Middle East Technical University
Dept. of Electrical-Electronics Engineering

EE 435 Communications I
Term Project (2024-2025)

(Updated)

Signal Classification with Deep Learning

Objective:
The goal of this project is to get acquainted with state-of-the-art techniques in communications. You will implement and replicate signal classification experiments focusing on specific types of amplitude modulation and frequency modulation signals using deep learning techniques.

Project Overview:
You will implement a deep learning-based classification system capable of distinguishing between the following modulated signals:

- AM-DSB-WC (Amplitude Modulation Double-Sideband with Carrier)
- AM-DSB-SC (Amplitude Modulation Double-Sideband Suppressed Carrier)
- AM-SSB-WC (Amplitude Modulation Single-Sideband with Carrier)
- AM-SSB-SC (Amplitude Modulation Single-Sideband Suppressed Carrier)
- FM (Frequency Modulation)
- Linear FM (Chirp Signal)

Traditional methods are not within the scope of this project.

Tasks:

1. **Literature Review**: Review the provided paper, *Over-the-Air Deep Learning Based Radio Signal Classification*[1], to understand the context and methodology behind deep learning approaches for radio signal classification. Focus on the analog communication components and disregard the digital communication related ones.
2. **Signal Model**: Determine the signal model parameters based on the reference paper that would be needed in generating signals. Note that randomness is needed in the messages. You are expected to make reasonable assumptions if any ambiguity or lack of clarity arises.
3. **Data Generation**:
    - Use simulation software to generate synthetic datasets for the specified modulation types.
    - Ensure data includes a variety of signal-to-noise ratios (SNR) and carrier frequency offset (CFO) values.
    - There should be at least two bandwidth values for all 6 modulation types where the second bandwidth is twice the first.
4. **Model Implementation**:
    - Implement a residual neural network (ResNet) to classify the generated signals.
    - Train the model using synthetic data and evaluate its performance on test data.
5. **Performance Evaluation**:
    - Evaluate the classification performance with varying SNR, window size, CFO.

[1] T. J. O'Shea, T. Roy and T. C. Clancy, "Over-the-Air Deep Learning Based Radio Signal Classification," in *IEEE Journal of Selected Topics in Signal Processing*, vol. 12, no. 1, pp. 168-179, Feb. 2018.

    - Demonstrate your implementation using a Pluto SDR where the faculty will be transmitting signals.
6. **Report**:
    - Write a report documenting the methodology, results, and conclusions drawn from the experiment.
    - Include code snippets and visualizations (e.g., confusion matrices, training curves) to support the findings.

Deliverables:

- PHASE 1: Task 1 to Task 3 (Codebase with scripts implemented by that time, a 3-page report)
- PHASE 2: Task 4 to Task 6 (Codebase with all implemented scripts, an 8-page project report)

Evaluation Criteria:

- Correctness and completeness of the implementation.
- Clarity of the analysis and discussion.
- Quality of the reports and insights provided.

(Updated part)

More specifically, at least the following are required in Phase 2 Report.

- An introduction describing the task of interest, motivation, and the content of the work conducted.
- A short literature review that helps the reader understand the context of the work.
- Signal model descriptions with mathematical formulas including and emphasizing the signal parameters that have been used in generating data: Sources of randomness should be clearly stated. Note that LFM is not required any more, only CFO and SNR should be considered with 5 modulation types.
- Dataset generation methodology with the sample size and format of the data
- The Resnet model used along with all parameters of choice
- Results of the classification task
- Concluding remarks

During the demo, you are supposed to

- Review your Phase 2 report in 2-4 minutes and answer related questions,
- Perform live classification with the random transmission of the messages and choice of modulation parameters you provide.