Project plan for degree project

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ET2606: MSc. THESIS IN ELEC. ENG. WITH EMPH. ON TELECOM. SYS.

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Title	Enhancing Physicla layer Security through Advanced Techniques for DOA Estimation Under Doppler Shift in Directional Modulation Systems	
Classification	Doppler Shift, Directional Modulation, Physical Layer Security	

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1 Introduction

In the ever-evolving domain of wireless communications, the necessity for robust security measures has become more crucial than ever. As dependence on wireless networks grows, so does the risk of unauthorized access and eavesdropping [1]. These security threats compromise the confidentiality of sensitive data and pose significant risks, including data interception and service disruption [2]. This challenge is particularly significant for both current and future wireless applications, especially as the industry transitions to more advanced systems like 5G and beyond [3].

To mitigate these security concerns, Physical Layer Security (PLS) has emerged as a promising approach. PLS exploits the inherent properties of the wireless channel, such as fading and interference, to enhance security without relying exclusively on conventional cryptographic techniques [4]. A notable innovation within PLS is Directional Modulation (DM), a technique that facilitates the transmission of confidential messages in a specific spatial direction while deliberately distorting the signal in other directions, thereby reducing the likelihood of interception by unauthorized entities [5].

However, both DM and Direction of Arrival (DOA) estimation can be significantly affected by the Doppler effect, particularly in high-mobility environments such as high-speed railways and vehicular communications [6]. The Doppler shift alters the frequency of received signals as users move, leading to errors in DOA estimation [7]. Such inaccuracies can weaken the effectiveness of DM, increasing the risk of unauthorized interception [8].

Accurate DOA estimation is essential to ensure the security of DM transmissions [9]. When DOA estimations are incorrect due to Doppler shifts, beamforming algorithms may fail to direct signals accurately, thereby exposing vulnerabilities that can be exploited by eavesdroppers [4]. Thus, precise DOA estimation is not only critical for effective DM implementation but also for maintaining the overall security of wireless communication systems [10].

Despite significant advancements in PLS and DM technologies, challenges remain. Existing techniques for estimating Doppler shifts and DOAs in high-mobility scenarios often lack the necessary accuracy and reliability [11]. This underscores the need for enhanced solutions capable of mitigating the disruptions caused by Doppler shifts while ensuring the integrity and security of wireless communications [10].

In conclusion, while DM offers a promising avenue for improving PLS, the challenges associated with Doppler shifts highlight the need for further research and technological advancements [2]. Addressing these issues is critical to the development of secure and reliable wireless communication systems that can meet the demands of modern applications [8].

2 Background

The integration of DM techniques with DOA estimation methods is crucial, especially given the challenges posed by Doppler shifts in environments with high mobility, such as those encountered in vehicular networks. Existing literature has primarily focused on the individual aspects of DM and DOA estimation, often overlooking the intricate relationship between these technologies and their collective impact on communication reliability and security.

The studies reviewed highlight that while DM offers a promising approach to secure wireless communications by distorting transmitted signals in undesired directions, the performance of these systems can be severely hampered by Doppler effects associated with rapid movement [5]. Furthermore, the current methodologies for Doppler shift estimation, such as those utilizing maximum likelihood functions and correlation techniques, often fall short in mobile scenarios where the channel characteristics can vary rapidly [4]. This presents a clear need for advanced techniques that not only estimate DOA but also compensate for the Doppler shift, thereby enhancing both the accuracy of signal reception and the integrity of the transmitted information.

Incorporating approaches such as instantaneous frequency estimation and least squares optimization could offer a robust framework for tackling these challenges. Recent advancements in machine learning for channel estimation and mobility prediction further highlight opportunities for innovative contributions [2]. By exploring the interdependencies between DOA estimation and Doppler shift management in DM systems, our research has the potential to enable resilient and secure wireless communication protocols, essential for the next generation of mobile networks.

3 Related Work

Several studies have explored the implications of Doppler shifts on DOA estimation, but most have concentrated on conventional antenna systems without addressing the unique challenges posed by DM systems, particularly in the context of physical layer security. For instance, Jeng et al. [1] presented a method for Doppler shift estimation in Orthogonal Frequency Division Multiplexing (OFDM) systems, utilizing spatial signatures to enhance DOA estimation accuracy under mobility conditions. Their work demonstrated that compensating for Doppler shifts could significantly improve the performance of smart antenna systems, yet it did not consider the security implications inherent in DM systems.

In the realm of DM systems, the research by Ramos et al. [8] highlighted the use of instantaneous frequency estimation combined with least squares minimization for DOA estimation in acoustic signals, indicating potential applications of similar techniques in wireless communications. However, this study did not focus on how these methods could enhance physical layer security against eavesdropping, which is a critical aspect for DM systems.

Furthermore, Zhong et al. [4] emphasized the need for accurate channel models that incorporate mobility effects for high-speed railway communications, highlighting various Doppler estimation techniques. These insights could be adapted for DM systems, but the implications for security in such contexts remain underexplored. Lastly, Ding and Fusco [5] provided a comprehensive review of DM technology, discussing the challenges of implementing secure communication in the presence of mobility and the necessity for high-precision DOA measurements. Their findings underscore the necessity for further research into advanced DOA estimation techniques that can effectively handle Doppler shifts in DM systems, especially in the context of enhancing physical layer security.

In summary, while previous research has made strides in understanding the impact of Doppler shifts on DOA estimation, there remains a significant gap in addressing these challenges specifically within the framework of DM systems and their security implications. This thesis aims to fill this gap by exploring advanced techniques for DOA estimation under Doppler shifts, ultimately enhancing the security and reliability of wireless communications in dynamic environments.

3.1 Ethical, societal and sustainability aspects

This research focuses on "Advanced Techniques for DOA Estimation Under Doppler Shift in Directional Modulation Systems" and is conducted through MATLAB and Python-based simulations. As it does not involve real-world data or human participation, it raises minimal ethical concerns.

The study addresses key challenges in wireless communications, such as the impact of Doppler shifts on DOA estimation and their effect on physical layer security. By tackling these issues, it aims to improve the reliability and security of modern wireless systems.
The research contributes to societal benefits by enabling secure and accurate communication in dynamic environments like autonomous vehicles, IoT networks, and smart cities. It helps mitigate risks such as signal interception and interference, fostering safer and more reliable connectivity.

In addition, the study emphasizes sustainability by developing computationally efficient algorithms that optimize resource use, reduce energy consumption, and minimize the environmental impact of wireless systems. These efforts support the long-term resilience of communication technologies, ensuring they can adapt to future demands while preserving resources.

4 Aim and objectives

4.1 Aim

To develop and evaluate a robust joint Doppler-DOA estimation framework that enhances the accuracy of DOA estimation and improves physical layer security performance in mobile wireless communication systems.

4.2 Objective

- To analyze the impact of Doppler shift on physical layer security through a comprehensive literature review.
- To analyze the impact of Doppler shifts on traditional DOA estimation algorithms in dynamic scenarios.
- To design and implement a joint Doppler-DOA estimation algorithm.
- To evaluate the proposed framework's performance under varying operational conditions.
- To assess the feasibility of the proposed system for real-time implementation and its implications for physical layer security

5 Research questions

RQ.1 How does varying Doppler shift impact the accuracy of traditional DOA estimation algorithms?

Justification:
In DM systems, precise beamforming and dependable communication are made possible by the precision of DOA estimation. The performance of conventional DOA estimate algorithms can be significantly harmed by Doppler shifts, which are introduced by frequency and phase distortions brought on by relative motion between the transmitter, receiver, or eavesdropper. This study aims to determine the limitations of these algorithms and create methods to lessen the effects of motion-induced distortions by examining how different Doppler shifts impact them. The results will improve DOA estimation's resilience in dynamic wireless settings, especially for applications like secure wireless systems, drone networks, and automobile communications.

RQ.2 How does the accuracy of joint Doppler-DOA estimation affect physical layer security performance?

Justification:
To reduce the possibility of eavesdropping and improve secure communication, physical layer security depends on accurate channel state information. Tracking motion and spatial signal properties is made possible by joint Doppler-DOA estimation, which is essential for safe beamforming and null-steering in dynamic situations. The trade-offs between system complexity and eavesdropping resilience will be revealed by examining how estimation accuracy affects security performance. By establishing standards for creating reliable joint estimating methods, this study hopes to further the creation of safe and flexible wireless systems in high-mobility and

dynamic threat situations.

6 Method

6.1 Literature review

This section explores the existing research in DOA estimation, Doppler shift compensation, and directional modulation systems, focusing on their relevance to mobile wireless security. Literature is sourced from reputable databases such as IEEE Xplore, Google Scholar, ScienceDirect, and Scopus using key terms like "DOA estimation," "Doppler shift," "mobile wireless security," and "directional modulation." Current DOA estimation techniques are reviewed to identify their limitations in mobility scenarios, emphasizing the challenges posed by Doppler shifts. Doppler shift compensation methods are analyzed to highlight advancements in mitigating motion-induced distortions. Joint estimation approaches, particularly in mobile and multi-source scenarios, are assessed for their ability to combine spatial and frequency-domain information. Additionally, the security implications of these techniques in DM systems are evaluated to establish a strong foundation for addressing challenges in mobile wireless environments.

6.2 Simulation Framework

The proposed methods are evaluated using a simulation framework developed in MATLAB. The framework incorporates signal model generation, including Uniform Linear Array (ULA) geometry, Doppler shift modeling for mobile scenarios, and environmental noise and interference modeling with multiple signal sources. Performance metrics such as DOA estimation accuracy, Doppler shift estimation precision, are used to assess the system.Additionally, physical layer security metrics such as signal-to-interference-plus-noise ratio (SINR), bit error rate (BER) under eavesdropping conditions are measured to see systems performance. This framework allows for a comprehensive evaluation under varying operational conditions, ensuring robustness and reliability in dynamic wireless environments.

6.3 Performance Analysis

The system's effectiveness is analyzed under diverse operational conditions. Estimation accuracy is assessed using metrics such as Mean Square Error (MSE) for DOA estimation, Doppler shift estimation precision, with a performance comparison against existing methods. Physical layer security is evaluated by examining Bit Error Rate (BER), Signal-to-Interference-plus-Noise Ratio (SINR) and Secrecy Capacity to assess the system to maintain communication integrity and effectiveness of proposed security mechanism. Robustness is tested by analyzing the system's behavior under varying SNR conditions,and multi-source scenarios. The approach includes comparative evaluations against existing methods to validate efficiency of the algorithm.

7 Expected outcomes

- Exploring the effects on physical layer security due to Doppler shift.
- Identification of limitations in existing DOA estimation techniques under mobility and Doppler shift conditions.
- A validated joint Doppler-DOA estimation algorithm with improved accuracy and robustness in dynamic wireless environments.
- Comprehensive performance metrics, demonstrating enhanced DOA estimation precision and efficiency.
- Practical insights into the real-time applicability and requirement of the proposed system, contributing to secure physical layer security and reliable wireless communication systems.

8 Time and Activity Plan

The plan is to keep updating our supervisor about our progress in each step towards the thesis. By having the virtual meetings and contacting through the emails regarding the doubts about the thesis. Using the feedback of the supervisor in updating the project accordingly. The final thesis

Draft is submitted to the supervisor for evaluation. If there are any corrections needed, they will be made in the report based on feedback.

Table1 : Timeline and Implementation Plan

TASK	DURATION	CALENDAR WEEK
Finalizing thesis topic	1 week	Week 2
Study of literature	3 weeks	Week 3,4,5
Writing of proposal	1 weeks	Week 6
Submission of proposal	1 week	Week 7
Exploring the effects on physical layer security	1week	Week 8
Analysing the DOA estimation under Doppler effect	2 weeks	Week 9,10
Proposal of algorithm and setup simulation environment.	3 weeks	Week 11,12,13
Analysing and Evaluating the performance of the proposed model.	3 weeks	Week 14,15,16
Writing of Thesis draft	2 weeks	Week 17,18
Thesis draft submission	1 week	Week 19
Opponent draft submission	1 week	Week 20
Final thesis submission	2 weeks	Week 21,22

8.1 Supervision plan

The supervision plan involves regular updates and guidance sessions with the supervisor, conducted preferably on-campus or virtually through platforms such as Google Meet or Zoom.

These meetings provide opportunities to update the supervisor on project progress and to seek advice for solving problems effectively. The insights and information gathered during these sessions are integral references for implementing the thesis work.

During the entire process of the project's development, encompassing both the planning phase and an extensive review of relevant literature, we meticulously documented every aspect. All project-related documents are submitted for the supervisor's approval. Subsequently, after considering the supervisor's feedback, necessary updates are made to the project report. The final thesis draft is then submitted to the supervisor for comprehensive review.

Moreover, the plan emphasizes open communication with the supervisor regarding our perspectives on different aspects of the thesis. This collaborative approach ensures that our views are considered alongside the best suggestions provided by the supervisor. In cases where our input has not been discussed, we make it a point to include our insights during the discussions and proceed based on mutual agreement. This iterative process allows for a comprehensive and refined development of the thesis.

9 Limitations and Risk Management

Risk	**Impact**	**Proposed Solution**
Time constraints	High	Complete each task as per the time plan
Student illness	Medium	Taking care of ourselves.
Compatibility issues between different technologies used in the simulation setup	Medium	Thoroughly research and select technologies that have proven compatibility. Allocate additional time for integration testing and troubleshooting.
Challenges in accurately modeling real-world mobile network scenarios	Medium	Collaborate with industry experts and researchers to validate the simulation scenarios.
Not getting expected outcomes	High	Taking supervisor help to get on the right path.
Visa expiry	Medium	Sticking to the schedule

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