An Educational Software for Digital Terrestrial Television Broadcasting (DTTB) systems to Engineering Students using Python

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***Abstract*—Digital broadcasting techniques in Digital Terrestrial Television which allow the use of single frequency networks (SFN), are developing rapidly and are useful in telecommunication networks. Consequently, the market demands qualified engineers with full knowledge on this field, particularly on the design and deployment of wireless networks and services. Also, many graduates from Electronic and Electrical engineering departments focus on wireless communications. Yet, the theoretical approach often becomes extremely complicated, and several technical terms might confuse students on this subject. This survey presents the "*Array Antenna Designer" (AAD)*, a GUI software tool for designing and optimizing array antennas in the UHF band, expected to give the students more information and technical skills on this field and help them understand theoretical concepts easier. It could also be a useful tool for specific panel antenna array topologies of various directions and channels and help the students obtain practical knowledge of the way the broadcast communications function in real-world applications.**

Keywords*—*DTT, GUI, Python, antenna array, radiation pattern

I. Introduction

Digital terrestrial television broadcasting is an important system, a primary method for governments to provide public radio and public television services and for citizens to obtain news and recreation information, so that they enjoy intellectual and cultural life [1].

In European Union the analog broadcasting system was replaced by the terrestrial digital video broadcasting television standard, DVB-T. A few years later, another standard developed in the EU, the second-generation digital terrestrial (DVB-T2) standard. The DVB-T2 standard has higher spectral efficiency. Higher spectral efficiency means that many programs can transmit together in the same spectrum or obtain higher audio/video quality for the same amount of programs and larger coverage area [2]. Digital television broadcasting systems can send image and sound data but also have capabilities such as disaster (DR Technologies) warning information [3].

Digital broadcast systems are based on single frequency networks (SFN). SFN is a network of transmitters that use the same frequency channel and carry the same data. This frequency is offered to all transmitters in a network that covers a specified service area. In SFN systems, the interference is being avoided by the COFDM modulation on which they operate. A significant benefit of the SFN network is that it is relatively easy to form a cluster of close stations on the same frequency [4].

According to the latest technological developments in wireless telecommunications and networks, many universities are adapting in their syllabus specialized courses to prepare modern electronic engineers or network engineers. Many colleges and universities teach "Electromagnetic Field," "Microwave Technology" and "Antenna and Radio Wave Propagation". Students who want a complete knowledge in the field of telecommunications should attend all of these courses. However, these courses, already enriched with detailed theoretical background, should also promote visual and intuitive teaching, in order to stimulate students' interest and this way gain as much as possible on this topic [5] [6].

Also, the use of simulation software tools is helpful for the practical understanding of telecommunication subjects and allows students to enhance their learning experience via the development of hands-on activities, designed sufficiently by their instructors [7]. This way Simulation Education (SE) brings out motivation for the hands-on learning activities developed by the instructors. Learning practices based on SE software tools draw the attention of academics and engineers, who see SE as a way to improve the training of today students and future field engineers. During the last two decades, the number of citations for "simulation education" increased from 47 in 2000 to 968 in 2018 and estimated to be approximately

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up to 1,200 in 2022[8].

To date, there are few efficient and economical radio frequency simulation tools to support teaching courses. However, there is need for more such simulation tools for the following reasons:

- An adequate number of simulation tools on the market are specialized on precision calculations and require an individual license. Such programs usually cost a lot and require deep knowledge of their features. This is a problem for engineers, researchers, and students who often need to use these software tools for their courses.
- Moreover, many study programs also have simulation tools that require expensive separate licenses. Also, several programs, for which universities run simulations, may lead to a complex process in sharing and analyzing data from other input formats.
- It also happens the design of an array antenna to contain many error simulations in order for the students to take into consideration and evaluate various array geometries and signal processing algorithms. For this reason, too, there is need for a more straightforward array antenna simulation in shorter run time.
- Furthermore, in array design many simulation programs focus on single-element antenna design and simulation, not an effective solution for an antenna array. It would be helpful for users to design the entire active antenna system (AAS), the azimuth antenna pattern and the total Gain (dBd).

The main contributions in this survey are listed as follows:

- Developing the python script in a Graphical User Interface (GUI) environment simplifies the antenna array system's design process. In addition, it allows students and academics to calculate the total dBd gain and extract the radiation diagram on horizontal plane. Also, the user selects the topology of the antennas according to the directions it should cover for a certain area.
- This simulation tool does not require any monthly payment, or subscription for any software or special license. Some students or mechanics can develop this tool with simple code knowledge in python.
- Additionally, the simulation tool code can run in all Integrated Development Environment (IDE) software applications and code editors or run as an executable file in Microsoft Windows.
- The use of the Tkinter standard GUI library is not random. Tkinter is an open-source, cross-platform widget toolkit used by many different programming languages to build GUI programs. It is a good choice because it is easy to learn, uses little code to make a functional desktop application and is pre-installed with a standard Python library.

The remainder of the paper is structured as follows. Section II includes related works using different programming languages and platforms. Section III introduces the methodology of application tools and the developed outcomes. Section IV surfaces the AAD simulation and presents the graphical environment. Section V analyzes two scenarios and experiment results drawn from the simulation. Finally, the conclusions are in Section VI.

II. Related Work

A. *Recent work on simulation-based education*

Several studies developed software tools in teaching areas and institutions for the further development of students in the field of telecommunications and networks.

Reference [6] presents a radio planning software tool for mobile networks currently used in Mobile Communications in telecommunications. The students use this tool to understand the implications of network elements and variations of the parameters of the different models used (radio propagation, traffic, network equipment). This simulation is implemented in Microsoft Visual C++ and works as a stand-alone application.

Reference [9] shows a simulator that is built in Java. Called J-Sim is used in Wireless Sensor Networks and helps the user understand these systems more quickly. The user can configure the top-level parameters of the Wireless Sensor Network, such as the number of sensors and target nodes. Also, the software requests the propagation model that is in use. The final step appears in a graphical form, in the signal-to-noise (SNR) ratio.

Reference [10] presents a simulation program made by MATLAB GUI. This software program applies to the teaching of two courses: one is “signals and systems,” and the other is “digital signal processing.” In such an environment, students can set radio parameters. In this way, users can observe output behavior graphically without the need to solve complicated mathematic integration or differential equations. This software analyzes signals generated from the “signal generation module” or the “signal collection module.”

In contrast to existing research, the present paper focuses on designing and calculating transmission parameters in the UHF band. It is also worth to mention that developing a GUI environment through the Python language and the Tkinter library is a good choice because it is a powerful programming language used by engineers, scientists, and students for computing tasks [11], [12], [13]. Finally, creating a script with these features does not require special equipment or preparation for institutions or universities.

B. *Benefits of simulation-based education*

The increase of personal computers and technological progress boost the simulation activities in many studies programs in higher education. Many research articles describe the experiences of simulation tools. For instance, in reference [14], they conclude that simulation allows students to gather hands-on experience in different realistic scenarios. Also, in operation management, simulation education facilitates the acquisition of analytical skills among students without owing a solid mathematical background [15]. The importance of simulation implies that problem-solving skills are present during learning, and the learners take an active role in the skill development processes. Simulation tools have features in the problem-solving of real-world situations and highlight their value, let learners use objects (virtual manipulatives), and conduct experiments to test hypotheses [16]. Simulations have a significant effect on learning goals. This kind of learning not only boosts students' motivation to create new knowledge but it also improves the understanding of topics studied at a mental level.

In addition, the theoretical instruction dimension facilitated by simulation tools programs could enhance students learning in the cognitive and affective domains and improve students' satisfaction [17].

III. Methodology

A. Python as a tool for system analysis

Python is a programming language for efficiently handling engineering and scientific computational tasks [18]. It is a universal language with unique built-in data types such as lists, libraries, and dictionaries. Mainly there are Python libraries for image processing (e.g., PIL), GUI development (e.g., Tkinter), Web programming (e.g., CGI), symbolic mathematics (e.g., SymPy), et. [11]. These packages and module extensions support the engineering branch by offering sufficient options to study, design, research and development (R&D), and education. Extensive use of all these tools requires knowledge of commands, syntax, functions, lists, and variables. It is essential that teaching and development of python are done efficiently without producing misuse of tools.

B. Graphical User Interface Programming (GUI)

The Graphical User Interface (GUI) is a programming environment that runs programs using Python and other languages. Python has a diverse range of options for GUI frameworks [18]. All these tools in GUI present many properties and functions that allow the creation of a user-friendly environment. Tkinter is the standard GUI library for Python. When combined with Tkinter, Python provides an easy way to create GUI applications. It provides a powerful object-oriented interface to the Tk GUI toolkit. It is a standard cross-platform UI library that makes creating a GUI much more accessible, the basic steps are presented in Fig.1

```
from tkinter import*
from PIL import Image, ImageTk
import tkinter as tk
import os

root = Tk()
root.wm_iconbitmap('tower.ico')
root.title("Array antenna designer (AAD)")

canvas = Canvas(root, width = 300, height =500 )
canvas1 = tk.Canvas(root, width = 1920, height = 1020, bg = "light blue")
canvas1.pack()
```

Fig. 1. The basic set of import Tkinter module and the creation of the main application window

C. Teaching approach

The simulation tool mentioned above does not require special programmed knowledge and techniques; on the contrary, it remains a user-friendly interface for either students or users. The teaching of wireless mobile communications can be enhanced through student interaction with the interface developed through a virtual learning environment.

By adding this tool to teach, there will be no significant changes to the student syllabus, nor will new hardware and software infrastructure packages be needed. It is something that all members of the class can easily use.

For the program to function correctly, the user must be able to define the antenna array data. The communication channel number in the UHF band is selected in the first step. The second stage chooses the number of directions in the horizontal radiation diagram. In the third stage, the user selects the number of antennas and bays that make up the active elements of the mast. In this way, having all the information in a single tool improves the understanding of the behavior of a wireless communication system

IV. Array Antenna Designer (AAD)

A. Main stages of the simulation program

An essential condition in this program is to give some basic transmission system parameters. This program calculates the gain of the phased array antenna (dBd) provided by the formula [20]. Also, the radiation pattern of the transmitting antenna is being calculated according to the number of directions. A panel antenna with a gain of 9 (dBd) is used as a reference antenna. Table I shows the specifications of the antenna panel that it uses.

A starting window revealing the workflow of the AAD software is shown in Fig.2. As soon as the tool starts the user will now have to enter the system parameters, such as the antenna gain, the number of communication channels, and the number of directions (one or two) of the antenna system. These parameters are necessary to calculate the total gain in an array antenna and the radiation antenna pattern of the horizontal plane.

TABLE I
Specifications of antenna panel in UHF band

Specifications	
Frequency range	470—806 MHz
Bandwidth	Any single UHF-TV channel
Impedance	50 ohms
VSWR	<1.1:1
Polarization	Horizontal
Maximum input power	500 watts (at 50° C)
Gain (dBd)	9 dBd (1220 x 458 x 229 mm), (915 x 364 x 204 mm)

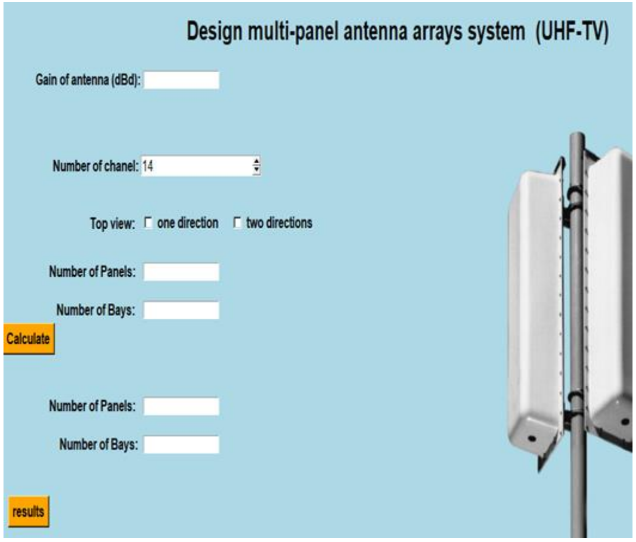

Fig. 2. The starting window of Array Antenna Design (AAD)

As mentioned above, the application features allow the calculation of the antenna array's total gain and depict the antenna array's radiation pattern. These calculations are implemented with basic programming commands, but knowledge of the telecommunications theory is necessary

V. Experimental Results and Evaluation

A. Simulations results

This section provides two examples of results of the GUI when inputting the set of parameters. These examples have realistic parameters in digital terrestrial television broadcast technology design.

In the first example, the gain of an individual element is selected. In this case, it is 9dBd. The operating channel, the antenna and the system's directions are selected from the predefined list (channel 14). Also, two-panel antennas (elements) are installed; essentially, there is a two bay panel antenna. After the above values are set, the calculate button is selected, and the total system gain is calculated based on the following formula (1).

$$G = 10log_{10}(N) + G_e \quad (1)$$

Where G is the array gain, N is the number of elements in the array; and Ge is the gain of an individual component [20]. Finally, the last two steps are repeated to design the radiation diagram in a new window, as shown in Fig.3.

In addition to these, there is the possibility of calculating (Effective Isotropic Radiated Power) EIRP which is a quantity that expresses the power of the transmit power of an antenna on earth; the formula is as follows [21].

$$EIRP = P_{TX} + G_{TX} - L_{TX} \quad (2)$$

Where, P_T is Transmit power (dBm), G_A is a transmitter antenna gain (dB), LTX is cable loss (dB).

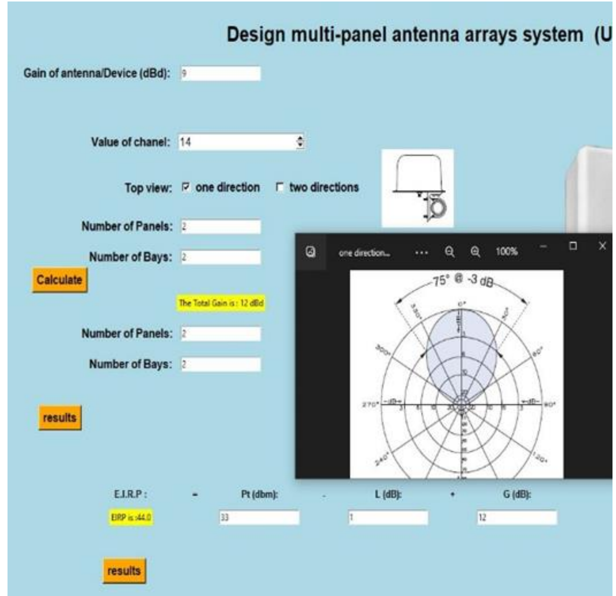

Fig.3. Experiment results of first example

In the second example, the same gain is selected as before. Also, the operating channel is chosen. In this case, the 24 channel is set. In addition, this time two directions are determined in the horizontal plane. Also, two-panel antennas (elements) and a bay panel antenna are installed. After the above values entered, the calculate button is being selected, and the total system gain is being calculated again, as shown in Fig.4.

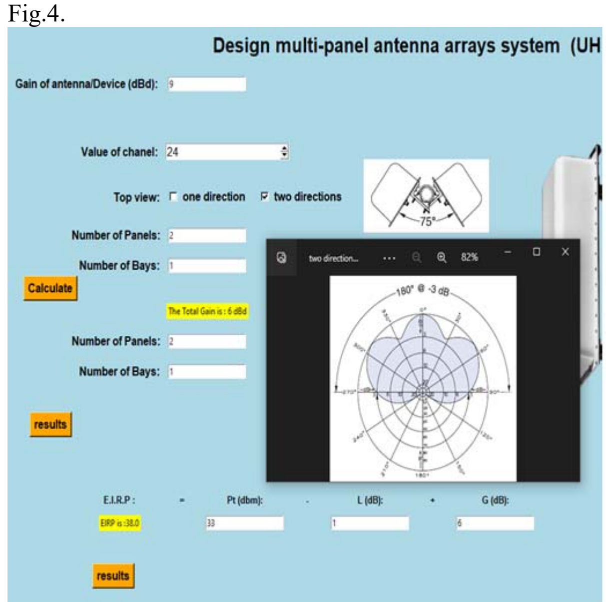

Fig.4. Experiment results of the second example

B. Experiment design

At the first step during the valuation 27 students, who completed the introductory wireless communication systems course at the Harokopio University of Athens and completed the simulation tool's theoretical part were selected.

They were asked to plan two array radiation patterns as presented earlier. The test has two scenarios that use the antenna device, 9 (dB), and the same channel value in 24. The first scenario describes planning an array antenna with two antenna panels and two bay elements in one direction. The second scenario describes two antenna panels in a bay element in two different directions.

Following this, students completed a questionnaire referring to their thoughts and created feelings about the simulation tool and their opinions about the pedagogical effectiveness of the software in teaching software engineering. Some of these questions were asked on a numerical answer on one to five scale, while other questions allowed students to write their responses in free text.

C. *Questionnaire results*

Students' feelings about AAD were generally positive, as presented in Table II. On average, students found the simulation easily understandable (3.6 rating out of 5) and relatively user-friendly (3.2). They also felt that it processes issues taught in the introductory wireless communications systems course, that they had taken (3.5). Most of them, agreed that AAD would be helpful for teaching radio planning concepts if included in the introductory wireless communication systems (3.2).

Furthermore, students responded positively to the available questions about ADD. Some students stated comment like the following: *"It does a good job excitingly improving the teaching process!", "It makes radio planning and design seem more useful for us in real-life issues and in a real workspace"*. Also, students wrote about how well the simulation teaches wireless communications in radio planning issues. *"It is fantastic to see how a project develops according to the selected appropriate covering materials and a specific area."* and "*I can experiment a lot and try several variations of building array antennas without paper and pencil!*".

Although most of the responses were positive since the students showed enough interest, there is always room for improvement in the application. The most negative response was that students didn't take any new knowledge on radio planning wireless systems (2.4). It's pretty apparent, however, that this software did not teach much new knowledge, since it was based on the theoretical background frequently discussed in lectures, and students have the general obligation to learn it. Moreover, other students were unhappy with other kind of issues, such as they could not print out their projects results. They also complained about the poor quality of the graphics analysis.

TABLE. II
QUESTIONNAIRE RESULTS

Question	1	1.5	2	2.5	3	3.5	4	4.5	5	**Avg**
How difficult/ easy? (1=most difficult, 5=easiest)	1	0	0	2	0	0	14	10	0	**3.6**
Is this interface user-friendly? (1=not at all, 5=definitely)	1	0	3	4	0	12	0	0	7	**3.2**
Are the topics related to those studied in class? (1=not at all, 5=definitely)	1	0	0	0	4	5	11	4	2	**3.5**
Incorporate into AAD course? (1=not at all, 5=very much so)	0	1	0	2	2	12	8	2	0	**3.2**
Offers new knowledge and new techniques? (1=not at all, 5=definitely)	2	0	8	12	0	0	3	0	2	**2.4**

VI. CONCLUSION

This survey aims to create software with inexpensive means, without financially burdening an educational institution, and utilize a well-known programming language to create a GUI code that will help instructors and students alike: This code script could benefit students in descriptively learning in the field of telecommunications. Using this educational software the students could get used to learning interactively. A graphical user interface allows the student to better understand and experiment on the theory of telecommunications by entering suitable values and selecting a button to get the results. The use of panel antennas - like in the two preceding examples presented- is an easy way to calculate the total gain of the antenna array. Also measuring the radiation pattern according to the selection data is faster. In the future, the described code and simulation tool may be an interactive educational tool that could develop more topics for analysis.

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