Course Projects

Wireless Communication Principles and Mobile Networks

2025 Spring

Projects Overview

- There are 10 projects in total. Team up and choose your project. Each project can be chosen by only one team.
- Each team consists of 3-5 members.
- Projects have basic tasks and extension tasks. Extension tasks have bonus scores **(+X%)**.
- Each project has a difficulty factor and bonus score. They all contribute to your final score.
- The scores are given according to the performance.

Part I. Project 1-5

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Supervisor： Prof. Meng Jin

Teaching assistants： Mingqi Xie, Tingchao Fan, Huangwei Wu, Bolin Chu and Qianwu Chen

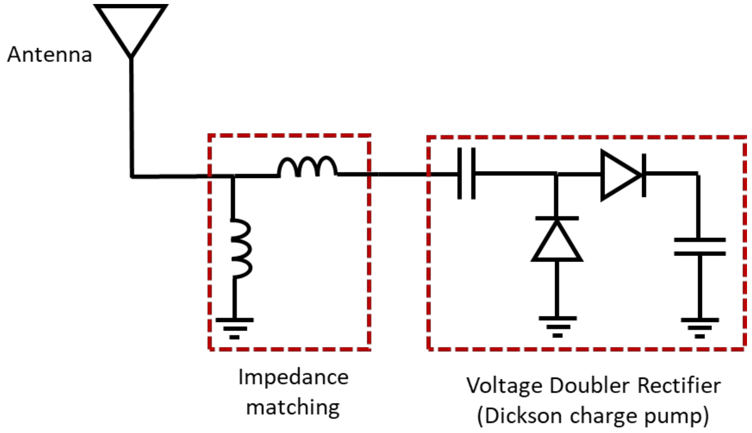
Project.1 Wireless Energy Harvesting

Difficulty factor： **1.0**
Task feature: software design & hardware design

Project introduction：

Wireless energy harvesting plays an important role in low-power Internet of Things (IoT) applications. It can convert ubiquitous high-frequency electromagnetic waves in space into DC voltage, thereby powering low-power IoT devices. The basic element of wireless energy harvesting circuit is a multi-stage rectifier, which takes high-frequency sinusoidal/cosine signals as input and outputs DC signals. When combined with impedance matching circuits and connected to an antenna, it forms a complete front-end of the wireless energy harvesting circuit. This project aims to explore a series of properties of rectifiers through simulation, design, and practical measurements.

A Reference Design:



Project.1 Wireless Energy Harvesting

Task List and Scores

1. Build and successfully simulate a one-stage rectifier circuit in ADS (Advanced Design System) (40%)
2. Extend the voltage multiplier rectifier circuit to higher stages, and investigate through simulation the relationships between energy efficiency, open-circuit output voltage and number of stage (30%)
3. Use EDA tools to create the schematic diagram and PCB layout for a three-stage rectifier circuit （30%）
4. Fabricate the PCB layout for the three-stage voltage rectifier circuit and perform practical testing of its energy efficiency and open-circuit output voltage (Bonus +20%)

Note

1. Reference designs are available for tasks 1, 2

Project.2 Parallel Decoding Technique for LoRa

Difficulty factor： **1.0**
Task feature: software design

Project introduction :

LoRa has become a promising Low-Power Wide Area Network (LP-WAN) technology for connecting a vast number of IoT devices. However, as IoT deployments grow denser, uncoordinated transmissions lead to frequent collisions. The existing MAC/PHY design of LoRaWAN lacks effective collision recovery mechanisms, causing performance to decline as the network scales.

This project addresses LoRa collisions at the physical layer, enabling parallel decoding of LoRa transmissions. The goal is to separate overlapping signals by leveraging both time-domain and frequency-domain characteristics. The approach is based on two key observations: (1) symbol edges within the same frame follow periodic patterns, whereas those from different frames are typically misaligned in time; (2) within a symbol, the LoRa signal frequency increases continuously, but abrupt changes occur at symbol edges.

Project.2 Parallel Decoding Technique for LoRa

Task List and Scores

1. Monitor channel activity and align starting edges of collided LoRa packets. (30%);
2. Extract the unique features of each packet (40%);
3. Decouple the collided packets (30%);
4. * Implement an online version of this system (+20%).

Notes

1. Task 1,2,3 only requires simulated packets

Project.3 Vision-based Acoustic Multipath Estimation

Difficulty factor： **1.05**
Task feature: software design

Project introduction :

Multipath channel estimation not only plays an important role in wireless communication for mitigating interference but also serves as a critical enabling factor in sensing technologies. Traditional channel estimation methods rely on collaborative signal exchanges between transmitters and receivers, limiting their applicability in scenarios where pre-established communication links are unavailable. Recent advances in computer vision, however, offer a promising alternative by enabling real-time multipath estimation with unilateral participation. For instance, using a stereo camera to reconstruct 3D spatial maps between transceivers, ray-tracing simulations can be performed to infer wireless signal propagation paths. This vision-based approach allows multipath channel prediction at the transmitter or arbitrary viewpoints, significantly enhancing deployment flexibility. In this project, we aim to develop a vision-based multipath estimation pipeline and evaluate its performance on embedded devices in practical environments. While the proposed method is not limited to signal types, we prioritize acoustic waves due to their lower propagation speed, which amplifies the discernibility of multipath delays compared to electromagnetic signals.

Project.3 Vision-based Acoustic Channel Estimation

Task List and Scores

1. 3D reconstruction with binocular camera. (20%)
2. Estimate the multipath channel based on the reconstructed 3D model with ray tracing. (20%)
3. Leverage AI model to accelerate the pipeline. (20%)
4. Implement the pipeline on Raspberry Pi and optimize for the delay. (40% + 10% Bonus)

Notes

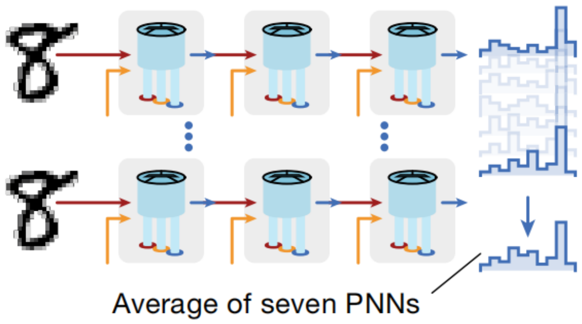
1. In Task 3, hints will be provided by TA.
2. In Task 4, basic points are given as long as the algorithm works correctly on Raspberry Pi, and extra points are given based on the optimized delay.
3. The Stereo camera and the Raspberry Pi will be provided by TA.

Project.4 The simulation model of the response of physical components based on deep learning

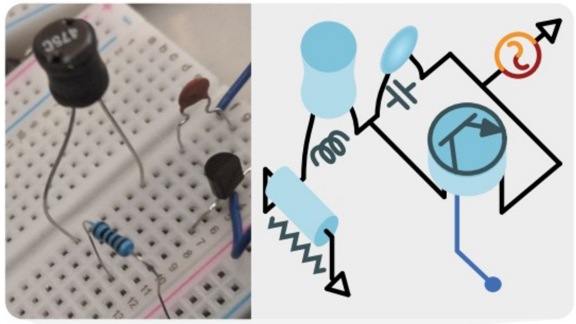
Difficulty factor： **1.1**
Task feature: software design

Project introduction：

Inspired by the rapid conversion of signals by physical components, the **physical neural network** constructed based on the fast and energy-saving physical conversion of physical components provides new possibilities for broadening the application of deep learning models. However, the performance of the physical neural network is **limited by the gap between the forward transmission of the model training process and the reality**. In this project, we need to build a simulation model of the response of physical components based on deep learning. Specifically, we need to use **MATLAB** to generate a large number of random currents as the **input current** of the circuit, and use **Advanced Design System(ADS)** to generate the corresponding **output current** of the circuit. Based on the input current and its corresponding output current, **a traditional neural network is constructed to simulate the characteristics of the circuit**.



[1]



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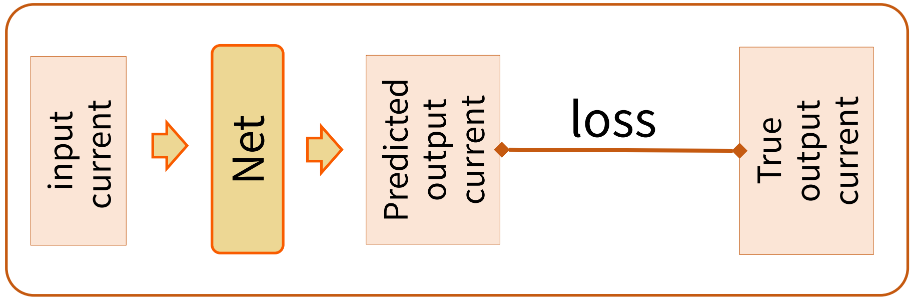


Project.4 The simulation model of the response of physical components based on deep learning

Task List and Scores

1. Use MATLAB/Python to generate a large number of random input currents. (5%)
2. Use ADS to build the electronic circuits (one from [1], and one without reference to [1]) and generate the output current corresponding to the input circuit. (25%)
3. Design characteristic simulation models of physical components based on deep learning. And design a training framework to implement simulation of physical component characteristics based on the above model. (65%)
   Reminder: the current waveform used in training needs to be different from the current waveform used in testing.
4. Use trained characteristic simulation models to implement simple classification tasks. (5%)

Notes

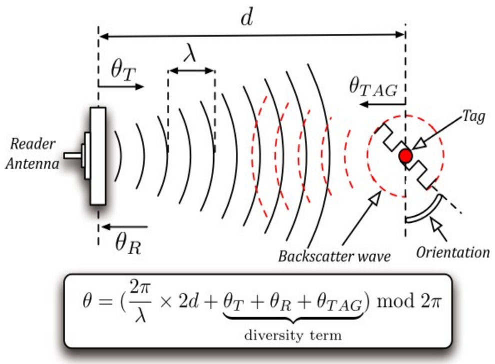
1. Reference [1]: Deep physical neural networks trained with backpropagation.

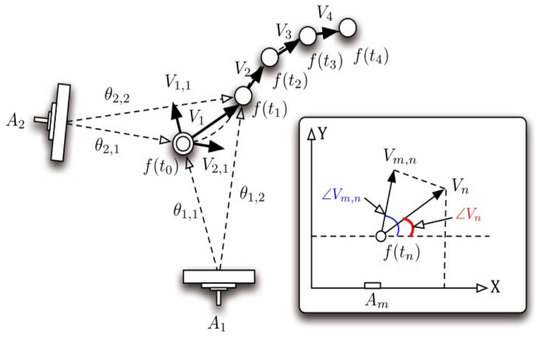
Project.5 Phase-based Backscatter Tracking

Difficulty factor： **1.05**
Task feature: software design

Project introduction：

Radio Frequency Identification (RFID) is a rapidly developing technology that uses RF signals for automatic identification of objects. RFID systems consist of a reader and a tag that communicate via a backscatter radio link, with the tag modulating its data on the backscatter signals using ON-OFF keying by changing its impedance. One of its applications is the accurate tracking of mobile objects, which can primarily be achieved through phase-based and RSSI-based methods. The key advantage of phase-based tracking lies in its high resolution. This project aims to develop a phase-based RFID tag 2D tracking system for both simulation and real-world environments. By utilizing variations in phase differences between co-located or distributed transceiver antennas, the system will accurately track the position of RFID tags in two-dimensional space, providing a robust solution for high-precision tracking applications.





Project.5 Phase-based Backscatter Tracking

Task List and Scores

1. Based on the principle of RFID phase tracking, develop a phase-based RFID tag 2D tracking system in a simulation environment (with co-located transceiver antennas). You may refer to the paper: Tagoram[1]. (40%)
2. Expand from commercial devices to a general backscatter tag system with separate transmit and receive antennas. (30%)
3. Improve performance under more challenging interference conditions, such as increased noise, multipath environments, and non-static backgrounds. （30%）
4. Set up a practical experimental testing platform to collect real data and evaluate the above algorithms. (Bonus +20%)

Note

1. Tagoram: real-time tracking of mobile RFID tags to high precision using COTS devices. In Proceedings of the 20th annual international conference on Mobile computing and networking (MobiCom '14).

Part II. Project 6-10

Part II. Project 6-10

Supervisor： Prof. Xiaohua Tian

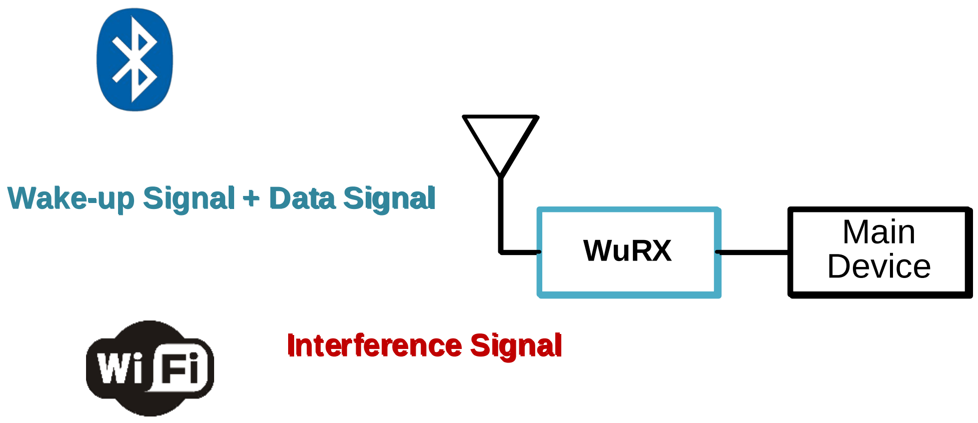
Teaching assistants： Fengyuan Zhu, Jiazhen Lei, Wenhui Li, Zemin Yang, Yibin Deng, Yushu Wang

Project.6 Wakeup Receiver for Servo Control

Difficulty factor： **1.05**
Task feature: hardware design

Project introduction：

A wake-up receiver (WuRX) is a miniature radio that wakes up the main device on demand. For instance, a smartwatch with a wake-up receiver can maintain low idle power while staying responsive to smartphone notifications. This enables low latency and low power for IoT. However, such receivers face interference in the 2.4 GHz band due to pervasive Wi-Fi and BLE signals. This project explores an anti-interference wake-up receiver design for the Wi-Fi band.



Project.6 Wakeup Receiver for Servo Control

Task List and Scores

1. Simulate our WuRX circuit in ADS and MATLAB. (40%)
2. Design and implement a small WuRX circuit based on our existing circuit structure. (40%)
3. Achieve better than -40 dBm receiver sensitivity and -20 dBc anti-interference capability. (20% +**20% Bonus**)
4. *Use commercial Wi-Fi device to wake up the WuRX. **(+20% Bonus)**

Notes

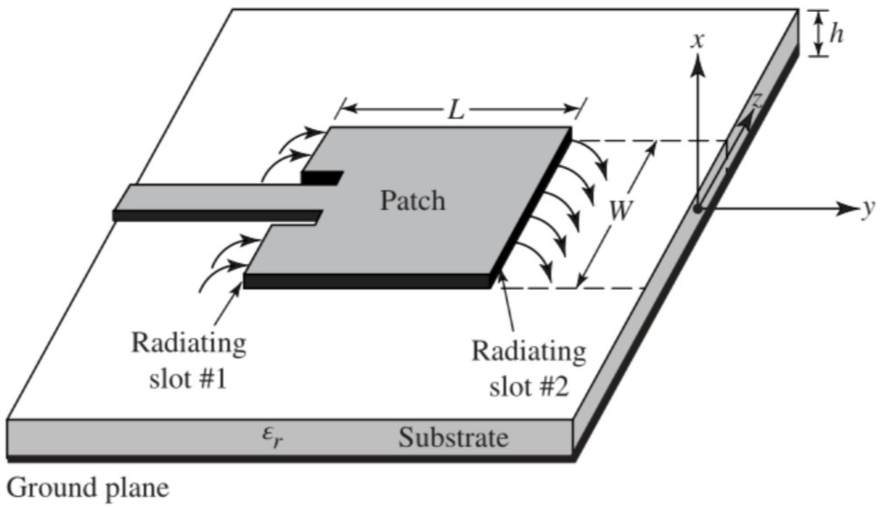
1. Hardware design and implementation.
2. In task 2, **extra scores up to 20%** are given according to the circuit performance.

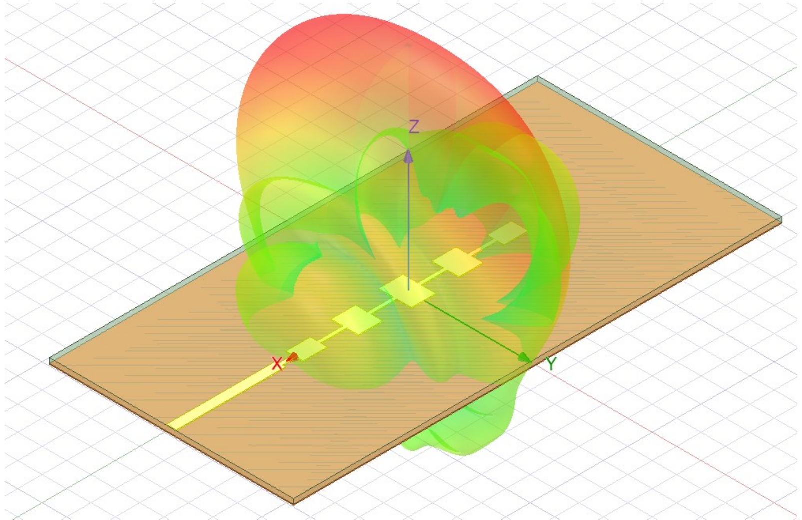
Project.7 Microstrip Patch Antenna Array Design

Difficulty factor： **1.0**
Task feature: Analysis and simulation

Project introduction：

The microstrip patch antenna is a type of onboard antenna that is easily integrated into circuit boards, making it a convenient solution for miniaturizing communication devices. Its structure includes conductive patches(导电贴片), a substrate(基板), and a ground plane(地平面), utilizing microstrip lines for feeding. The dimensions and shape of the patches have a direct impact on their operating frequency, bandwidth, and radiation characteristics. By adjusting parameters such as patch length and width, antennas can be designed to meet the signal reception requirements across various frequency bands.





Project.7 Microstrip Patch Antenna Array Design

Task List and Scores

1. Patch element design: Design a microstrip patch antenna with a single-patch element, providing the dimension parameters of the antenna. The antenna needs to meet the requirements of the operating frequency band, with a gain of no less than 6 dBi, and a return loss lower than -30 dB. (40%)

2. Based on the previous task, cascade multiple patch elements to form a patch antenna array to increase the radiation gain to more than 12 dBi. The return loss needs to be lower than -30 dB. Moreover, it’s needs to provide the dimension parameters of the antenna array. (60%)

3. Based on Task 2, explore the design methodology of the Van Atta antenna array, and provide simulation results of the Radar Cross Section (RCS) for the Van Atta antenna array. **(+20% Bonus)**

Notes

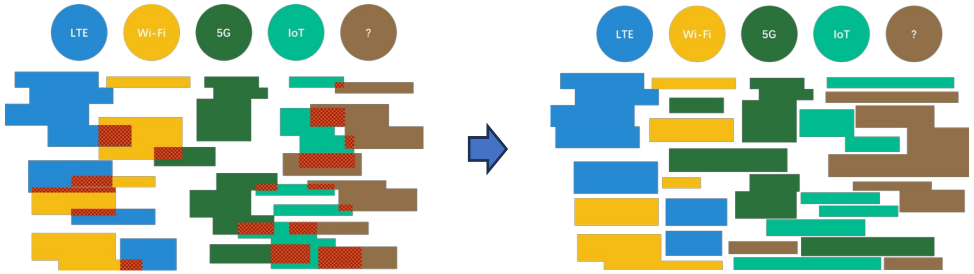
1. There are many online calculators for determining the dimension parameters of patch antenna.

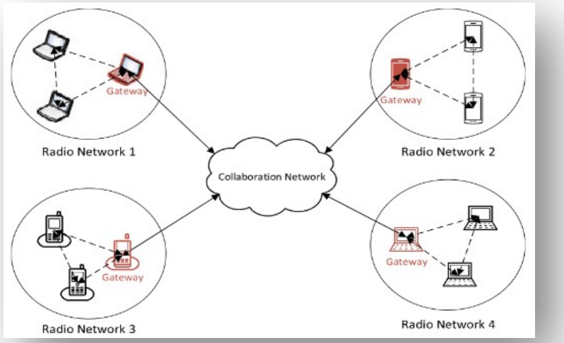
Project.8 Multi-band Spectrum Sharing Based on Multi-agent Reinforcement Learning (MARL)

Difficulty factor： **1.1**
Task feature: software only

Project introduction：

With the development of wireless technology, there has been a surge in wireless traffic. The traditional method of statically allocating spectrum to different services to avoid cross-technology interference is gradually becoming inadequate. This is because it leads to a mismatch between resources and demand, resulting in some spectrum being excessively crowded while others remain idle and wasted. To address this, we propose a novel decentralized spectrum allocation method to achieve multi-band spectrum sharing for intelligent networks. Unlike centralized scheduling, each wireless network independently selects time-frequency spectrum resources through local observation and learning. Through the competition and cooperation of multiple agents, an optimal spectrum allocation strategy that aligns with supply and demand is formed without the need for message exchange or global information.





Project.8 Distributed Multiple Access Mechanism based on Reinforcement Learning

Task List and Scores

1 Construct a simulation experimental environment by treating spectrum resources and network access behaviors as pixel blocks in the time-frequency domain (35%);

2. Use various distributed multi-agent reinforcement learning methods to simulate and explore spectrum allocation strategies under specific supply-demand relationships (35%);

3. Apply the aforementioned method to CSMA/CA networks to build a more realistic wireless network system, achieving a more concrete and fine-grained simulation (30%);

4. *Compare the performance of centralized multi-agent reinforcement learning with global information **(+20% Bonus).**

Notes

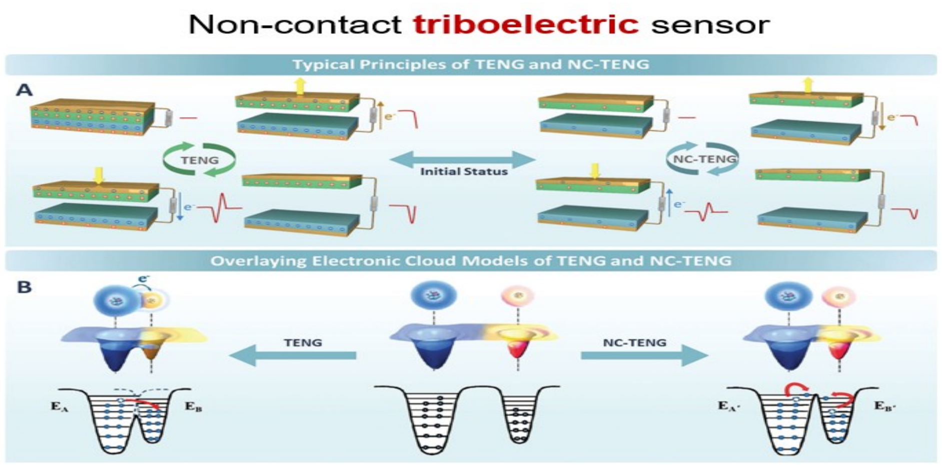
1. Simulation only.
2. Use PyTorch.

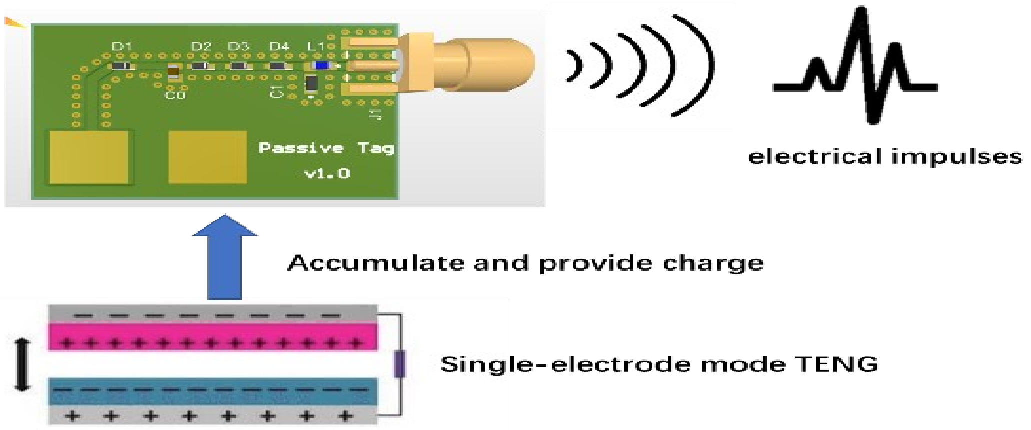
Project.9 Triboelectric Wireless Sensor

Difficulty factor： **1.1**
Task feature: hardware design

Project introduction：

The triboelectric nanogenerator （TENG） has recently been proposed as a self-powered sensor for distance and vibration sensing. TENG generate electrical impulses through mechanical friction. This project explores a new passive wireless sensing method by harvesting electric energy from triboelectric materials and actively transmitting pulses to the air. This method can enable wireless connectivity for passive sensors without the use of batteries.





Project.9 Triboelectric Wireless Sensor

Task List and Scores

1. Use capacitors to replace TENGs in the circuit and successfully observe pulse signals on an oscilloscope. (40%)
2. Analyze the relationship between capacitor charging voltage and pulse generation patterns, including the minimum voltage required to produce a pulse and whether there is a connection between these two factors. (40%)
3. Enable wireless communication for passive TENG sensor.**(**20%**+20% Bonus)**

Notes

1. Circuit analysis and signal processing.
2. An example TENG and a radio frequency front-end circuit are provided in the project.

Project.10 RF-GAN for Channel Estimation

Difficulty factor： **1.00**
Task feature: software design

Project introduction：

In wireless communication systems, accurate channel estimation is crucial for enhancing signal quality and system performance. Traditional methods often rely on physical models or limited training data, which may not adapt well to dynamic environments. This project proposes using RF-GAN (Generative Adversarial Networks) for generating high-quality, time-series RF data for channel estimation. RF-GAN offers the advantage of creating realistic RF signals without the need for extensive ground truth data, making it suitable for real-time and large-scale wireless applications. The goal is to utilize RF-GAN to simulate realistic wireless channel conditions and improve channel estimation performance in complex, dynamic environments.

Project.10 RF-GAN for Channel Estimation

Task List and Scores

1. Design a neural network model for Wi-Fi signal channel estimation. (30%)
2. Design a GAN to generate Wi-Fi signals based on real Wi-Fi data (40%)
3. Evaluate the impact of GAN-augmented data on Wi-Fi channel estimation performance and compare the model performance across different parameter sizes. (30%)
4. Use a diffusion model to achieve the above tasks. (+20% bonus)

Notes

1. It is possible to use an existing dataset or acquire a dataset independently through devices such as SDRs.

How and When to Choose a Project

- How?
  - Option 1: Find your teammates, form **a team of 3-5 people**, and determine your team leader. Each team leader needs to log in to Tencent Documents to fill in a online EXCEL for choosing the project.
  - Option 2: If you cannot gather a team of 3-5 people, or you do not want to actively select, please contact the teaching assistant for random assignment of projects (Wechat or email: leijiazhen@sjtu.edu.cn).
- When?
  - Option 1 starts at **19:00 (17th Feb.)** and ends at **24:00 (18th Feb.)**
  - Option 2 starts when option 1 finishes.