MIDDLE EAST TECHNICAL UNIVERSITY

DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

EE 493-DESIGN STUDIO 1

WEEKLY REPORT V

Company Name: Revolutionary Systems Inc.

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1. SUMMARY OF THIS WEEK'S PROGRESS

This week, work on the proposal report continued and finalized. Executive summary, team organization, scaling of design objectives, description of solution approach to the problem, planning of project schedule, test plans, budget plans, and other necessary parts were prepared for the proposal report.

After the completion of the report, a search in the market for the availability and price of the project components and further research on the VLC were started.

2. WORK ON PROPOSAL REPORT

2.1. Executive Summary

In this era we are all aware of that accessing to information has a crucial importance, but the more important and challenging part is how to transfer that information. Although RF transmission has been the conventional mean of data transmission up to these days, due to the increasing mobile data transmission RF technologies started to struggle on resolving our needs. In addition to the highly occupied bandwidth RF technologies suffer from speed, security and power efficiency problems. The best way to accomplish these problems is using a revolutionary method: visible light communication.

As Revolutionary Systems we will design an image transmission platform where VLC is combined with data transportation by a vehicle. The system will consist of two end terminals that can receive or transmit an image as data packets while a vehicle rushes between these terminals to handle the long distance transmission of the data. While combining communication and transportation the main purpose is to transfer an image as accurately as possible in the shortest time. For achieving this goal the main tasks and our solutions approaches can be listed as:

- Data Compression and Division into Data Packets
  - Compression of image data to enable faster transmission
  - Division of the image data into smaller matrices to get smaller data packets
- Visible Light Communication
  - Sending and recieveing light signals by LEDs and photodiodes
  - Modulation of the original signal for communication
  - Filtering in order to cancel noise
  - Use of preamble signals for handshaking between receivers and transmitters
- Data Transportation by Vehicle
  - Control of the vehicle on physically guided tracks
  - Distance detection by IR proximity sensor
  - Transceiver unit placed and memory chunk on the vehicle

Even though handling all these tasks require knowledge from a diversity of electrical engineering areas, our team contains engineers specialized in the areas of communication, computer, electronics and control. Thus, a correct division of labor between us enables us to handle this big task as smaller and manageable problems and come up with a competitive product build upon the skills of each member.

Our company aims to build up a fast and accurate system for the minimal cost while taking physical robustness and the immunity of the system to variable conditions into account. The project is planned to be finished in 6.5 months with a total budget of about 130$.

As the end product, a vehicle that is moving on a physically guided track with a transceiver on it and two end terminals which are a transmitter and a receiver will be delivered. In addition to these, a camera to take the photo and a display will be supplied to the customer with a user manual and two years of warranty.

2.2. Team Organization

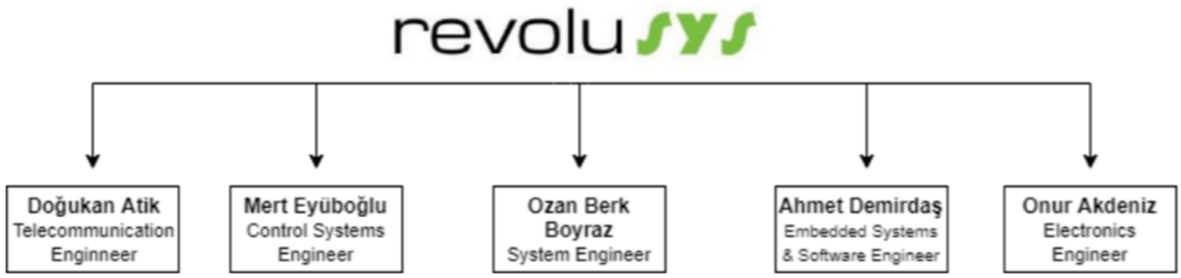

Figure 1: Organization of Revolutionary Systems Inc.

Revolusys is a company that consists of 5 senior engineering students from different specialization areas. Each member of Revolusys has different skills in different areas. There are tasks on different areas of electrical and electronics engineering and these tasks have been shared with respect to the talents of each engineer. This leads to an organizational structure seen in Figure 1.

2.3. Revision of Requirement Analysis

After getting feedback at the last meeting with the company DS coordinator, requirement analysis is revised. Functional requirements are itemized, physical and performance requirements are rewritten.

4.1 <u>Functional Requirements</u>

- The system must be able to take a photo.

- Some portion of the photo must be transmitted to the vehicle by VLC (Visible Light Communication).
- The vehicle should go to the receiver terminal on a physically guided track.
- The data packets carried by the vehicle needs to be delivered to the receiver terminal.
- The vehicle must go back and forth until the transfer of the full photo is done.
- As the full photo is delivered, the photo must be displayed at the receiver terminal.

4.2 Performance Requirements

- A minimum DTR (data transfer rate) of 0.013 Mbps will be achieved.
- The average velocity of the vehicle shouldn't be lower than 25 cm/sec for the maximum distance case (1.5 meters).
- The minimum accuracy rate of 90% should be achieved for the reconstructed image.

4.3 Physical Requirements

- The vehicle should be able to move on a physically guided track.
- The receiver terminal will also be able to move on the track.
- The distance between two terminals should vary between 0.4 meters to 1.5 meters.

2.4. Scales for Design Objectives

The design objectives are scaled so that the company can assign points to the alternative designs and find the best-matching design considering the company's milestones.

Performance Objectives:

Speed:

- 5 points – Operation time under 60 seconds
- 4 points – Operation time between 60 and 75 seconds
- 3 points – Operation time between 75 and 90 seconds
- 2 points – Operation time between 90 and 105 seconds
- 1 points – Operation time between 105 and 120 seconds
- 0 points – Operation time over 120 seconds

Accuracy:

- 5 points – The displayed image has %100-85 accuracy
- 4 points – The displayed image has %85-70 accuracy
- 3 points – The displayed image has %70-55 accuracy
- 2 points – The displayed image has %55-40 accuracy

- 1 points – The displayed image has %40-25 accuracy
- 0 points – The displayed image has under %25 accuracy

Marketability Objectives:

Cost:

- 5 points – Total cost is under 100$
- 4 points – Total cost is between 100-125$
- 3 points – Total cost is between 125-150$
- 2 points – Total cost is between 150-175$
- 1 points – Total cost is between 175-200$
- 0 points – Total cost is over 200$

Immunity to Variable Light Conditions:

- 5 points – Works under sunlight.
- 4 points – Works under indoor lightening.
- 3 points – Works at shadows at daytime.
- 2 points – Works under indoor shady lightening.
- 1 points – Works unsteadily under shady indoor lightening.
- 0 points – Works only under complete darkness.

Robustness:

- 5 points – System is robust for its operation and transportation of the system.
- 4 points – Risk of disintegration of several parts of the system while packing and transporting whole system to another location.
- 3 points – Disintegration of several parts of the system while packing and transporting whole system to another location.
- 2 points – Risk of disintegration of one part of system in operation time.
- 1 points – Disintegration of one part of system in operation time.
- 0 points – Disintegration of several parts of system in operation time.

2.5. Project Schedule

Each task that needs to be accomplished was organized in a schedule. This schedule is presented as a Gannt Chart in Figure 2, where each period represents 1 week starting from 4 November 2019.

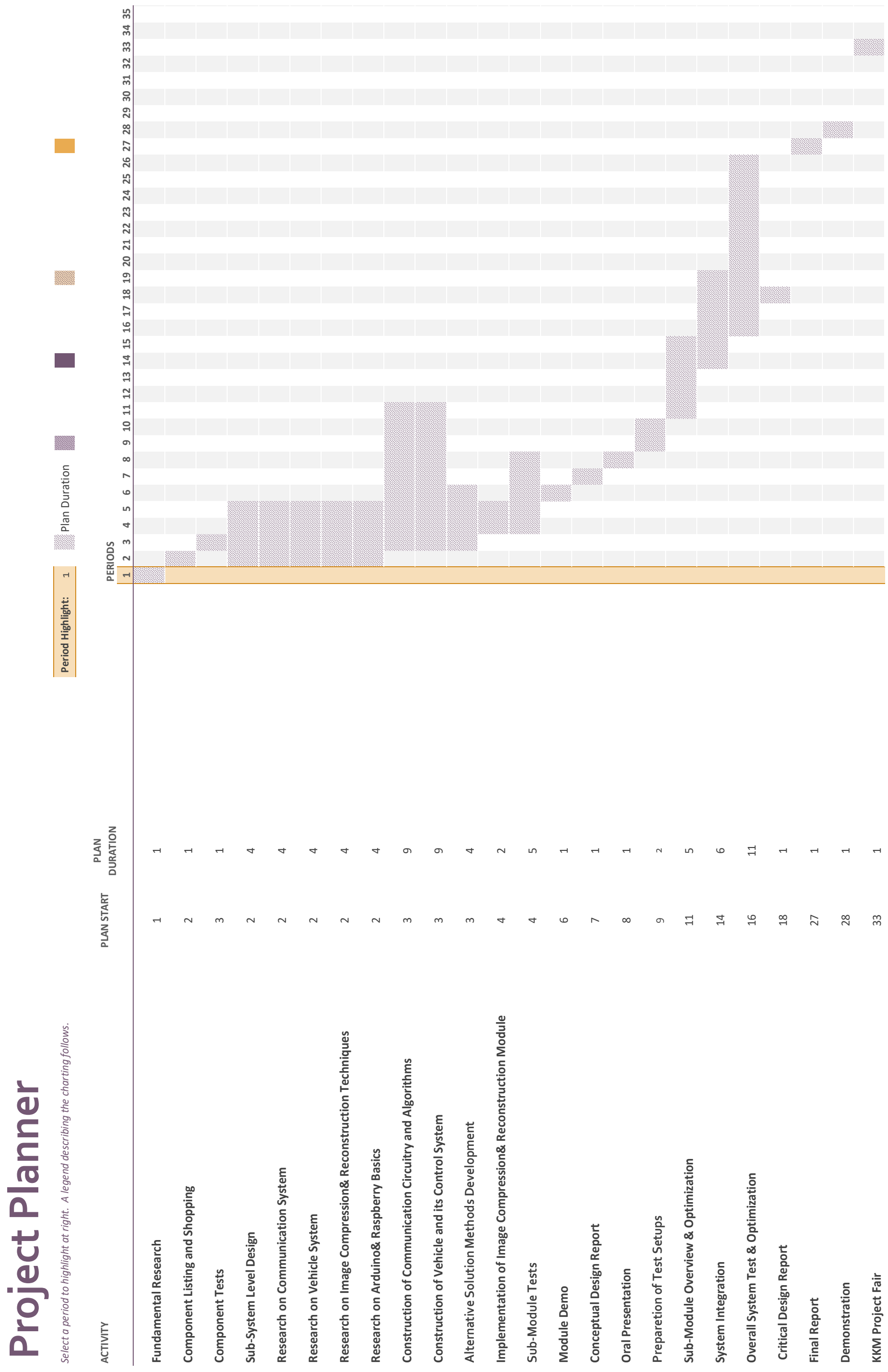

Figure 2: Gannt chart of the project schedule.

2.6. Budget Plan

The company has noted down the estimated R&D costs considering each party involved in the project. The total estimated budget of the project is calculated as about 130$, which is in the limits of the budget constraint.

2.7. Deliverables

The Revolutionary Systems Inc. plans to deliver the following items to its customers.

2.7.1. Equipment

- *Vehicle*
  The user will be provided with a vehicle which has a transceiver embedded on it. The transceiver unit includes 4 LEDs and 4 photodiodes. The vehicle is able to detect the terminal and accelerate or decelerate accordingly.
- *Physically Guided Track*
  The user will be provided with a 1.5 meters long plastically constructed rail on which the vehicle can move.
- *Transmitting Terminal*
  The user will be provided with a rectangular prism shaped transmitting terminal which contains a camera, to take a photo, transmitter unit which consists of 4 LEDs and its own computational unit.
- *Receiving Terminal*
  The user will be provided with a rectangular prism shaped receiving terminal which contains a receiver unit consisting 4 photodiodes, a 3.5 inch LCD screen to display the taken photo and its own computational unit.

2.7.2.Documents

- *Warranty*
  Revolusys Inc. provides two (2) years warranty in both transportation and communication breakdowns of the system except the user faults.
- *Manual*
  A manual will be provided to the users to get informed about the utilization and the maintenance of the system.

2.8. Solution Approach and Test Plans

The solution methods that Revolusys plans to utilize were determined. The details of solution methods are in the submitted Proposal Report.

To check whether a proposed method or design matches the project requirements and objectives, it is necessary to perform tests on the component, subsystem, and system level. The tests that Revolusys plans to perform were determined. The details of the test plans are in the submitted Proposal Report.

3. RESEARCH ON COMMUNICATION

To transmit digital data, the light intensity of the LEDs will be modulated and by using photodiodes, the modulated signal will be received by detecting the change of amplitude the incoming light.

To modulate the signal, there are several options that can be seen in the graph below.

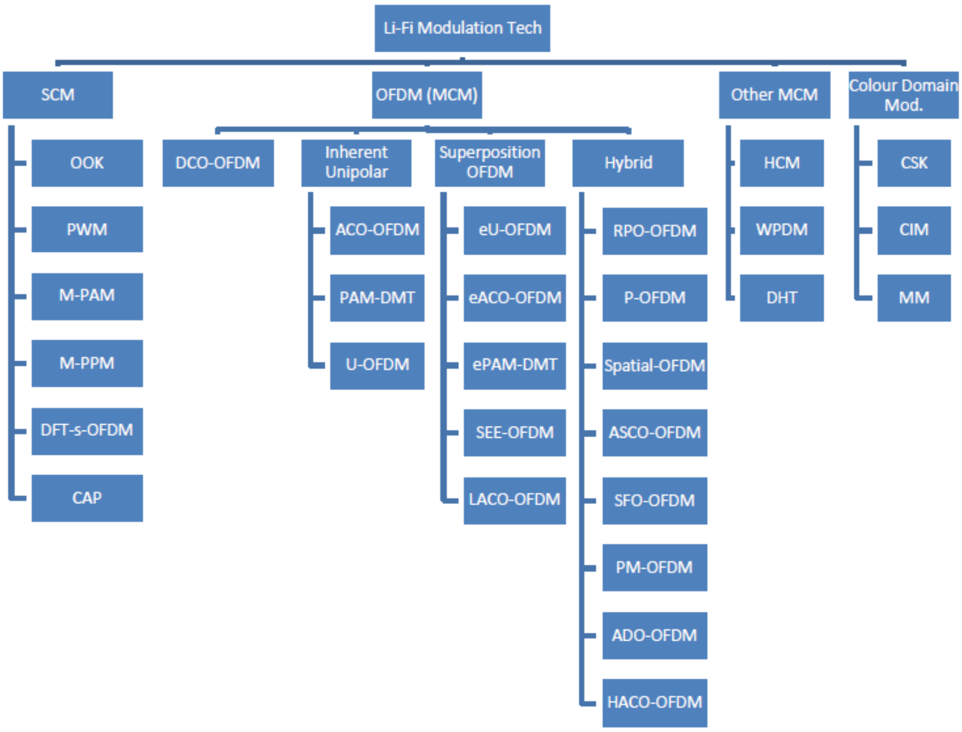

Figure 3: The modulation techniques for Li-Fi

As can be seen from the graph, there are overwhelmingly many options to choose from. However, due to the inherent nature of the project, low transmission speeds are possible. Therefore, at this moment, there doesn't seem to be a need for investigating multi-carrier techniques (MCM) at this moment. The required transmission speed can be met by using single carrier modulation techniques (SCM).

- OOK

This is called as on-off keying. Here, the LED is at the “on” state whenever the digital information is equal to one and at the “off” state whenever it is equal to zero. The “on” state has a higher light intensity than the “off” state and the photodiode will detect the incoming bit according to that intensity. This method seems pretty straightforward to implement.

❖ BPSK

Another method of interest that is not listed here is binary phase-shift keying. In this method, cos(wt) is transmitted if the incoming bit is 1 and –cos(wt) is transmitted if it is 0. In Figure 4, the waveforms can be seen.

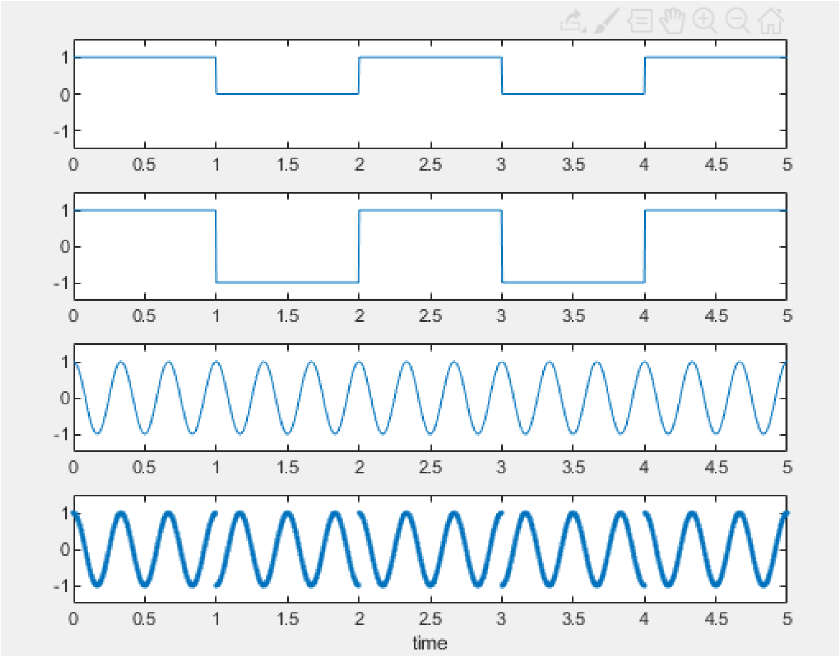

Figure 4: MATLAB implementation of BPSK waveform

In Figure 4, the first graph is the digital data stream. This digital data stream is processed and then the second graph is obtained. The second graph is the graph with which the carrier cosine is multiplied. After the multiplication, the fourth graph will be given to the LED and the light will be transmitted across.

The main problem with the BPSK is that the demodulation process can be very complex. First of all, the carrier frequency and the demodulator frequency should be ideally the same. To make them the same, the carrier frequency of the received signal can be used in the demodulator. For that purpose, the Costas loop can be used.

Apart from frequency matching, another issue arises when it comes to bit matching. A case where the receiver perceives one bit as the last half of the previous bit and first half of the current bit is possible. If the previous bit and the current bit are different than each other, this can put the system in a wrong state. For that purpose, bit synchronization is also required. To do this, the early-late gate synchronization method can be used as proposed in [1].

4. CONCLUSION

This week, the proposal report was completed and submitted. Market search and literature research is ongoing.

5. REFERENCES

1. “DIGITAL IMPLEMENTATION OF A BPSK DEMODULATOR.” [Online]. Available: https://repository.arizona.edu/bitstream/handle/10150/608921/ITC_1992_92-0514.pdf?sequence=1&isAllowed=y. [Accessed: 07-Nov-2019].