Research Article

The Development of Interactive Antenna Module for Wireless Communication Practical Assessment

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Abstract: *This research focuses on the development of an interactive antenna module to enhance hands-on learning in wireless communication, specifically within the DEP50063 Wireless Communication course at Politeknik Sultan Salahuddin Abdul Aziz Shah. Traditional teaching methods and outdated laboratory equipment have limited student's ability to fully understand antenna systems and wireless communication concepts. This problem has motivated the creation of an innovative antenna module that incorporates both omni-directional and directional antennas, modems and signal analysis tools to improve practical assessments. The objective of this innovation is to provide students with a comprehensive understanding of antenna characteristics, such as signal strength, coverage, and environmental factors, through interactive, real-world learning experiences. The developed module allows students to engage in experiments using modern equipment, facilitating the exploration of antenna performance in varying conditions and distances from the Base Transceiver Station (BTS). The results of these experiments showed that the directional antenna provided better performance in terms of higher download and upload speeds, emphasizing the importance of antenna type in optimizing wireless communication systems. The interactive module not only deepens student's- comprehension of theoretical concepts but also enhances their technical proficiency in real-world applications. This approach offers a significant benefit by bridging the gap between theory and practice, preparing students for industry demands. The findings demonstrate the module's potential in transforming wireless communication education, making it more engaging and practical. Overall, this innovation improves student learning outcomes and better equips them for future challenges in wireless communication.*

Keywords: Interactive antenna module; wireless communication; educational tool; hands-on learning; antenna characteristics.

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1. INTRODUCTION

To enhance hands-on learning in wireless communication, an interactive antenna module was developed for practical assessment in the DEP50063 Wireless Communication course. Introduced during the 2023/2024 academic session at Politeknik Sultan Salahuddin Abdul Aziz Shah, this module was specifically designed for semester 5 students in the Diploma in Electronic Engineering (Communication) program. The module focuses on Topic 4: Types of Antennas, particularly Radio Propagation Waves and aims to help students achieve Course Learning Outcome 2 (CLO 2) and Program Learning Outcome 5 (PLO 5) (PSA, 2024). By bridging the gap between theory and practice, this module enhances students' understanding of antenna concepts and wireless communication systems, making their learning experience more impactful and practical.

Antenna Characteristics is a key topic in the DEP50063 Wireless Communication course, requiring students to understand the fundamental concepts such as frequency, download and upload speeds, distance, coverage and environmental factors. However, the limitations of outdated laboratory equipment inhibited student's ability to explore modern antenna technologies effectively. This challenge highlights the need for modern or updated tools that provide better practical exposure with new experience and help students engage with advanced wireless communication concepts in another meaningful way.

Additionally, the conventional one-way teaching model restricts opportunities for interactive and practical learning, making it difficult for students to grab the complexities of antenna systems and their real-world applications. By transitioning to an interactive teaching framework that integrates modern tools and resources, students can gain a deeper understanding of antenna characteristics through hands-on activities. This approach not only enhances comprehension but also fosters critical thinking and problem-solving skills, better preparing students for real-world challenges in wireless communication that can fulfill the industry needs.

Antennas play a fundamental role in wireless communication systems, serving as critical components for transmitting and receiving signals. However, teaching and learning antenna concepts can be challenging due to the mathematical complexity and difficulty in bridging theoretical knowledge with practical applications. Studies have emphasized the importance of hands-on learning approaches to address these challenges and improve students' comprehension of antenna theories and real-world implementation (Crilly, 2014) (Espinosa et al., 2020).

Traditional lecture-based methods often fail to engage students effectively, leading to gaps in understanding essential concepts such as radiation patterns, impedance, and antenna efficiency. Innovative pedagogies like experiential learning, problem-based learning, and case-based learning have proven effective in enhancing students' engagement and technical skills. For instance, the incorporation of project-based activities, simulation tools, and experimental setups has been shown to help students connect theory with practice, thereby fostering deeper understanding and critical thinking (Chankong & Maneetien, 2018) (Espinosa et al., 2020) (Abulgasem et al., 2021).

One notable example is the use of real-world cases to demonstrate antenna properties, such as signal enhancement through unconventional setups or the effects of structural modifications on performance (Logeshwaran & Karthick, 2022) (Schwarz & Pratschner, 2023). These approaches encourage students to explore key parameters like frequency, coverage, and environmental factors, enabling them to design and test their own antennas while gaining hands-on experience (Chankong & Maneetien, 2018) (Zhang et al., 2020). Such methods not only make learning more interactive but also align with the demands of modern wireless communication industries, which require engineers equipped with both theoretical knowledge and practical expertise (Khan et al., 2022).

2. METHOD & MATERIAL

This research follows a well-defined methodology to create and assess an interactive antenna module aimed at enhancing practical assessments in wireless communication in Politeknik Malaysia. The process is outlined as follows:

1. Literature Review & Discussion: An in-depth review of relevant literature was conducted to explore the challenges faced in wireless communication education and the potential benefits of incorporating various antenna types in practical training. Based on the discussions with educators and industry professionals helped shape the objectives of the project.

2. Problem Definition & Objectives: During this phase, key issues, including the use of outdated laboratory equipment and low student participation were identified. Clear objectives were set to address these challenges by integrating practical hands-on learning experiences using the interactive antenna module.

3. System Design and Planning: The design of the system was found out, selecting appropriate components such as omni-directional and directional antennas, modems, laptops, speed test applications CellMapper and Android phones. A detailed integration plan was created to ensure effective assembly of the module for teaching purposes.

4. Software/Hardware Configuration: In this stage, the configuration of both hardware and software was carried out, including the installation and setup of modems, the antennas, mobile apps (speed test and CellMapper) and ensuring smooth communication between all components for optimal functionality.

5. Prototype Development: A functional prototype of the interactive antenna module was developed, incorporating both the hardware and software elements designed to meet the learning objectives and offer students an immersive experience.

6. Testing and Validation: The prototype has been carrying out thorough testing to verify its reliability, ease of use and compliance with educational goals. The system's performance was evaluated in practical scenarios to ensure it fulfilled the intended learning outcomes for both students and instructors.

7. Data Collection and Analysis: During practical sessions, data and feedback were collected from students and lecturers. This data was analysed to make sure the effectiveness of the interactive antenna module in enhancing student learning and engagement during wireless communication assessments.

8. Evaluation and Documentation: The trainer's success in achieving the course's learning objectives (CLO 2) and program outcomes (PLO 5) was evaluated. Comprehensive documentation of the development process, results and suggestions for future improvements was compiled for continued refinement of the module.

This innovation aims to enhance teaching and learning in wireless communication by integrating various antenna types, including omnidirectional and directional antennas, along with supporting tools like modems and analysis applications. Table 1 provides an overview of the main components, their quantities and its functions (Memon, Nisar, & Ahmad, 2019) (Dai et al., 2020) (George & Mary, 2020).

Table 1 : Main Components, Its Quantity Needed and Its Function

Component	Quantity Needed	Main Function
Omni Directional Antenna	1 Set	Think of an omni-directional antenna as a Wi-Fi sprinkler that evenly distributes signals in all directions. This ensures seamless connectivity for devices anywhere within its range, without needing manual adjustments.

Directional Antenna	1 Set	A directional antenna works like a Wi-Fi laser pointer, focusing a strong signal in one specific direction. This makes it highly effective for providing a stable connection in a targeted location, much like shining a focused beam of light on a distant object.
Modem	1 Set	A modem acts as the internet's translator. It transmits your device's requests to the internet and relays the responses back, enabling your computer to process and utilize the information efficiently. It serves as a critical link for internet communication.
Laptop	1 Unit	A laptop, equipped with the Ookla app, functions like an internet speedometer. It measures your internet speed, helping you understand if your connection is fast enough for activities like streaming or web browsing without any interruptions.
Speed Test Application	1 Unit	The Ookla Speed Test app evaluates your internet speed, like checking how fast your Wi-Fi connection is and helps to determine whether your internet is suitable for streaming, gaming, or other bandwidth-heavy activities.
CellMapper Application	1 Unit	CellMapper is a mapping tool that identifies cell tower locations and evaluates your phone's signal strength in different areas. It provides a visual representation of the best spots for optimal network performance.
Android Phone	1 Unit	An Android smartphone is essential for running the CellMapper app. After downloading and installing the app, the phone helps analyse signal strength and locate cell towers were enabling real-time network mapping and assessment.

To set up the interactive antenna module, start by preparing the components. Connect the omni-directional antenna to the modem. This antenna will broadcast Wi-Fi signals evenly in all directions, ensuring all devices in the surrounding area can connect seamlessly. Next, attach the directional antenna to the modem for focused, long-range signal testing. Position the directional antenna to aim at a specific area, as it concentrates the signal in one direction for optimal connectivity. The modem should be powered on and connected to the internet to facilitate wireless communication.

Set up the laptop and install the Ookla Speed Test app. This will act as a tool to measure the speed and stability of the Wi-Fi connection. Ensure the laptop connects to the Wi-Fi network broadcast

by the modem. For mobile signal testing, use the Android phone with the CellMapper app installed. This app will identify cell tower locations and display signal strength across different areas.

To measure readings, begin with the omni-directional antenna. Use the laptop to perform a speed test via the Ookla app, recording the internet speed and connection stability. Next, switch to the directional antenna and repeat the speed test, noting any differences in speed and signal quality in the focused direction. For mobile signal mapping, use the CellMapper app on the Android phone to observe the location of nearby towers and signal strength at various points. This step helps identify the best spots for network performance. By combining these tools and measurements, we can evaluate the effectiveness of the antennas and optimize wireless communication.

3. FINDINGS

The findings from this innovation in teaching and learning are derived from a series of hands-on activities where students engaged in wireless communication experiments using various antenna types, including omni-directional and directional antennas. Students explored signal transmission and reception while testing different configurations and setups to understand antenna functionality and performance. The experimental results, particularly focusing on signal strength and coverage, demonstrated that the directional antenna significantly enhanced signal range and stability compared to the omni-directional antenna. Feedback from students and staff was overwhelmingly positive, with students emphasizing how the practical activities deepened their understanding of theoretical concepts, and staff recognizing the value of the exercises in improving students' technical proficiency in wireless communication systems.

3.1 Hands-On Learning

In this hands-on activity, students will explore the setup and performance of a wireless communication system using different types of antennas. Initially, students will work with components such as omni-directional antennas, directional antennas, modems and supporting devices like laptop and smartphone. They will assemble the system step by step under the instructor's guidance, ensuring proper configuration of the components.

Once the setup is complete, students will measure the download and upload speeds as well as the distances to the Base Transceiver Station (BTS) under various conditions. Using tools like CellMapper and speed test applications, students will first map the location and signal strength of nearby BTS towers. They will then conduct tests using the omni-directional antenna and the directional antenna to compare performance metrics. The tests will measure download and upload speeds at different locations, demonstrating how antenna type influences wireless communication effectiveness.

Students will observe that the directional antenna provides a stronger and more focused signal, resulting in higher download and upload speeds compared to the omni-directional antenna. These practical activities will enhance their understanding of how antenna design and placement impact wireless performance, offering valuable insights into real-world communication systems.

3.2 Experimental Results: Download and Upload Speed, Location and Distance of Base Transceiver Station (BTS)

The experimental results highlight the relationship between download and upload speeds, the type of antenna used and the proximity to the Base Transceiver Station (BTS). Figure 1 shows the available BTS around Politeknik Sultan Salahuddin Abdul Aziz Shah and its detailed information as identified using the CellMapper application on a mobile phone. The BTS locations and their respective bands provide essential context for evaluating signal reception and network performance.

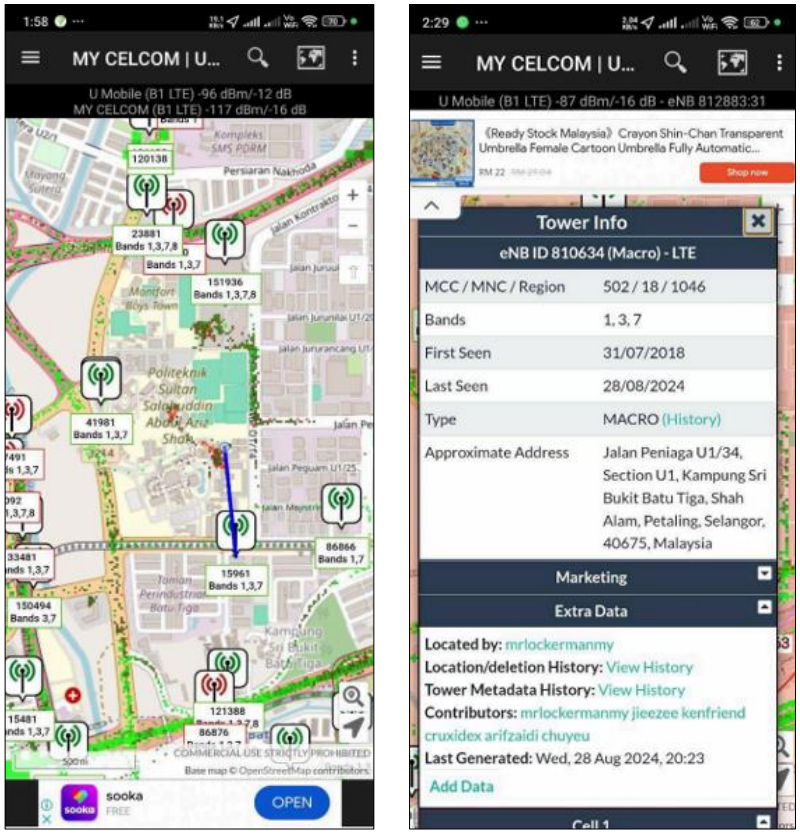
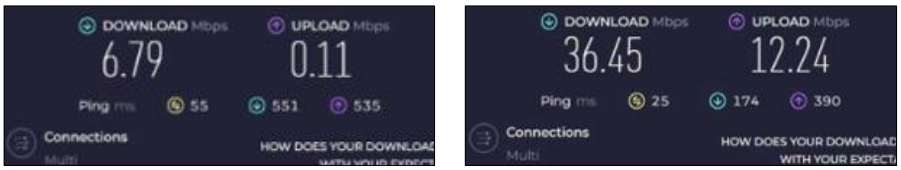


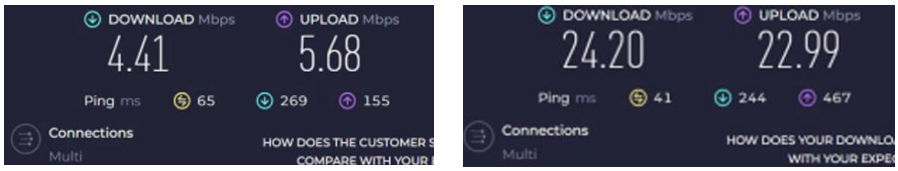
Figure 1 : The Available BTS and Its Detailed Information

The omni-directional antenna, designed to provide uniform coverage, demonstrated relatively low performance. Figures 2 and 3 illustrate the results of speed tests conducted using the Ookla Speed Test application on a laptop during both morning and evening sessions, providing insights into network performance variations over time. At Jalan Kontraktor U1/14, the download speed was recorded at 6.79 Mbps, while the upload speed was just 0.11 Mbps. These results, captured in Figure 2, indicate that while omni-directional antennas can provide coverage over a broad area, their signal strength is insufficient for high-speed data transfer when the device is farther from the BTS or faces environmental obstacles. This makes them less effective in areas with suboptimal network conditions.



Omni Directional Antenna Directional Antenna

Figure 2 : Speed Test During Morning Session



Omni Directional Antenna Directional Antenna

Figure 3 : Speed Test During Evening Session

In contrast, the directional antenna exhibited significantly better performance, as shown in Figure 3. At Jalan Peniaga U1/34, the download and upload speeds reached 36.45 Mbps and 12.24 Mbps, respectively. The directional antenna's focused signal reception allowed for improved signal strength and reduced interference, which enhanced performance. The proximity to the BTS at this location further contributed to the higher data rates, demonstrating the effectiveness of directional antennas in achieving better network performance.

The experiment also highlights the impact of distance from the BTS and time of day on network speeds. Locations closer to the BTS, such as Jalan Peniaga U1/34, achieved better performance due to stronger signal reception. Meanwhile, longer distances, such as Jalan Kontraktor U1/14, resulted in weaker speeds. Additionally, variations in speed between the morning and evening sessions suggest the influence of network congestion or usage patterns during peak hours.

In conclusion, the results show the important role of antenna selection and strategic BTS placement in optimizing network performance. Figures 1, 2, and 3 collectively demonstrate the advantages of directional antennas in providing higher speeds, particularly in areas with weaker signal strength or greater distances from the BTS. These findings emphasize the importance of aligning antenna design and placement with network requirements to ensure reliable connectivity.

3.3 Students and Staffs Feedback

The feedback gathered from students and lecturers evaluates the effectiveness of the Interactive Antenna Module as a teaching tool for wireless communication practical assessment. The analysis covers four main questions:

1. How effective is the module in helping students bridge the gap between theory and practice?
2. How effective is the module in enhancing student's understanding of wireless communication concepts?
3. How effective is the module in helping students apply theoretical knowledge in practical scenarios?
4. How effective is the module in improving student's overall grasp of wireless communication?

The results highlight strong positive feedback for the Interactive Antenna Module's role in wireless communication education. Students have expressed strong support for its effectiveness, with an outstanding percentage agreeing that it helps to enhance practical learning, knowledge exploration, theory application and understanding of wireless communication concepts.

Figure 4 presents the response statistics for Survey Question 1, which asks how effective the module is in helping students bridge the gap between theory and practice. Most respondents (82%) strongly agree that the Interactive Antenna Module effectively bridges the gap between theoretical concepts and practical application. This demonstrates high satisfaction with the module's role in enhancing applied learning. Another 17% agree, indicating room for further improvement to convert these responses into stronger agreement. Overall, the module is seen as highly successful in bridging theory and practice, with 99% of responses being positive.

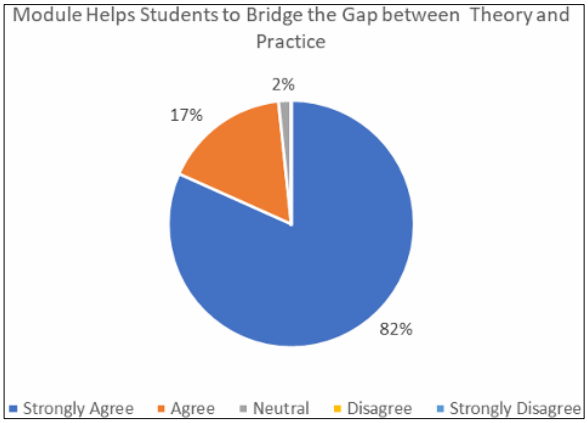


Figure 4 : Feedback for Survey Question 1

Figure 5 illustrates the response statistics for Survey Question 2, which examines the effectiveness of the module in enhancing student's understanding of wireless communication concepts. A significant portion of respondents (85%) strongly agree that the module effectively enhances their understanding of wireless communication concepts. This reflects strong confidence in the module's ability to deliver impactful learning outcomes. However, 15% agreed by suggesting that while the module is beneficial, there is potential for further improvements to encourage stronger agreement from this group. Besides this, the module is considered highly effective in improving understanding, with 100% of responses being positive.

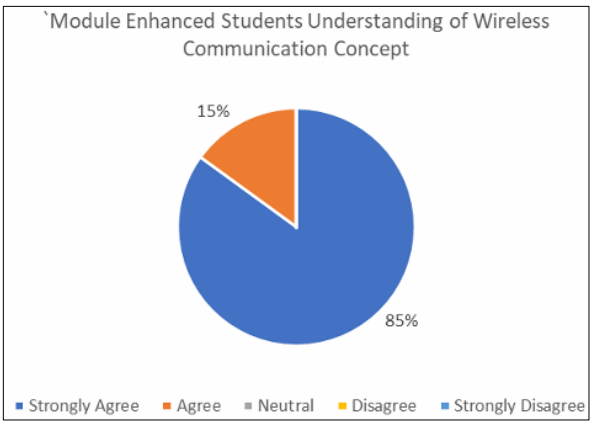


Figure 5 : Feedback for Survey Question 2

Figure 6 presents the response statistics for Survey Question 3, which addresses the module's effectiveness in helping students apply their theoretical knowledge to practical scenarios. The chart indicates that the Interactive Antenna Module is highly effective in helping students apply their theoretical knowledge to practical situations. Most of the respondent's express satisfaction with the module's contribution to practical learning, with no negative feedback received. Continued efforts should focus on maintaining high satisfaction levels and exploring ways to convert "Agree" responses into "Strongly Agree."

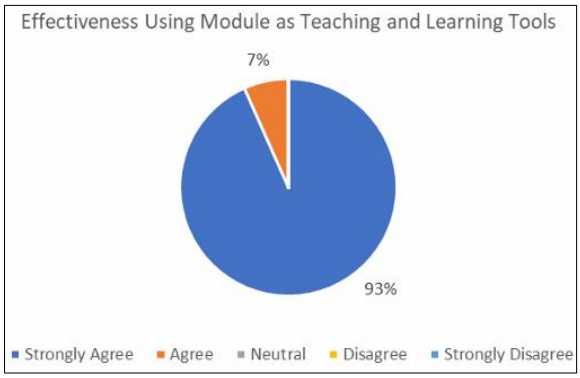


Figure 6 : Feedback for Survey Question 3

Figure 7 illustrates the response statistics for Survey Question 4, which asks how effective the module is in enhancing student's overall grab of wireless communication. A big majority of respondents (88%) strongly agree that the module encourages students to explore and expand their knowledge, demonstrating its significant impact on the student's understanding of wireless communication. A smaller percentage (8%) agrees, indicating that the module is still seen as beneficial but with potential for an even greater impact. Only a minimal portion (4%) remains neutral, suggesting the module could be further refined to reach all students.

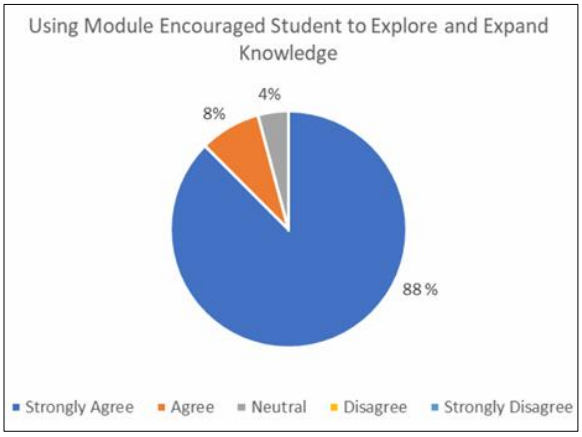


Figure 7 : Feedback for Survey Question 4

The data overall reflects the Interactive Antenna Module's success in meeting educational objectives, with an emphasis on maintaining and improving student engagement and understanding.

4. DISCUSSION

The findings of this study highlight several important aspects of using an interactive antenna module in wireless communication education. One of the key results was the comparative performance of the directional antenna and omni-directional antenna. The directional antenna demonstrated better performance than omni-directional antenna, which has higher download and upload speeds and better signal strength. This outcome supports the theoretical understanding that directional antennas are more effective in focusing the signal on a specific direction, resulting in stronger and more reliable connections, especially over long distances. In contrast, the omni-directional antenna, while designed to provide broader coverage, showed a decline in performance, particularly as the distance from the Base Transceiver Station (BTS) increased. This result emphasizes the trade-off between the broad coverage provided by omni-directional antennas and their reduced efficiency at longer ranges.

The proximity to the BTS was another significant factor affecting antenna performance. Both types of antennas experienced a decrease in signal strength and data speeds as the distance from the BTS increased. However, the omni-directional antenna was more affected by this distance, experiencing a drop in performance compared to the directional antenna. This finding verified the idea that while omni-directional antennas are useful for covering larger areas, they are not as effective at maintaining high performance in situations where the distance between the antenna and the BTS is considerable.

In terms of educational impact, the interactive antenna module had a clear effect on student learning outcomes. By providing hands-on experience, the module allowed students to observe how different antenna types impacted wireless communication performance. These practical helped students better understand theoretical concepts such as signal strength, range and data speed. Feedback from students indicated that the interactive nature of the module was highly beneficial, as it bridged the gap between theory and practice, allowing them to apply their knowledge in real-world scenarios. The module's ability to engage students in a more interactive and dynamic learning environment contributed significantly to their technical knowledge and problem-solving skills in wireless communication.

Overall, the findings suggest that the interactive antenna module not only improved the understanding of antenna performance in wireless communication systems but also enhanced the educational experience for students. By combining theory with practical application, the module helped students gain a deeper understanding of how antennas function in different scenarios, leading to improved learning outcomes in the field of wireless communication.

5. CONCLUSION

In conclusion, the development of the interactive antenna module for wireless communication practical assessments proved to be a valuable educational tool, enhancing student's understanding of antenna performance and wireless communication principles. The hands-on approach allowed students to directly observe the differences in performance between directional and omni-directional antennas, support theoretical concepts and provide practical experience in real-world applications. This innovation demonstrated its potential in bridging the gap between theory and practice and able to offer a dynamic learning experience that improved student's technical knowledge and problem-solving skills in wireless communication.

However, several challenges were identified during the implementation of this module. One of the primary challenges was the limited coverage and signal range, especially for the omni-directional antenna, which impacted performance at longer distances. Additionally, while the module provided valuable insights into antenna practice, some students struggled to fully grasp the technical aspects without additional support or guidance. This highlights the need for more in-depth instructional materials and step-by-step guides to maximize the learning potential of the module.

To improve the module, future iterations could focus on enhancing the antenna performance by integrating more advanced technology, such as higher-powered antennas or adjustable settings that simulate different environmental conditions. Additionally, incorporating more interactive features, such as real-time performance tracking or automated feedback, could further engage students and provide immediate insights into their understanding by expanding the module to include more diverse antenna configurations and wireless technologies would also allow for a broader exploration of wireless communication systems, offering a more comprehensive learning experience.

Overall, while there are challenges to address, the interactive antenna module represents a highly effective innovation in wireless communication education, with significant potential for clarification and expansion in the future.

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