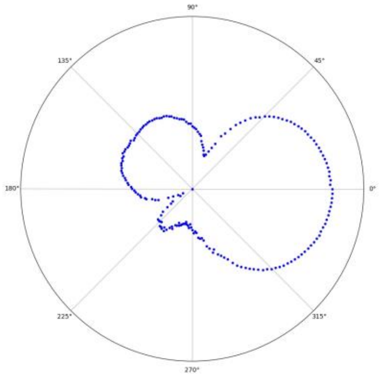

Fig.2 a) Radiation pattern of PN: SW19008IB77 in E plane

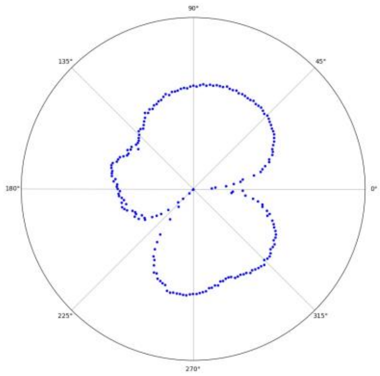

Fig.2 b) Radiation pattern of students' dipole antenna in E plane

To design and manufacture a dipole antenna, certain steps need to be followed. As it is known, MIMO functionality requires multiple antennas to exist simultaneously on the device and operate in the same frequency bands. The technology itself is already used in the 4G LTE network in the form of SU-MIMO and MU-MIMO (Single-user MIMO and Multiple-user MIMO).

To achieve high educational results in the design of a dipole antenna, the industry-leading software package Ansys Electronics Desktop Student is used, which offers free access to a wide range of multifunctional modules and simulators for training purposes. It includes various design and analysis modules such as Ansys HFSS, Ansys Maxwell, Ansys Q3D, and Ansys Icepak, which provide a wide range of options for studying the operation of antennas, radiofrequency devices (RF), microwaves, printed circuit boards, integrated circuits, as well as electromechanical devices (https://www.ansys.com/academic/students/ansys-electronics-desktop-student).

Students are trained on how to work with the multifunctional module Ansys HFSS (https://courses.ansys.com/index.php/courses/ansys-hfss-getting-started/), which is used to design the geometry of the dipole antenna and 3D simulation of the distribution of the electromagnetic field emitted by the antenna. This approach to learning allows students to evaluate the design of their antennas and refine them so that they work optimally in the first 5G frequency band before moving on to expensive antenna prototypes and real-world performance testing. In this way, students learned not only to design antennas and work with leading professional class multifunctional simulation software which provides them with meaningful enough practical training to bring them as close as possible to the needs of the industry. Only practical training allows students to be well prepared for their future careers.

In the laboratory of educational practice, the students prepared prototypes of the dipole antennas designed by them with means of the software by etching the geometry of the antennas on FR4 based printed circuit boards. The prepared prototypes of dipole antennas were measured and compared with factory ones through the experimental setup.

4 RESULTS

Twenty-seven students took part in the training of the course "Mobile Information Systems". Their results on the three assignments in the module "Study of 5G antennas" are shown in Table 1. The scores are in the first column from poor 2 to excellent 6 on a six-point scale. The module is divided into 3 tasks, and for each of the tasks, the number of grades is described. As an analysis of the table itself, it can be said that the evaluations are quite mixed, but also the students have shown that they have mastered the research of factory antennas as well as antenna design.

Table 1. Students' results

Grade	Module "Study of 5G antennas"		
	Task 1	Task 2	Task 3
2	0	1	3
3	7	9	8
4	10	9	3
5	5	3	4
6	5	5	9

5 CONCLUSION

In the course for design and analysis of the main characteristics of antennas operating in the first frequency band of 5G, created for the training of engineering students at Plovdiv University, one student will be able to study factory antennas, create and design an antenna and then make a comparative analysis of the characteristics of all antennas. The results of the research show that the prototype antennas of the students provide good coverage and can be used for 5G applications in the respective operating range.

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