RUTGERS
School of Engineering

ECE Co-Op Internship Course Report

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COURSE: 14:332:497
SEMESTER/YEAR: Fall 2021
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INTRODUCTION

I worked in the product research and development team in Signify (formerly Philips Lighting) as an assistant engineer. And I worked in an office for 40 hours per week. My internship started on August 1, 2021, and terminated on August 31, 2021, which lasted for exactly 6 months.

The team I worked in primarily focused on product development and benchmark on industrial ceiling-mounted microwave sensor that operates on the microwave frequency of 24 GHz which is definitely an industrial leading standard. Beyond the common features – like daylight and motion detection – that the most industrial sensors on the market have, the Signify product I worked on featured noise, humanity, and temperature detection.

REGULAR ASSIGNMENTS

As an assistant engineer, I was mainly responsible for assisting sensor engineers in the product benchmarks, including report writeup on microwave sensors, the field test in a cooperated university laboratory, data classification, detection pattern graphing, and search on the rival products. And sometimes I was assigned to assist the molding team in assembling the housings of the sensor.

PROJECTS

Task One – Search on Rival Product

1. **Introduction**
   Microwave sensors generate an electromagnetic field between transmitter and receiver, thereby creating an invisible volumetric detection. And on the market, the prevalent microwave sensors are with microwave frequencies of 5.8 GHz and 10.5 GHz, and the technology that operates on both frequencies is quite mature and stable. The majority of the sensors feature daylight and motion detection which are designed to perceive the occupancy of the high-bay area – whose ceiling height is usually ranging from 6 to 12 meters – like the warehouse, or low-bay area – whose ceiling height is below 6 meters – like an office.

   Sensors usually operate at temperatures ranging from -20 degrees to 60 degrees with a power consumption no greater than 1W. And they can be designed either to be wall-mounted or ceiling-mounted or both (which is a rare case). Different mounting methods would result in a dissimilar effective detection pattern. And the detection pattern and the appearance of the sensors vary from manufacturer to manufacturer.

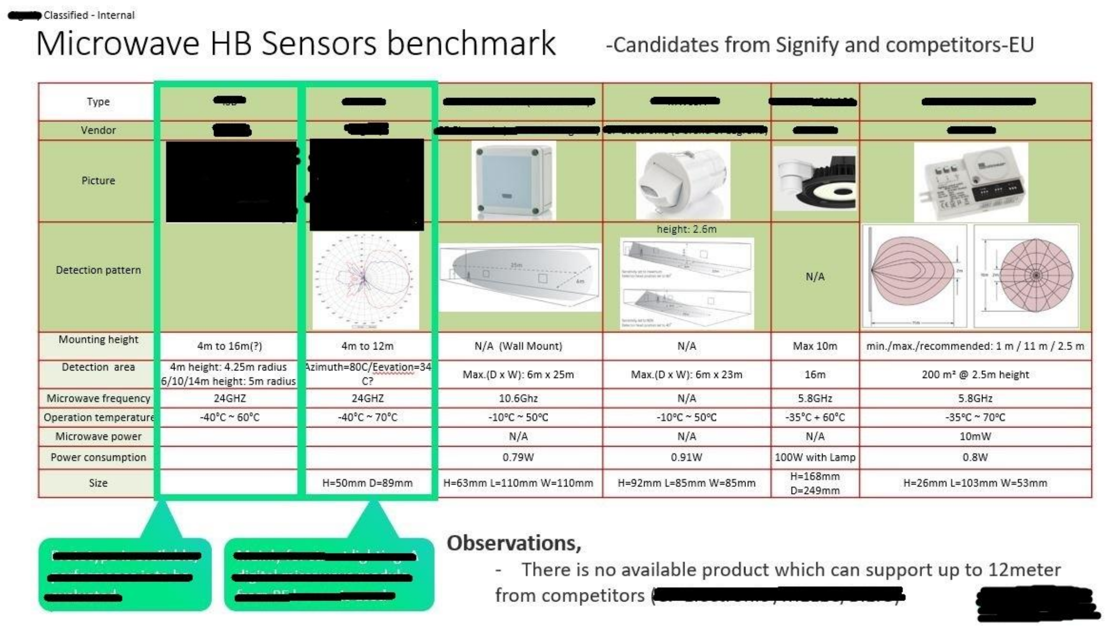
2. **Assignment**
   The first task assigned to me was to thoroughly search the relevant microwave sensors from world-class rival firms. More specifically, I was assigned to collate the demanded specifications – including pictures of the sensors, detection pattern, mounting height, optimum detection area, microwave frequency, operation temperature, microwave power, power consumption, etc. – from the rival firms.

   Collected specifications are shown in Figure 1 and Figure 2. All required information was correctly extracted from the specification sheets provided by other manufacturers.

3. **Challenges**
   The challenge I faced while working on this task was to correctly extract the demanded specifications. The specification sheets provided by different rival companies did have dissimilar formats. Rather than clearly indicating the optimum detection diameter and height, some specifications sheets just offered the general detection pattern as I had to figure out the optimum information by eyeballing the pattern graph which might potentially cause slight inaccuracy. After discussing with my supervisor, we decided to take the optimum height when its detection diameter reaches the maximum. And the sum of the optimum height and diameter would be the optimum area.

Another challenge I faced was about determining the detection pattern based on the antenna characteristics (as shown in Figure 3). The antenna characteristics pattern was completely different than the detection pattern I dealt with, which is detailed in Task 3 – Detection Pattern Graphing.

4. Figures



[redacted] Classified - Internal

Microwave HB Sensors benchmark -Candidates from Signify and competitors-EU

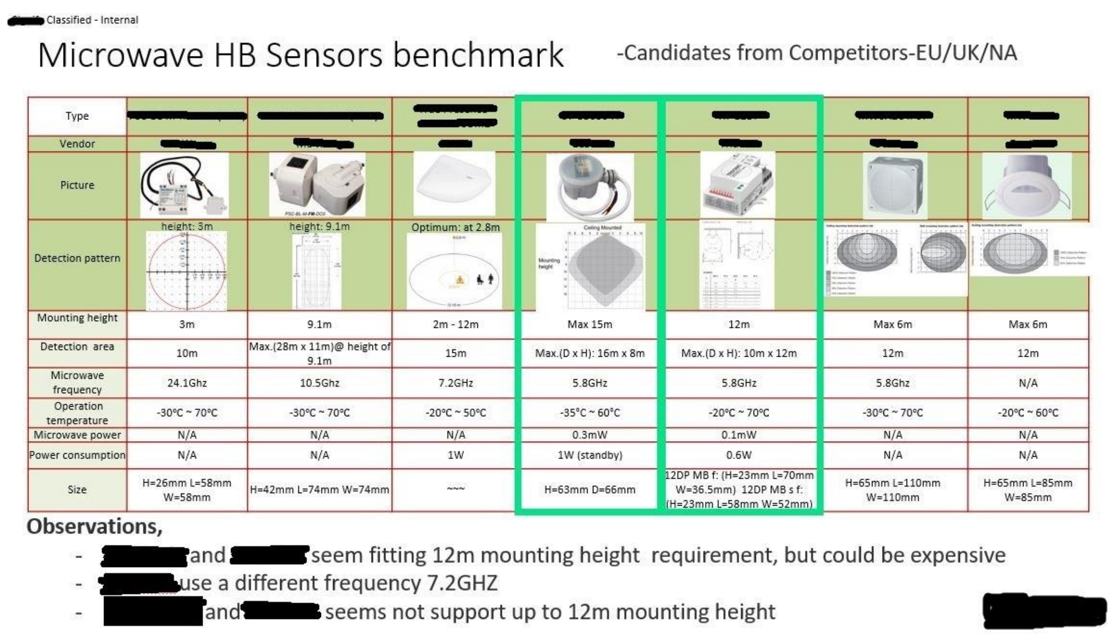
Type	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Vendor	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Picture	[redacted]	[redacted]				
Detection pattern		[redacted]		height: 2.6m	N/A	
Mounting height	4m to 16m(?)	4m to 12m	N/A (Wall Mount)	N/A	Max 10m	min./max./recommended: 1 m / 11 m / 2.5 m
Detection area	4m height: 4.25m radius 6/10/14m height: 5m radius	Azimuth=80C/Eevation=34C?	Max.(D x W): 6m x 25m	Max.(D x W): 6m x 23m	16m	200 m² @ 2.5m height
Microwave frequency	24GHZ	24GHZ	10.6Ghz	N/A	5.8GHz	5.8GHz
Operation temperature	-40°C ~ 60°C	-40°C ~ 70°C	-10°C ~ 50°C	-10°C ~ 50°C	-35°C + 60°C	-35°C ~ 70°C
Microwave power			N/A	N/A	N/A	10mW
Power consumption			0.79W	0.91W	100W with Lamp	0.8W
Size		H=50mm D=89mm	H=63mm L=110mm W=110mm	H=92mm L=85mm W=85mm	H=168mm D=249mm	H=26mm L=103mm W=53mm

[redacted] [redacted]

Observations,

- There is no available product which can support up to 12meter from competitors [redacted] [redacted]

Figure 1



[redacted] Classified - Internal

Microwave HB Sensors benchmark -Candidates from Competitors-EU/UK/NA

Type	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Vendor	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Picture							
Detection pattern	height: 3m	height: 9.1m	Optimum: at 2.8m				
Mounting height	3m	9.1m	2m - 12m	Max 15m	12m	Max 6m	Max 6m
Detection area	10m	Max.(28m x 11m)@ height of 9.1m	15m	Max.(D x H): 16m x 8m	Max.(D x H): 10m x 12m	12m	12m
Microwave frequency	24.1Ghz	10.5Ghz	7.2GHz	5.8GHz	5.8GHz	5.8Ghz	N/A
Operation temperature	-30°C ~ 70°C	-30°C ~ 70°C	-20°C ~ 50°C	-35°C ~ 60°C	-20°C ~ 70°C	-30°C ~ 70°C	-20°C ~ 60°C
Microwave power	N/A	N/A	N/A	0.3mW	0.1mW	N/A	N/A
Power consumption	N/A	N/A	1W	1W (standby)	0.6W	N/A	N/A
Size	H=26mm L=58mm W=58mm	H=42mm L=74mm W=74mm	~~~	H=63mm D=66mm	12DP MB f: (H=23mm L=70mm W=36.5mm) 12DP MB s f: (H=23mm L=58mm W=52mm)	H=65mm L=110mm W=110mm	H=65mm L=85mm W=85mm

Observations,

- [redacted] and [redacted] seem fitting 12m mounting height requirement, but could be expensive
- [redacted] use a different frequency 7.2GHZ
- [redacted] and [redacted] seems not support up to 12m mounting height [redacted]

Figure 2

Task Two – Field Test in the Cooperated University Laboratory

1. Introduction

Compared to the passive infrared detectors (PIR) sensors, microwave sensors are much more sensitive since they can detect the object behind the wall and even catch a slight movement. Due to its high sensitivity, microwaves sensors can be negatively impacted and possibly false-triggered by the non-human presence, fluorescent lights, ventilation, water pipes, and any devices and object that can either generate or reflect the microwave – like a smartphone or a wall. And long exposure to the high-frequency sensors would result in potential health issues.

Conversely, PIR sensors - which measures infrared light radiating from the object - are less sensitive and consume less energy, and would not detect beyond the solid obstacle – like a wall. Thus, whether to use PIR or microwave sensors is greatly determined by the company's budget and the installing environment.

The maximum detection area increases as the mounting height reach its optimum. And the maximum detection area decreases and fades away as the mounting height goes beyond its optimum height.

2. Assignment

The field test in the cooperated university laboratory was aimed to verify and standardize the detection pattern from the specification sheets provided by other manufacturers. And four sensors – including three microwave sensors and one hybrid (microwave + PIR) sensor – were required to be tested.

The sensors that were being tested were required to be mounted on a solid and stable platform, and left at the demanded height of 8m, 12m, and 15m, respectively, to perform the task. The area right below the sensors was divided into several 1m x 1m grids along with the x-axis and y-axis. Walking on the grids along with two axis can generate sufficient data to make the ground truth table.

3. Challenges

While working on the platform setup, I and my colleague had trouble dealing with the wiring. Every cable and adaptor had to be matched correctly; any false connection and unworkable devices would stop us from performing the field test. As educated engineers, I and my colleague successfully diagnosed every wiring issue after thoroughly checking every detail that we might have a mistake on. And the field test was operated successfully.

Task three – Detection Pattern Graphing

1. Introduction

Microwave sensors, also known as RF(radio frequency) sensors, can detect the presence, speed, and distance of a moving object. Microwave is generated by the antenna module, and when the microwave is reflected and absorbed by the object, the receiver analyzes the waves that are bounced back. And the different patterns of interconnection among the antenna chips would result in dissimilar azimuths and elevations which are the two coordinates that define the position of a celestial object. And the azimuths and elevations of an antenna module are the key factors that determine the detection pattern of a sensor.

2. Assignment

I was assigned to graphically demonstrate the detection pattern, purely based on the antenna characteristics (shown in Figure 3), at different heights with different detection angles in an intelligible approach.

3. Challenges

The first challenge I faced was that, when the antenna characteristics was handed to me, I was quite confused about the representation of the polar graph, the meaning of the angles that appeared next to the antenna module, and the definition of azimuths and elevations. After consulting with a couple of engineers, I eventually got to know that the angles that appeared next to the antenna module represent the azimuths and elevations which are measures used to indicate the optimum detection angles on a different axis. And the polar graph indicates the overall detection diameters on azimuths and elevations. The polar graph contains much more details on the detection pattern once I could understand it.

The second challenge I faced was to find an approach that can intelligibly illustrate the detection pattern. The first method I thought of was to graph on the modeling software. However, I had no prior knowledge of any modeling software. MATLAB might be a solution to perform this task but quantifying the polar graph that can be imported to MATLAB was really out of my competence. Thus, I decided to graph the detection pattern purely by hand. The polar graph already provided sufficient information. By just narrowing the azimuth from 50 degrees to 130 degrees on the polar graph, the detection angles of 80 degrees on one side of the antenna module would be obtained. (Same to elevations) And by placing a vertical bar 10 units away from the center to the right, the detection diameter (with a detection angle of 0) can be represented by the enclosed area. By rotating the vertical bar, we will get different detection angles at the demanded height.

4. Figure

Figure 2: Antenna characteristics

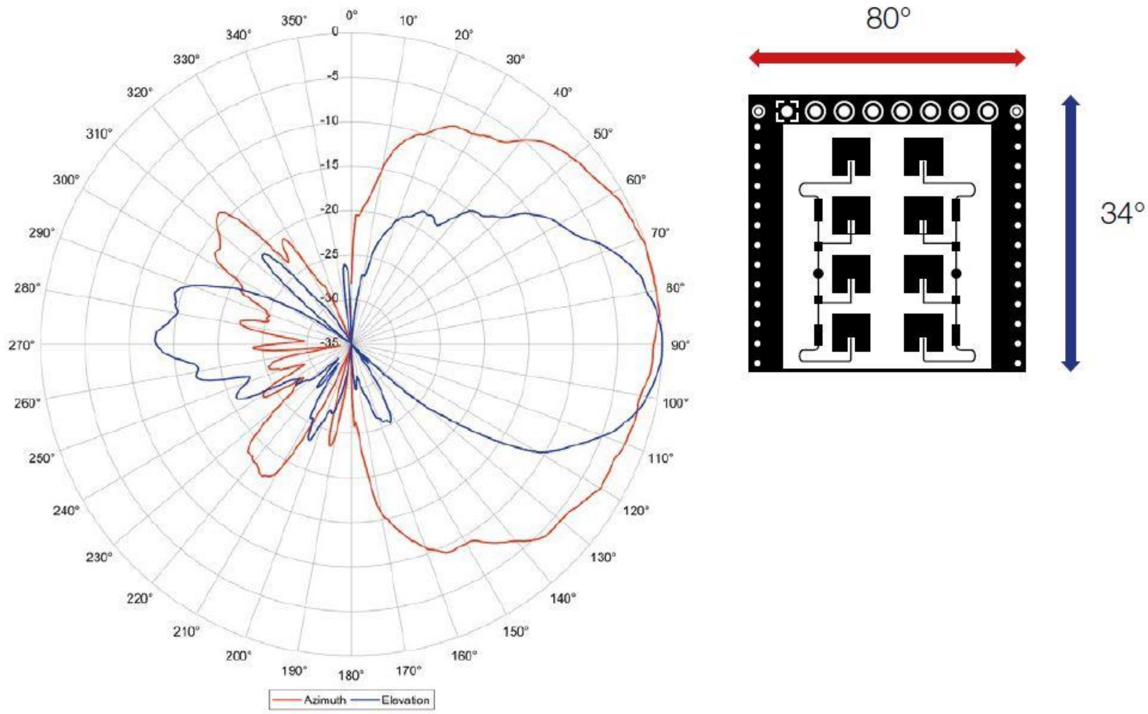


Figure 3

Task Four – Data Classification

1. **Background**
   Collected by the Signify microwave sensor, all datasets contained the temperature fluctuation within a finite area. The algorithm can compute and mark the occupancy by measuring the temperature change of the moving objects that dissipate heat (as shown in Figure 4). However, undesired objects like a computer, a cup of hot tea, even a chair that is sat for a long period of time can dissipate heat as a human does, and those factors can cause false triggers which would result in inaccurate results.

2. **Assignment**
   I was assigned to examine the raw dataset files that contain up to 20000 frames (every second contains 4 frames). The raw dataset had to be uploaded to a MATLAB-based data processing application. Each frame contained in the dataset had to be checked manually. Collect the actual occupancy along with the time stamp, and save them as the ground truth. Then, upload the ground truth to the data processing application which would compute the desired information, including total time and percentage of occupancy (occupied time/total time), etc. Lastly, upload the demanded information and dataset files (as shown in Figure 5) to the Signify server.

3. **Challenges**
   While checking the raw dataset files frame by frame, sometimes it was quite difficult to determine the occupancy when heat sources (usually dissipated by humans) were closed to each other. Thus, to overcome this challenge, I had to repeatedly check several frames that were right before and after the suspicious frames in order to track the trace of the suspicious object.

   If the heat source suddenly appeared and did not have a reasonable movement, like staying still for a long period of time, the heat source was a non-human object. My task was to find the non-human object that was algorithmically classified as occupancy. It was hard to spot the false trigger when there were many participants involved. To overcome this difficulty, I had to check frame by frame with my greatest patience. And dataset that held multiply participants usually contained much more frames which were time-consuming files to deal with.

4. Figures

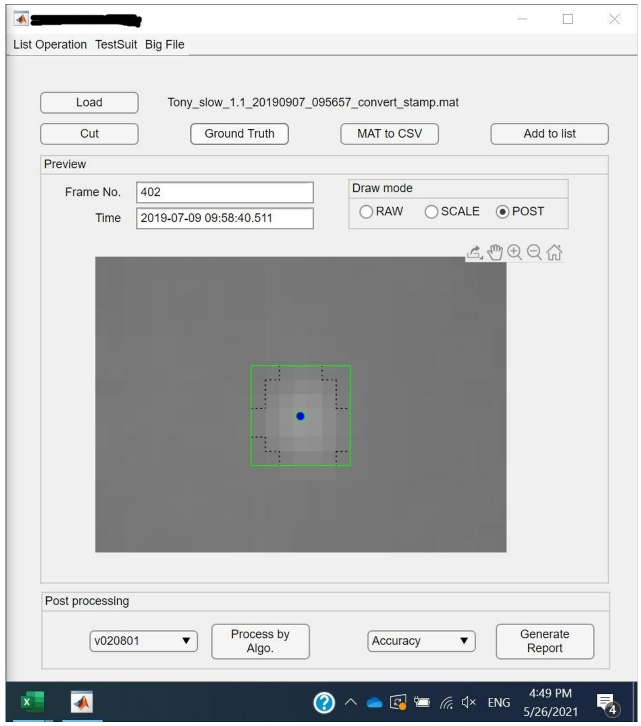


Figure 4

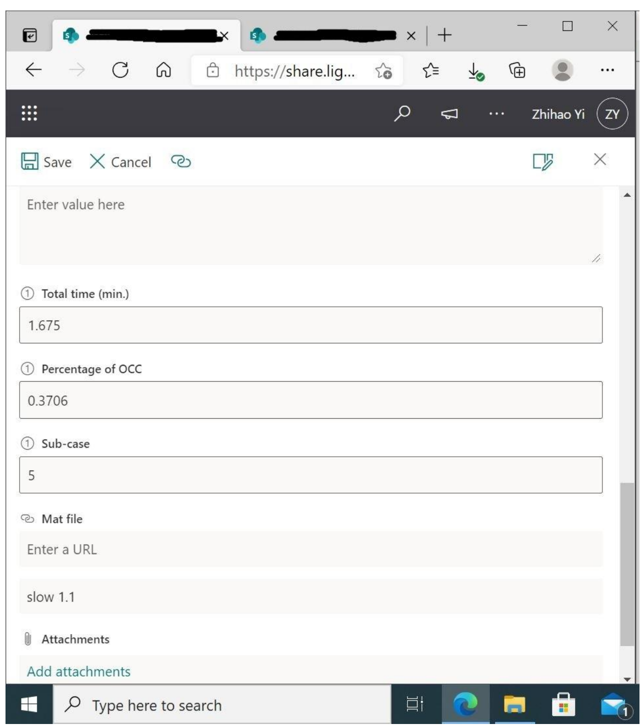


Figure 5

CONNECTIONS TO THE ECE CURRICULUM

My coursework from Rutgers discipline definitely helped me in performing those tasks. While my coding experience from Digital Signal Processing and Methodical Programming assisted me in handling data classification on a MATLAB-based application, my mathematical and electrical engineering intelligence made me a fast learner who could perform any work within a fairly short time with the proper instruction.

With such a precious internship in Signify, I

- Acquired a better MATLAB application handling skill
- Acquired an extensive knowledge of PIR and microwave sensors, including basic principles, industrial applications, and types of sensors
- Promoted my interest in the field of digital signal processing further
- Acquired a deep insight into the field of digital signal processing
- Acquired great work and social experience

FEEDBACK

I want to thank everyone from the product research and development team in Signify. And I greatly appreciate my supervisor Jane Song and senior engineer Mason Gui for their kind assistance in shaping me into a well-educated engineer during my six-month internship. And I appreciate Rutgers University for offering the course 14:332:497 which I could have credit exchange as I deserve it, and the curriculum Rutgers offers definitely helps me become a qualified engineer.

Speaking of recommendations for the ECE department, I would suggest the department offer more software courses rather than one credit software lab. Coding skill is very helpful for an engineer.

CONCLUSION

Inspired by my coursework in digital signal processing and the internship experience in Signify, I started to work on an independent research paper - titled “Design of Multi-sensor Digital Signal Processing Module in Wireless Sensor Network” - during my internship period. The research paper was indexed by EICA, and it definitely fostered my academic competence. I believe my academic coursework and professional experience with industrial sensors would make me successful in my graduate school.