Simultaneous Call Transmission (SCT)

Design Document

sddec22-13

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Revised: 4/24 - Version 1

Executive Summary

Development Standards & Practices Used

- IEEE 2755-2017 - *IEEE Guide for Terms and Concepts in Intelligent Process Automation*
- IEEE 1139-2008 - *Standard Definitions of Physical Quantities for Fundamental Frequency and Time Metrology - Random Instabilities*
- IEEE 1641-2010 - *IEEE Standard for Signal and Test Definition*

Summary of Requirements

- The algorithm must alert the user when an SCT event has occurred
- Training data for the algorithm will be simulated
- The alert must come within 1 second of the signals being transmitted
- The algorithm should be able to run on the hardware that it will be implemented on, meaning that it should be efficient enough for a small device

Applicable Courses from Iowa State University Curriculum

- COM S 228 - *Introduction to Data Structures*
- EE 224 - *Signals and Systems I*
- EE 321 - Communication Systems I
- EE 422 - Communication Systems II
- ENGL 314 - *Technical Communication*

New Skills/Knowledge acquired that was not taught in courses

- Machine Learning Concepts
- Python Development
- Complex Baseband Modulation
- IQ Mismatch/ Imbalance

Knowledge/ Experience from Classes

- Sampling
- Digital signal processing
- Amplitude/ Frequency Modulation
- Amplitude/ Frequency Demodulation
- Digital Filter Design

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1 Team

1.1 Team Members

- Sullivan Jahnke, Json Rangel, Tyler Mork, Austin Rognes, Hani El-Zein

1.2 Required Skill Sets for Your Project

- Digital Signal Processing
- MATLAB and Simulink
- Algorithm Design
- Machine Learning
- Research and Note Taking
- Communication (Between Client/Advisor and Team) (Between Team Members)

1.3 Skill Sets covered by the Team

- Digital Signal Processing & Communication Systems - Json Rangel
- MATLAB and Simulink - Tyler Mork, Hani El-Zein, Json Rangel
- Algorithm Design - Sullivan Jahnke & Austin Rognes
- Machine Learning/AI - New to All
- Research and Note Taking - All
- Communication - All

1.4 Project Management Style Adopted by the team

- The team has adopted the Agile project management methodology.

1.5 Initial Project Management Roles

- Team Lead & Machine Learning: Sullivan Jahnke
- Reports, Webmaster, and Communication Systems: Json Rangel
- Reports and Communication Systems: Tyler Mork
- Research and Machine Learning: Austin Rognes
- Research and Digital Signal Processing: Hani El-Zein

2 Introduction

2.1 Problem Statement

The problem we are trying to solve is Simultaneous Call Transmission (SCT). An SCT event is when multiple aircraft communication devices are trying to transmit messages to the same person at the same time. This frequently causes interference between the signals due to their carrier frequencies being very similar which causes noise disruption or a loss of information. Our job is to develop an algorithm that can be implemented into a hardware device that would detect and alert users when multiple calls are being transmitted simultaneously.

Our algorithm does not need to correct the frequency error/ aliasing/ overlap, but only detect when it is happening, making the task a little simpler.

2.2 Requirements & Constraints

Our requirements are not strict to a certain method of development, but our client does have preferences. We are to design the basic layout of the algorithm and its functions in MatLab and Simulink. Eventually Collins would like us to incorporate some form of machine learning to the system in order to train it to recognize and detect patterns on its own.

The project will last 1.5 - 2 years and has a budget of $8K. It is expected to be passed down to a future senior design group to pick up where we left off, and so we are careful in our planning and scheduling the course of the project. Once the project does come to fruition, it is expected that the device will be able to fit into the cockpit of an aircraft, or air traffic control towers.

Functional

The sole function of the project is to alert the user when an SCT event has occurred.

Training data for the algorithm will be simulated.

The alert must come within 1 second of the signals being transmitted.

Qualitative

The algorithm should be able to run on the hardware that it will be implemented on, meaning that it should be efficient enough for a small device. Our team does not have to implement hardware however because another design team has been tasked with that part.

Economic/Market

We have $8,000 to work with right now to solve this problem.

We do not believe we would need to worry about consumer cost until after we have passed the project to another group next year.

Size

Able to fit seamlessly into the cockpit of a plane and an air traffic control tower. (constraint)

2.3 Engineering Standards

https://ieeexplore.ieee.org/document/8070671

This standard is called the "IEEE Guide for Terms and Concepts in Intelligent Process Automation." This could be relevant to our project because we plan to have our software automatically process these signals without any human help. Our project is not just taking data and displaying it, it will be learning from simulated data then processing new data to make a prediction.

https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=6581834

This link listed above takes you to a PDF of the IEEE Standard titled, "IEEE Standard Definitions of Physical Quantities for Fundamental Frequency and Time Metrology - Random Instabilities." It covers randomness and instabilities in signal processing. This could be useful for our project because we need to factor in randomness, such as noise, when designing our amplitude modulation machine learning algorithm. The standard helps with understanding how to recognize it and how to predict it.

https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=4410235

The standard above is known as the "Standard for Signal and Test Definition." Seeing as much of our training data will originate from self-made simulation signals, a standard to define those signals mathematically would prove very useful. Not only that, multiple instances throughout the document detail various transformations we can make the signal undergo to change its "viewed" characteristics.

2.4 Intended Users and Uses

If all goes as planned, the SCT detection device could possibly become patented. Many people would benefit from this project (not just the client) including pilots, ATC operators, passengers, airline companies, airports, and more. It is not so much an improvement, but a prevention which will stop these events from happening. This project can potentially save lives. Anyone communicating with Air Traffic Control at airports would use this, and it would just be a small piece of hardware that properly alerts the user when a SCT event has occurred. Important communication signals would not be lost. Our project is based on a single use case (a simultaneous call transmission), which makes it hard to brainstorm for more situations.

3 Project Plan

3.1 Project Management/Tracking Procedures

We are following a hybrid waterfall-agile project management style for our project. This means that we will first be spending a lot of time in the planning stage. Our planning stage includes a deep understanding of our problem, in-depth research, and frequent meetings with both our client and faculty advisor for continued check-ins on our planning. Once we get through this stage, development on the system and algorithm can begin. This stage will be a mixture of both waterfall and agile, as we will most likely be sprinting towards completion, but will be taking steps back along the way for testing at certain points. We do not want to get too far along in development before testing and realizing problems with our product.

We will be tracking our progress through a mixture of Discord, Google Drive, and Gitlab. Our primary mode of communication is through our custom Senior Design Discord server, which allows us to post and accomplish what we call "Action Items." This server also has different subcategories in it, which involve research. We also have a Google Drive that we upload files, research, reports, and anything else related to the project. The Drive is used as a secondary source for members to go to access project work. However, the Drive is used primarily for paperwork. Finally, we have a GitLab repository that we will upload our project files to. The project files include Simulink simulation system files, any code relating to our machine learning algorithm, and any other technical files directly related to the project.

3.2 Task Decomposition

Required Task	Task Description	Reason for Completing Task
Understand Simultaneous Call Transmission	Research into what happens when people transmit a message across radio communications.	Gives an understanding on what might be happening on a technical level, giving us a jump into how to solve the problem.
Simulate Simultaneous Call Transmission	Create a radio communication system in Simulink to simulate the problem.	Allows us to analyze through graphs and frequency spectrum analyzers the problem. Also allows us to change parameters to adjust severity of radio interference.
Research Machine Learning	Gain an understanding on what machine learning is, how to implement it, and why we should use it.	Client wants a machine learning algorithm to detect when multiple people are transmitting at the same time. None of the team has any experience with machine learning, thus research and guidance from our faculty adviser will give us the necessary information to begin drafting an algorithm.
Finalize Draft of Simulink Simulation	Creates received signals mimicking aircraft transmissions with real world signal phenomena introduced.	This will serve as input data to the machine learning algorithm. Helps to analyze possible transforms and patterns used to detect an SCT event.
Generate Training Data	Using the Simulink file, we can run the system many times while varying parameters of the signals to create training data.	The machine learning algorithm needs necessary training data to begin to learn the difference between a simultaneous call transmission event and a normal singular radio transmission.

Draft Machine Learning Algorithm	Begin the creation of a machine learning algorithm using Python.	Machine learning algorithms will be used to detect a simultaneous call transmission.
Research / find optimal data transformations	Find ways to transform radio wave data to make SCT more apparent.	Feeding the raw data to our ML algorithm may not be the best option for it to learn from.
Train ML algorithm	Train models on multiple different transformations of our radio sample dataset	Some transformation of the data may yield a significantly better end performance
Hand Algorithm Off to Future Senior Design Group	Finalize the machine learning algorithm and pass it to the future team to implement into hardware.	Since this project is a two-year project, with two major phases (software and hardware) another senior design team will be taking the project over to finish and implement into hardware (a radio).

3.3 Project Proposed Milestones, Metrics, and Evaluation Criteria

Task 1 – Understand Simultaneous Call Transmission

M1.1 - Understand mathematical construction of radio signals in aviation

M1.2 - Understand the underlying issue at receiver level

M1.3 - Gather understanding of receiving mechanics and systematic processes involved.

Task 2 – Simulate Simultaneous Call Transmission

M2.1 - Create an output model that resembles an input that a radio receiver would see.

M2.2 - Create parameter blocks to allow for distance and physical obstruction gain

M2.3 - Understand signal phenomena and how to model them

Task 3 – Research Machine Learning

M3.1 - Determine type of machine learning required (Unsupervised, supervised)

M3.2 - Determine method of Unsupervised/Supervised learning to use (Regression, classification)

M3.3 - Understand labels and features of our problem as well as inputs and training data

Task 4 – Finalize Draft of Simulink Simulation

M4.1 - Introduce noise, reflection, doppler effect into model

M4.2 - Create duplicate models. One at DC Baseband. One at AM carrier band.

M4.3 - Determine necessity of modeling receiver design.

Task 5 – Generate Training Data

M5.1 - Adjust Simulink Model to include variable parameters that allow for change in signal strength, frequency offsets, doppler effect based on aircraft speed, time in which signal transmissions are introduced.

M5.2 - Generate iterations

Task 6 - Draft Machine Learning Algorithm

M6.1 - Determine features to be extracted

M6.2 - Construct any pre-processing if required

M6.3 - Develop supporting code

Task 7 - Research / find optimal data transformations

M7.1 - Research Fast Fourier Transformations

M7.2 - Test methods of data analytics on signals to extract key features of the sampled waveform

M7.3 - Optimize methods of transformation

Task 8 - Train ML algorithm

M8.1 - Successfully test ML algorithm with initial learning data

M8.2 - Test ML algorithm with randomized input models

M8.3 - Obtain 90% success rate

3.4 Project Timeline/Schedule

Date	Progress/Milestone
2/11/2022	Draft a tentative plan for progress
2/16/2022	Meet w/ Dr. Bolstad
2/17/2022	Familiarization with environment / MATLAB Exercise Marty Gave us

2/22/2022	Further research on machine learning
3/3/2022	Decide on which route we want the algorithm to take (Machine Learning or not, etc.)
3/7/2022	**Begin Drafting Algorithm**
3/10/2022	**Get a working simulation of the problem on Simulink/MATLAB**
3/12/2022 - 3/20/2022	**SPRING BREAK**
3/25/2022	Discuss and optimize feature selections for the ML algorithm.
4/01/2022	Introduce noise, doppler effect, and other signal phenomena into simulation
4/02/2022 - 4/27/2022	Further complete algorithm code. Discuss hardware with assisting M2I group. Begin constructing variable parameters for input test data
4/28/2022	**Complete First Draft of Algorithm**
5/12/2022	**Draft testing plan for algorithm**

3.5 Risks And Risk Management/Mitigation

Task 1 – Understand Simultaneous Call Transmission

We may not learn about every edge case of SCT: **0.4**

Task 2 – Simulate Simultaneous Call Transmission

Our simulation may vary from real life radio transmissions: **1.0.** We should obtain real recording logs of SCT happening or at least radio transmissions.

Our radio is theory based and variables such as distance between radios may cause different output than our simulation: **1.0**

Task 3 – Research Machine Learning

This is a vast subject and we may not cover enough ground to make a practical algorithm: **0.3**

Task 4 – Finalize Draft of Simulink Simulation

Certain real world signal phenomena may be difficult to accurately model in Simulink: **0.2**

Task 5 – Generate Training Data

Our training data may vary from real life by a large amount: **0.4**

Many different edge cases or rare occurrences that happen in real life will not be simulated: **1.0**. The only way to fix this is to use real life training data from pilots.

Task 6 - Draft Machine Learning Algorithm

Machine Learning algorithm may not obtain desired detection time: **0.1**

Task 7 - Research / find optimal data transformations

We may find too many ways to transform our data for the time taken to train with them all: **0.4**

Task 8 - Create ML Algorithm Variations

Our machine learning algorithm may just not work: **0.2**

Our machine learning algorithm may only work in very controlled environments: **0.4**

Our machine learning algorithm may work in nearly every condition, but fail drastically in a few: **0.8**. We would need to have a lot of testing of edge cases.

Our machine learning algorithm may not fit into the airplane radio hardware or require too many resources to properly function: **0.5**. This would require some honing in on what makes our algorithm successful to try to replicate it on a smaller scale.

Task 9 - Hand Algorithm Off to Future Senior Design Group

Not enough documentation about how we arrived at our simulation / data transformations / neural net build.: **0.4**

3.6 Personnel Effort Requirements

Task (See Sections 2.2, 2.3 and 2.5 for more detailed info)	Estimated Person-Hours
1	5
2	15

3	15
4	25
5	5
6	40
7	10
8	20
9	3

This table provides estimated person-hours required for each task. This is obviously subject to change depending on the complexity of the task involved once pursued.

It is rather difficult to allocate a specific amount of needed hours for each task.

3.7 Other Resource Requirements

Our project is strictly software based and will not require any parts or materials on our portion. Although, we will be in discussion with the group responsible for hardware construction of the radio.

4 Design

4.1 Design Context

4.1.1 Broader Context

Area	**Description**	**Examples**
Public health, safety, and welfare	Project affects people both indirectly and directly. Affects the aviation community (ATC and pilots) and the welfare of passengers.	Decreases safety risk of aircraft collision and/or runway excursions at airports.
Global, cultural, and social	All cultural groups may be affected. It would be a global influence within the aviation workplace. For all end and indirect users, this project values safety to people and aircraft which would reflect positively on the aims of all parties involved.	An addition of SCT event detection in radio receivers would not cause drastic change to systematic processes of ATCs. No cultural or global communities would be adversely affected by such an implementation.
Environmental	Under specific analysis, this project would have a front end environmental effect due to material demand of manufacturing the radio system. Unsure as to the hardware choice of filtering products and processor at this time.	Increasing use of non-recyclable materials in radio construction. Although minute, increase power demand of radio (higher energy use)

Economic	If software based with SCT detection, may drive radio prices higher. This can be dictated by FAA regulation in the future by requiring SCT detection in all towered airports.	Cost of production is expected to be low. Highest expense will be the processor required to run the algorithm in real time. Embedded software application so it may drive the cost of hardware down.

4.1.2 User Needs

ATC needs a system application that allows for him/her to be alerted to the event of an SCT. The ATC can then perform a SOP (Standard Operating Procedure) to prevent any runway mishaps. An ATC may only receive a single aircraft transmission or static tone due to the interference of two received transmissions.

4.1.3 Prior Work/Solutions

– Many pending patents exist. Various types exist with use of some form of signal demodulation and decimation. Most, if not all, prior designs incorporate some use of the Fast Fourier Transform (FFT) to derive the frequency spectrum of the signals as well as a systematic process of mixing and down converting the RF signal to baseband frequency. The designs further incorporate logic sequences, error optimization, buffers, and additional filtering. Some designs incorporate deep learning algorithms and some do not. Of the algorithms that exist, there have been applications that utilize Gaussian Mixtures Model, fuzzy clustering, neural networks, support vector machines, etc.

– We are not following any prior work. We have dissuaded from relying on external designs to implement the SCT event.

– We can not accurately give pros or cons versus any other particular designs seeing as our algorithm has not been implemented quite yet and we will be unable to credit any hardware capabilities until that milestone is reached.

4.1.4 Technical Complexity

1. Digital signal processing (DSP) is a vast realm with many already modern applications. This project is of sufficient technical complexity as it requires not only Digital Signal Processing, but efficient use of a deep learning algorithm that is capable of providing real time event detection in an estimated 1 second.

2. Many of the engineering principles reside in the DSP portion of the project where an RF signal is modeled as a complex sinusoidal function. This complex sinusoidal input undergoes FFT transformation through use of its mathematical representation in programming. This is preprogrammed as a function in the machine learning algorithm platform we utilize. From there, the signal undergoes more signal manipulation such as mixing, filtering and decimation such that we are required to design the LPF according to specifications of the project and design the ADCs to produce the necessary sample input to our algorithm. All of these instances require an understanding of complex signals and their corresponding transformation functions. Once the basis of the process is established, we will further look into other processing techniques that can be used to increase processing

time, reduce total samples required, or create looping mechanisms to promote efficiency. Furthermore, we must distinguish between mathematical model and real world variations considering we are working with RF signals that are subject to many distortions in its process such as Doppler Effect (objects moving at a distance and speed relative to each other), reflections (circulating signal within coaxial cable), or noise (acquired signal distortion due to hardware or transmission through air).

4.2 Design Exploration

4.2.1 Design Decisions

A key decision for our design was to implement the deep learning algorithm on TensorFlow-Keras with the plan to utilize a classification type network.

Another key decision of the design was to pursue IQ demodulation in our application as it allows for full analysis of any RF signal received, no matter how it was modulated to be transmitted.

Lastly, a key decision of the design was to not worry about the hardware and its capabilities while drafting the algorithm. The client suggested first to get a working algorithm, then once that is done we will fine tune it with hardware capability in mind.

4.2.2 Ideation

Our decision to use TensorFlow-Keras to create the machine learning algorithm came after looking at all of the available options and finding what we valued in the framework.

Theano looked appealing as it was a highly optimized matrix based machine learning tool. We didn't use this as it was difficult to set up and looked painfully above our heads as it allowed too much control over everything.

We also looked at Numpy quickly before seeing that it was even more barebones than Theano.

Matlab ML is built into Matlab so we could have used it there. Not many of us have enough experience with Matlab to delve into more complex parts of the language. We figured piping a file into a python script would be better.

Pytorch looked interesting but it didn't have the best debugging or visualization tools, which would help us greatly.

Using TensorFlow alone was also an option, but using the Keras library made it easier to use.

4.2.3 Decision-Making and Trade-Off

The process we used to identify pros and cons was to try and get a real example of what each option would be like to develop with. They all could have achieved the same outcome, however if we had a tough time learning or developing with an option, we would not choose it. So there weren't several factors in our decision making, it was just "we like this, let's use it."

4.3 Proposed Design

The beginning of our project entailed creating simulatory input signals within Simulink where an SCT event could be modeled by summing two RF signals together that are slightly offset in carrier frequency. This model utilized DSB-AM modulation and demodulation to generate the signals and analyze them. It just so happened that there was a more efficient means of undergoing the demodulation such that an IQ demodulation process is now being implemented. This model was also created in simulink, where the filters, local oscillator, and ADCs can be designed and implemented as well. With this model, we can simulate received signals to a receiver that are subjected to signal distortions and randomized in signal strength and frequency offsets so that the data to the machine learning algorithm is random in nature.

We plan to embed a matlab code that allows for random variable generations within our simulink model and run multiple iterations to acquire files to use as training data in our machine learning algorithm. The proposed idea is to create a random function generator in Matlab using trueRand() or using a seed that is based on real time. From there, the output of the simulink model can be sent to the Matlab Workspace or exported as a .csv file for implementation into Keras.

4.3.1 Design Visual and Description

This model is the beginning construct of an I-Q demodulator with the goal of taking a received RF signal into a receiver and implementing I-Q demodulation. A summed RF signal of two different frequency signals is the input to the I-Q demodulator. This is a modeled input to a RF signal with two transmitted signals at the receiver. From that point, the transmitted signal is multiplied by a LO (Local Oscillator) Frequency. The I phase of the received signal is multiplied by a sinusoid with no phase offset present, but the Q phase of the received signal is multiplied by a sinusoid with a 90 degree phase offset present. From there, the two channels each go through the exact same lowpass filter to acquire the certain frequencies we are interested in. Finally, the lowpass filter output is run through a decimation process of some sort to acquire digitized data that allows for analysis. Currently, we are pursuing how to go about implementing the representation of an ADC after the lowpass to get proper data samples. Currently, we have just used a quantizer for ease. With this digital data representing the I and Q channels, they can either be further processed using hardware or can be directly input into the SCT event detection algorithm.

Simulink Construct of I-Q Demodulation

The model will further be constructed to allow for random generated signals and signal distortion. The machine learning algorithm will then be trained with the randomized data under thousands of iterations to effectively train the model for a certain error rate. The algorithm will be implemented using TensorFlow-Keras, a common DSP neural network platform. From there, we know we will require a Fast Fourier Transform of the signal to analyze its frequency components and further decide peaks and differences within the frequency spectrum. It is unknown as of now what other data manipulation we may use.

4.3.2 Functionality

Our design will turn on a light in the hardware of a radio to tell the radio operator when simultaneous call transmission has been detected. We will have a hardware component built into the radio that will detect SCT by running the radio wave data through the ML algorithm after IQ Demodulation. It will try to detect multiple radio waves being combined in one output, which means simultaneous call transmission is happening. In the real world, when airplanes are calling the air control tower, the tower and airplanes will know that their transmission was inaudible or difficult to hear so they can try to call again.

The current design is just generating data to simulate radio transmissions so that we may create our own simultaneous call transmission events to generate massive amounts of data to train our machine learning algorithm on. So nothing functional is available yet.

4.3.3 Areas of Concern and Development

Concern

Some main concerns we have aside from the SCT device working properly, is will our algorithm detect an interfering signal within our desired time period of one second.

Our other main concern is the implementation of our training data. It would be widely easier to do with real world data, but we are confined to simulating the data within Simulink. This requires configuration of real world hardware scenarios and could be very difficult to model.

Development

The more accurate our training data is, the smoother/ more precise the algorithm will run, which should technically be able to detect the SCT event within that time.

We are currently working on modeling the training data and have a fairly clear objective. It is more so the learning curve associated with finding and implementing the block functions properly.

4.4 Technology Considerations

We have chosen to develop our signals in Matlab as the computer engineers are comfortable with the program. Our software engineers have chosen to use Python with Tensorflow and Keras. Our decision was after trying machine learning in Matlab and deciding that we should stick to a language we are more familiar with like Python. Our use of Python means that we will have to output data from matlab to a file and input it into our Python program. This is a just tradeoff. There are 2 major machine learning frameworks for Python, Pytorch and Tensorflow. We arbitrarily chose Tensorflow as for the depth we are using machine learning this will not affect us negatively. Keras is a library we use on top of Tensorflow to handle common machine learning modules.

4.5 Design Analysis

Our proposed design may or may not work. It is in theory correct and should accurately model radio transmissions from varying distances. We will use this to generate vast amounts of data for our machine learning model to learn from for its classification detection algorithm.

We have been constantly modifying and reiterating over this design this whole semester and are just about done. Now we will be able to modify and reiterate over how our machine learning algorithm works. We will try many different manipulations of the dataset to see what helps our model learn the best.

4.6 Design Plan

We design a very realistic simulation of radio waves and generate copious amounts of radio wave samples labeled 'normal' and 'SCT'. We find the optimal way to feed in the most data possible into our Python script. In Python, we continually refine and modify our data and record what our machine learning model learns best with. We iterate through designs on the neural network layer to see if efficiency may be gained there. Data about how each ML design performs is gathered to find the best algorithm for the common environment.

5 Testing

In order to maintain proper functionality of our design, it is important that we test at many stages in the process of development. However, we shall only be testing the software side this first year, as the hardware component and implementation will happen during Phase Two (Year Two) of this project.

5.1 Unit Testing

Software Testing

A unit of software that will require testing is the algorithm itself. There is a function in Keras that we will use to determine the accuracy of the predictions that the neural network is making. We will then put the output of the keras function into a Python unit testing framework to ensure it meets the requirement. We will test this with many different inputs to ensure that the accuracy does not decrease for any given case.

The other unit of software that will require testing is the simulation of data that will be used to train the algorithm. The Communications Division will be testing many points in their I-Q Demodulation system in Simulink. Almost all test points will be observed using the Frequency Spectrum Analyzer Block in Simulink.

Hardware Testing

As stated above, we will not be implementing hardware for this phase of the project, therefore there is no testing to be done at this point in time.

5.2 Interface Testing

Data Exchange between Simulation and the Algorithm

This interface will be used to send the simulated training data to the algorithm. To test this, we just need to make sure that the data being sent from the simulation is equal to what the algorithm is receiving so that it can be trained properly. We are not sure which tools can be used for this, however it seems very simple to be able to compare data like this.

5.3 Integration Testing

We have the Communication Division creating a radio wave simulator to generate large amounts of data. The Machine Learning Division is building the machine learning model. We need to integrate the generated radio data into our machine learning algorithm in a simple and easy to understand format. To integrate it, we will need to format the data to be fed into the neural network by determining the input layer size. To test it, we will make sure that the data is in the correct format, and that no input layer of the network will be repeated.

The Communications Division will also be testing the effects of real-world natural interference and discrepancies on their simulation. Some examples of this include adding in white noise and recreating signal reflection and doppler effect. In order to create an accurate design that can be implemented in a real-life scenario, it is highly critical that their simulation test results will be accurate to hand over to the Machine Learning Division for training the algorithm.

Once again, they will be tested using Spectrum Analyzer Blocks in Simulink and a Python library to be determined at a later date.

5.4 System Testing

In order to test the system as a whole, we will run multiple different combinations of tests for each of the unit, interface, and integration. If at any point a combination fails, we will pinpoint that area of failure, analyze it, fix, and repeat. We will begin with simpler combinations of tests, then as we become more confident with the results of our system, we will keep trying to break it with more complex combinations of tests.

Some examples of tests would be beginning with an ideal system and creating the data for the Machine Learning Division to test and analyze. If this test goes well, then we can begin to make the system more complex by adding in noise and testing again.

Tools used will be the same as described in each section, with them being run at the same time.

5.5 Regression Testing

We will write tests that ensure that changes to our machine learning algorithm or data input do not result in a less optimal algorithm. We will do this by saving the most optimal algorithms on our GitLab Repository to ensure that our most optimal solutions are available on a branch. The repository will also serve as a backup. In the case of a colossal failure when adding complexity, we can easily work backwards to a working design and go from there.

This process will also be driven by tools described earlier in this document.

5.6 Acceptance Testing

Since response time is the most important requirement of our design, we will demonstrate that this requirement is being satisfied by timing how long our design takes to respond to an SCT event. In order to include our client, we will show them how our design responds to multiple kinds of inputs with the timer in a live meeting. If they are unable to attend such a meeting, we will create a video demonstration of our acceptance testing. We will also demonstrate to them the efficiency of our implemented algorithm based on our analysis.

5.7 Results

So far, we are still in the process of testing a small scale design. However, our small scale results have aligned with what the theory says in ideal situations. Testing will continue with more complex simulations and designs. Early results from tests show promising results and great potential. Our testing ensures that our machine learning model is continuing to improve and run with the correct training data.

6 Implementation

Next semester we plan to refine our machine learning algorithm and keep records of how different variables in our design and training environments affect the algorithm's performance and correctness in different environments. We plan to collect and organize data on a few key metrics we will decide on. One such metric would be time until detection, which should fall under 1 second. We want to graph out how long it will take our algorithm to detect a SCT event given several environment and training variables.

7 Professionalism

We chose to follow the IEEE code of ethics documentation. The added column with corresponding relational addresses is included.

7.1 Areas of Responsibility

Area of Responsibility	Addressment
Work Competence	Sections 5, 6, and 7 tend to follow the idea of work competence and what it stands for with regards to the "Definition" column. Each section references a technical understanding of the work at hand. **In our own words** : This area describes an ability at a professional level to perform work capable of safety and performance regulations.
Financial Responsibility	Section 3 tends to follow the idea of financial responsibility where the code claims to follow the act of "stating claims and estimates" of reasonable origin. It bases those claims on valid data present. **In our own words** : This area describes a sense of moral discipline for a service/product supplier to not drive the cost of something higher than is needed.

Communication Honesty	Sections 2 and 4 follow what is disclosed within communication honesty where problems arise are presented to the corresponding parties and no bribes are taken to possibly present ill-intent. **In our own words** : This area describes the idea of providing a product and its corresponding documentation without the "Engineering" annotation to it; basically make it understandable to the user.
Health, Safety, Well-Being	Section 1, 2, and 9 follow a risk minimization guideline as shown in this area of responsibility. They are sections to realize the well-being of the public and to uphold a level of satisfactory safety for shareholders and the public alike. **In our own words** : This area generally describes the need to keep the safety of people and products in mind with any problems or issues acknowledged and addressed.
Property Ownership	Sections 2, 8, and 9 include the dynamics of respect for property, ideas, and information. Each section tends to touch on respect regarding different areas. **In our own words** : This area makes the idea of "treat others how you want to be treated" come to mind with the inclusion of property as well.
Sustainability	Section 1 references this area of responsibility the best with disclosure to the public when factors endangering the public or environment exist. **In our own words** : This area describes the need to preserve the natural entities of nature, both natural resources and ecosystems.
Social Responsibility	I would not say there is a specific section to reference Social Responsibility. Possibly section 10 as it presents a service by the IEEE community to better themselves. **In our own words:** This area describes the need of products that will benefit society and mankind; not cause chaos or destruction (warfare).

The NSPE version compared to the IEEE Code of Ethics seems to be much broader in definition. For each fundamental Canon, the NSPE contains a descriptive that provides further specific guidance on each area of responsibility. The IEEE Code of Ethics lacks that and contains only the basic statement presented. With that, there is not much difference besides the fact that the NSPE version contains more detail than the IEEE Code of Ethics.

7.2 Project Specific Professional Responsibility Areas

Area of Responsibility	Application	Performance
Work Competence	Yes – Technical competence in Machine Learning/Algorithm design as well as adequate knowledge in matlab syntax	High – There is a dynamic between group members consisting of software and hardware that allows for high performance
Financial Responsibility	Yes – It would if we were charging our client for the design of said product. In realism, the integration of the proposed design into the existing system is very reasonable in cost for the client.	High – Considering there is no cost involved in the product until the hardware implementation, I would say our group is doing very "High" in this area.
Communication Honesty	Yes – This product is integrated into an already existing system. Our portion of design is critical in both parties understanding what has been done.	Med – Our team is good at explaining what we have done and ideas presented. There is an unfortunate learning curve with many of the project items.
Health, Safety, Well-Being	Yes – This product deals with moving aircraft with passengers on board and lives at stake.	High – we are not able to apply this area yet but once testing and "teaching" our algorithm comes around, it will be greatly considered.
Property Ownership	Yes – As a newly presented topic to most group members, this area is subject to a lot of new ideas. We haven't received any property.	High – We understand property rights are that of our clients when the product is finished.

Sustainability	Yes – Only application I can think of is the material for hardware later on.	Low – Not exactly needed in our project, as we will not be dealing with mass produced hardware and are focusing on the software portion.
Social Responsibility	Yes – It prevents possible fatal altercations between moving aircraft.	Technically low/high – We haven't produced anything but we uphold ourselves responsibly and ethically

We would consider Work Competence to fulfill the requirement of importance to our project and the requirement of high level of proficiency within the group. This responsibility will play a vital role one the success of this project as many members of this group are not familiar with the project scope. Machine Learning and Algorithm design is a new realm for our engineering pursuit, as well as an understanding of the industrial realm of aircraft transmitter and receiver hardware and its systematic process.

This responsibility will entail hours of professional competence to ensure we are producing the product as intended and how it will interact with existing systems in the real world. It will require an abundance of educated questions as well as an integrity in oneself and the group to become knowledgeable on the subject matter. This can be a difficult process with other classes and homework. Our group has observed a multi-step process to procure research information and questions for weekly meetings with our client to ensure a systematic approach to our project.

8 Closing Material

8.1 Discussion

Results of the project include a platform used to generate training data by modeling of a complex baseband in Simulink, and a Machine Learning algorithm capable of detecting an SCT event. Currently, the requirements are not achieved in full for the algorithm. Initial design has an operating machine learning algorithm capable of doing simple comparisons on real time data. Further implementation of the design will include taking Fast Fourier Transforms of the input data to analyze the frequency components of the signal, and separating the complex data into I and Q data points for phase and magnitude comparisons.

Our main result is our own understanding of the Python TensorFlow Keras frameworks. We are able to train a machine learning algorithm to detect artificial SCT events given very basic randomly generated training data.

8.2 Conclusion

Goals:

- Have a draft of a working algorithm.
- Ensure the working algorithm is the most efficient means of the intended product.
- Incorporate machine learning or AI into the working algorithm.
- Implement accurate training data generator

Work completed so far includes a simple training data generation model created in Simulink, and the basis of our machine learning algorithm in a Python based script. The training data generation model includes probable signal discrepancies such as frequency error and phase offsets, which are introduced by the multiplication of a cosine wave with a phase offset or frequency offset. The model also includes a factor of white gaussian noise in the complex summation of the signals to depict real world noise. The resulting summation of the message and interferer signals with frequency and phase offsets, as well as noise, are exported to a .mat file to be used as an input to the machine learning algorithm.

We have designed a machine learning algorithm that is able to take in two arrays of arrays of numbers that represent a complex signal composed of one or more multiple radio signals. This is used as training data for our machine learning algorithm to train on. In the future, we hope to include more variables than just the waves themselves such as the I-Q variable. The more data we get the more efficient our algorithm will be. We are currently unable to generate the training data so in Python we generate random sound waves and create artificial SCT events by adding waves to each other in segments. This yielded good results but is also very optimal and artificial.

The majority of our goals have been met within our allotted time this semester. Some of the major goals include a model for training data generation and an initial draft of the Machine Learning Algorithm. There are a few discrepancies in both our simulink model and the machine learning algorithm that will need to be addressed for proper product results. Many of our setbacks occurred due to lack of knowledge and time invested into research and understanding.

8.3 References

"IEEE Guide for Terms and Concepts in Intelligent Process Automation," in IEEE Std 2755-2017 , vol., no., pp.1-16, 28 Sept. 2017, doi: 10.1109/IEEESTD.2017.8070671.

"1139-2008 - IEEE standard definitions of physical quantities for fundamental frequency and time metrology--random instabilities," IEEE Xplore, 27-Feb-2009. [Online]. Available: https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=6581834. [Accessed: 24-Apr-2022].

"62529-2007 - IEC 62529 ed. 1 standard for signal and test definition," IEEE Xplore, Nov-2007. [Online]. Available:

https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=4410235. [Accessed: 24-Apr-2022].

8.4 Appendices

8.4.1 Team Contract

Team Members:

1) Sullivan Jahnke
2) Json Rangel
3) Tyler Mork
4) Austin Rognes
5) Hani El-Zein

Team Procedures:

Team meeting: 4pm Sunday at the TLA (face-to-face)

Meetings with advisor: 9am Wednesday Coover 2011

Meetings with Collins Aerospace: 1pm Friday virtual through Zoom

Preferred method of communication updates, reminders, issues, and scheduling:

Discord server and email

Decision-making policy (e.g., consensus, majority vote):

We used a majority vote to determine our decisions.

Procedures for record keeping (i.e., who will keep meeting minutes, how will minutes be shared/archived):

Our meeting minutes are rounded to about how many hours we spend in the TLA.

Participation Expectations

Expected individual attendance, punctuality, and participation at all team meetings:

Team members must announce beforehand if absent for a meeting with a reason.

Expected level of responsibility for fulfilling team assignments, timelines, and deadlines:

Team members are all expected to help with weekly assignments and must stay in contact with the team to see what they can help with.

Expected level of communication with other team members:

Team members should reply to discord messages and emails within 24 hours.

Expected level of commitment to team decisions and tasks:

Team members should complete weekly canvas assignments, and help further our project in any way possible as well as look for ways to contribute.

Leadership

Leadership roles for each team member (e.g., team organization, client interaction, individual component design, testing, etc.):

Client / Advisor Interaction: Sullivan Jahnke

Testing: Tyler Mork

File and Report Management: Json Rangel

Machine Learning Expert: Austin Rognes

Strategies for supporting and guiding the work of all team members:

Try to give everyone an even amount of responsibility so that if someone has questions then every group member can have a chance to help. Not just putting heads down while working and answering all questions you can in an efficient manner.

Strategies for recognizing the contributions of all team members:

Write down contributions in the weekly reports and meeting minutes, and write down action items for each team member to look back on when meeting again.

Collaboration and Inclusion

Describe the skills, expertise, and unique perspectives each team member brings to the team:

Sully provides a software background with strong problem solving skills, experience with many group projects, and the motivation to learn something every day.

Tyler provides a large Matlab and Simulink background. Has performed multiple coding projects and Simulink constructs through coursework. Avid learner of new concepts and technicalities, with the ability to invest time into project research and design applications.

Json has a background in communications systems and is in the process of completing the communications sequence at Iowa State. He has experience in MATLAB and Simulink and has completed projects using Simulink. Json also has a management background and is excellent at communicating with team members and team leads. He also has access to specialized meeting rooms, which can serve to organize team meetings.

Strategies for encouraging and support contributions and ideas from all team members:

Not shutting down the ideas that members bring up. Talking rudely is just not helpful for anyone. Assist other team members when they are struggling to complete a task.

Procedures for identifying and resolving collaboration or inclusion issues (e.g., how will a team member inform the team that the team environment is obstructing their opportunity or ability to contribute?)

Don't be afraid to talk to the team, everyone is here to learn and even if you need to directly message the team member you feel most comfortable talking to. Don't keep it to yourself.

Goal-Setting, Planning, and Execution

Team goals for this semester:

Have a draft of a working algorithm.
Ensure working algorithm is most efficient means of intended product.
Incorporate machine learning or AI into working algorithm.

Strategies for planning and assigning individual and team work:

We will assign individual work based on how much collaboration is needed for each task, and whether someone plays a better role for a certain part. It will differ.

Strategies for keeping on task:

Keep meetings on track by having an agenda, then have action items for the time period after the meeting.

Incorporate milestones for each member. Provide objective goals to reach on a weekly basis.

Consequences for Not Adhering to Team Contract

How will you handle infractions of any of the obligations of this team contract?

We will talk to the infractor as a team and try to help them stay motivated.

What will your team do if the infractions continue?

We will report repeated infractions to our instructor and ask for more help.

****

a) I participated in formulating the standards, roles, and procedures as stated in this contract.

b) I understand that I am obligated to abide by these terms and conditions.

c) I understand that if I do not abide by these terms and conditions, I will suffer the

consequences as stated in this contract.

1) Sullivan Jahnke	DATE 2/13/2022
2) Tyler Mork	DATE 2/13/2022
3) Json Rangel	DATE 2/13/2022
4) Austin Rognes	DATE 2/13/2022
5) Hani El-Zein	DATE 2/13/2022