

Design & Development of an Intelligent fault tracking system using optical fiber cable in Railway Tracks

Rahul Choudhary, Shubham Wagh, Aditya Vidolkar, Rohit Salem, Ashish Ghatge
Dr. B.S.Umre
Visvesvaraya National Institute of Technology,Nagpur
VNIT,South Ambazari Road,Nagpur,Maharashtra. (440010)
shubhamwagh48@gmail.com

***Abstract*—** The ability to maintain rail networks poses substantial logistics and engineering challenges that are compounded by; increasing number of passenger traffic, loner operational hours (24 x 7) rail networks and the drive for more energy efficient travel. Thus in this era where austerity measures are dominant, clever and novel engineering techniques for monitoring the critical, maintenance-intensive sub-components of these networks is essential. This paper presents an engineering solution using fiber optic cable to supplement track circuits for detection of broken rails. The paper will demonstrate a more advanced and intelligent railway security using engineering solutions. According to this method, light is fed from an optical source into an optical fiber cable arranged along a railway track and comprising one or more optical fibers, each fiber having a uniform structure along the railway track; a light detector for receiving light pulses and for converting the light pulses into electrical signals. If fault is detected this will alert the control station as well as send a message to the train driver via GSM to warn him of the danger ahead.

Keywords—Optical fiber cable ; Railway tracks; condition monitoring; GSM

I. INTRODUCTION

India has one of the largest railway network in the world. The increase in the naxalite activities in the Eastern region has put the security of millions of passengers at stake. One of them which concerns the railway authorities the most is the blowing off of the railway tracks. This puts the life of millions of people travelling on train in danger as well as affects the economy and pace of development of the nation. Companies suffer large losses in their business. More importantly it raises security question on the use of railways as a reliable means of transport. Although there is an advance ACD (Anti-Collision Device) network to prevent train collisions but still depend upon pilot engines to tackle this sort of problem which is not only slow but risky enough. RPF (Railway Police Force) patrols give some protection but still it comes at the cost of their own lives. There had been many cases of train derailment and pilot engine derailment. ***Fig. 1.0 shows the graph representation of the cases of track blown off in comparison with total number of attacks on train every year. It clearly shows that we can no more rely on this manual system for security especially when we are about to enter into an era of*** *bullet trains****.***



	2009	2010	2011	2012	2013	2014
Track blown off cases	25	23	15	3	7	5
Attacks on Trains	32	30	20	4	17	13

In a quest to develop a more advanced and intelligent system for the railway security, fiber optic cables are used for fault tracking in railway tracks. The advantage of using fiber-optic cables is that they overcome some of the limitations associated with track circuits and may also provide greater sensitivity to rail breaks. This will lay the foundations for a dependable and connected intelligent infrastructure.
This is a fully automated system which can detect the faults such nuisance cause. Not only it reduces the death tolls which

keeps on increasing every year but also boosts the industrial production and market by reducing the insecurity in transport of good and raw materials via railways. Current track circuit technology relies on the electrical conductivity and ultrasonic imaging techniques of the rail to monitor for rail breaks. If a rail break occurs over tie plates or in the presence of salt-ionic substances, for example, the conductivity may not be disrupted and the break not detected. Track circuit operation can be also disrupted by lightning strikes. Furthermore, track circuits are not available in dark territory.

The overall system is divided into three major sections:

1) Optical pulse generator
2) Optical pulse detector
3) Control station

A **pulse generator(1)** generates the pulse to drive the **laser** and injects a stream of periodic optical pulses in the optical fiber through a **SC connector**. On the receiving side of the cable is a **photo receptor(2)** which senses the light from the optical fiber. An **amplifier** amplifies the equivalent voltage signal produced and feed it to the **ADC** of microcontroller. This setup relies on the same microcontroller so that the time delay obtained is as accurate as possible. A **wireless module** is attached to the micro controller to send the signals to the micro-controller/processor or our **control station(3)** which sends SMS to the motorman of the train scheduled on that route to warn him of the danger ahead.

C. Organization of the Report

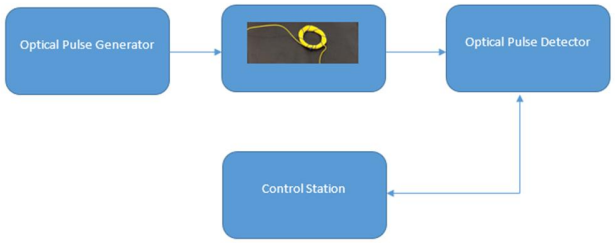
Report contains principle we have used for the detection of the fault in railway track. The reason for the use of various components have been stated thereafter. Also the pcb design, circuit diagram along with test results have been compiled in the report. It also contains the list of the references that we had gone through during the project.

II. PROPOSED SOLUTION

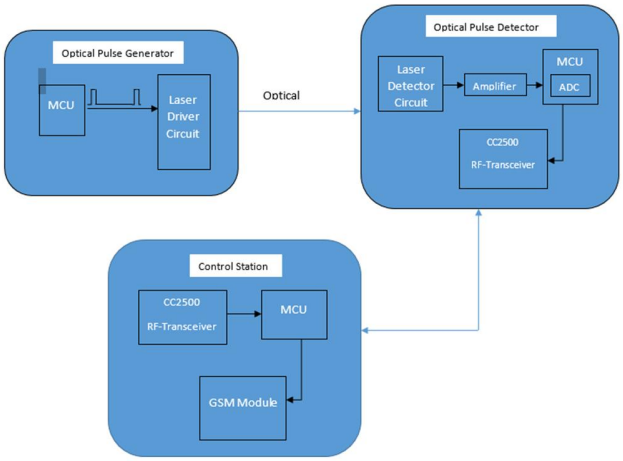
Rail break Detection

Detection of broken rails is a high priority in the railroad community. Broken rails can cause service disruptions, affect system reliability, and have the potential to cause serious accidents. Fiber-optic sensor technology is a relatively new way to perform rail break detection and can be used to supplement track circuits to decrease the number of undetected rail breaks. Fiber-optic sensors can offer high-sensitivity performance and their small size (< 1mm diameter) allows them to be unobtrusively bonded to rail. The fiber is placed on rail in a position where it is least likely to be damaged by maintenance-of-way equipment. Light produced from a laser is coupled into the fiber cable which acts as a channel for the laser light signal. This signal is monitored using a photo-detector as a function of time. If a rail breaks, the fiber also breaks and light transmission decreases dramatically. After the rail break is detected, the optical connectivity gets disrupted, leading to lowering of the amplitude of the optical signal. This sends an alert signal from the detector section to the control station. On sensing the alert signal, an SMS is generated by the control station to the driver of the train scheduled on that track at that time.

Top Level Block Diagram



System Level Blog Diagram



Type of Optical fiber used for sensors

Optical fiber is a cylindrical waveguide consisting of two parts: an inner core region and an outer cladding region which has a lower refractive index than the core. Light travels through optical fiber by total internal reflection in the core.

Type of optical fiber	Performance	Cost
Conventional glass fiber	Very low attenuation (<1dB/km@1.55mm)	$0.10 per meter
Polarization-maintaining glass fiber	Sensitive measurement, complex setup	Several times higher than conv. glass
Plastic fiber	Very high attenuation	Lower than conv. glass

Table.1

The high cost and attenuation of polarization-maintaining glass fiber make it unsuitable for railroad applications. As the length of fiber required for testing was small, single mode Plastic optical fiber of length 30m was considered for implementation of prototype. Table.1 shows comparison of conventional glass fiber, polarization-maintaining fiber, and plastic fiber.

Fiber location on rail

The optimum location for installing fiber in rail was found to be on the vertical portion of the web directly under the head as shown in Fig. 11. This location avoids rail fasteners at the base, maintenance-of way equipment, and rail markings on the center of the web. This location also avoids damage from the drilled holes for rail joints.

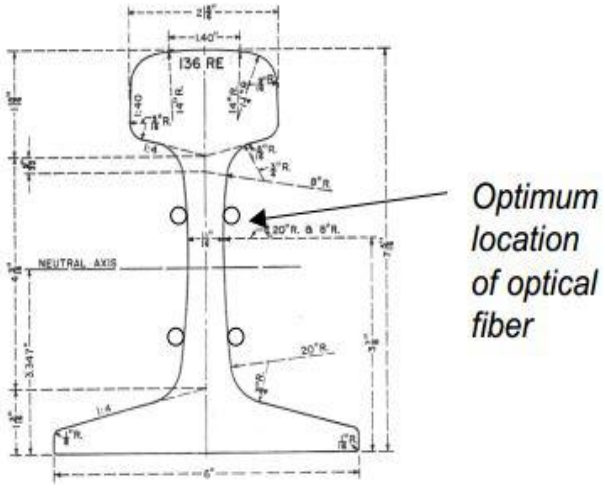


Fig.3

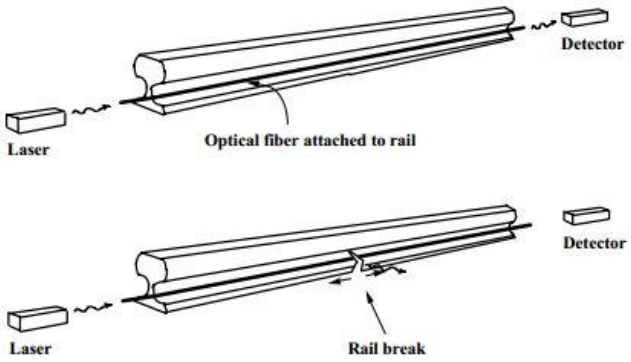


Fig.2

III IMPLEMENTATION

A. Hardware Implementation

OPT101-IC is a monolithic photodiode with on-chip trans impedance amplifier. It has a responsivity of 0.45A/W and bandwidth of 14Khz at Rf = 1Mohm. It is extensively used in high speed data communication system. Also the external circuitry to be connected to is very less. Because of its high sensitivity it could easily detect very small amount of light coming from the optical fiber. Owing to all these benefits, we chose to used this IC in designing our detector circuitry.

LM741:

The output although detectable, but was of very less intensity, because of which on 10bit scale, the variation was too less. This could lead to triggering error of the circuitry. To overcome this short coming we used LM741 op amp based non inverting amplifier. We have this subject in our curriculum, so it was easy for us to design this circuit and set its parameter according to our need.

Laser Driver circuit:

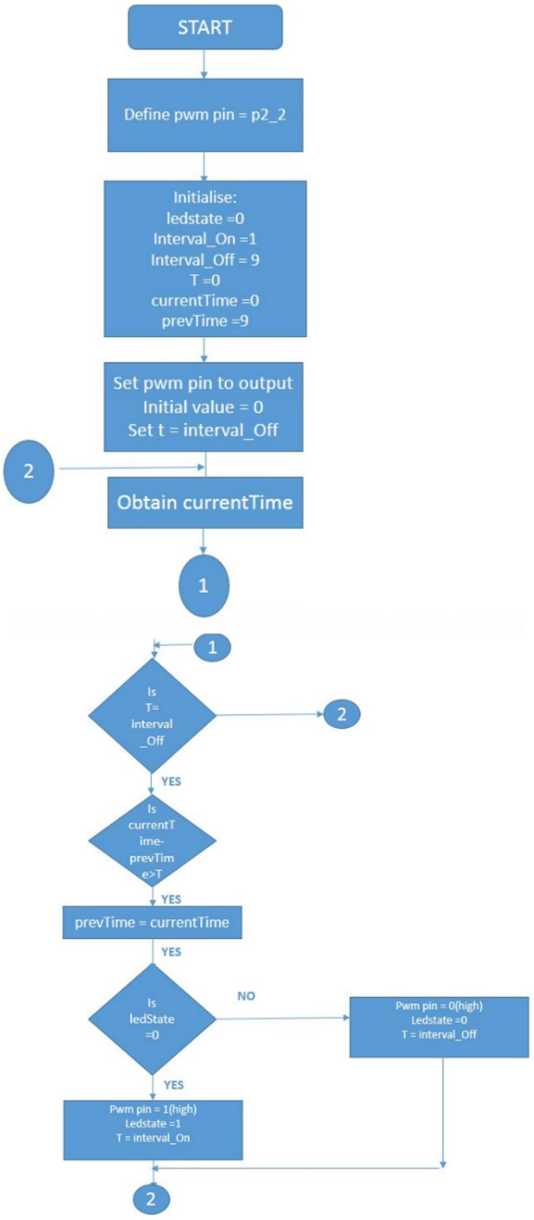
The laser couldn't be directly switched on and off from the data pin of the microcontroller as this would draw excess current leading to damaging of the board. So we needed to design a driver circuit. WEBENCH made it easier for us to design it though it user friendly interface.

B. Software Implementation

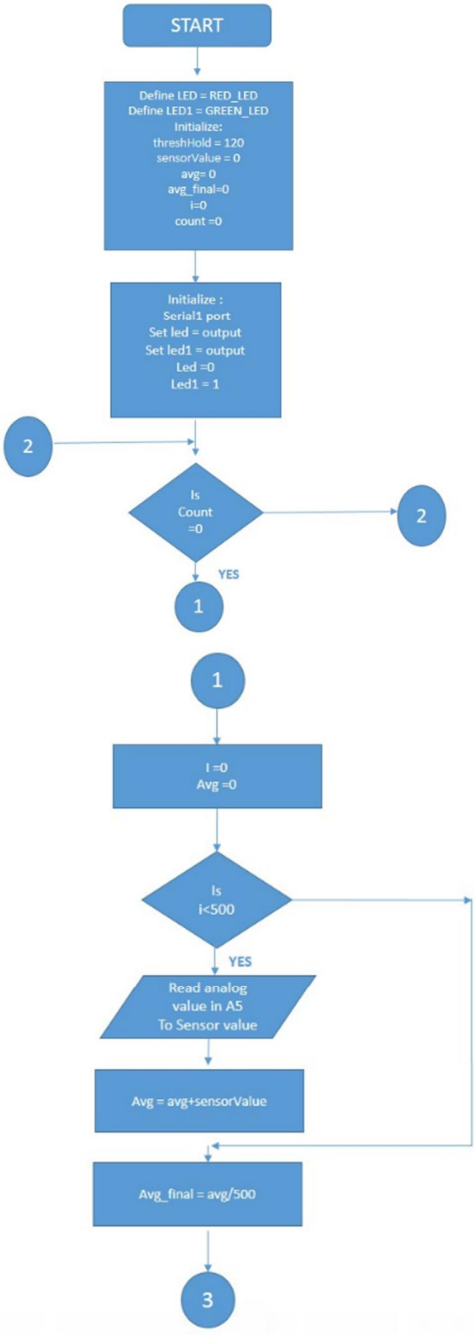


The programming of the launch pads were done on Energia.
We used 3 launchpads for:
1. PWM generation
2. Optical pulse detection
3. Control station modelling

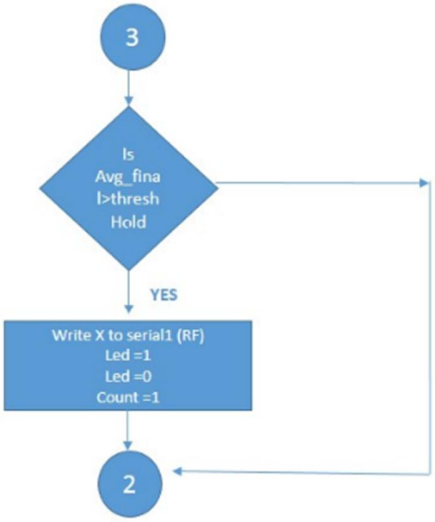
1. PWM flowchart:

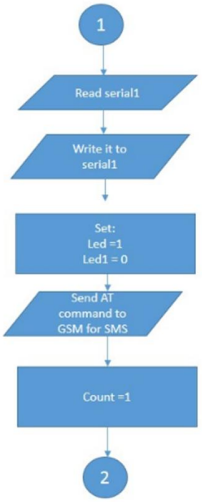


2. Optical pulse detection algorithm





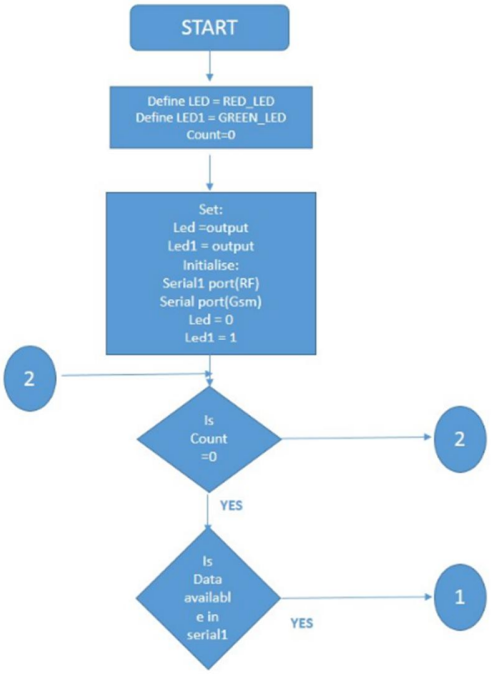


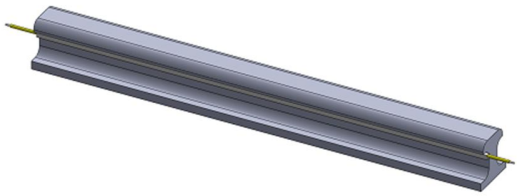


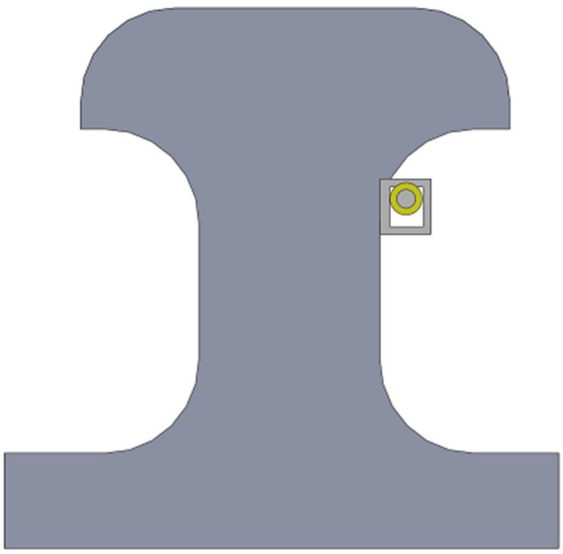
For the modelling of the track we used Solid Works.

3. Control Station modelling which includes:
RF module
GSM module
MSP430f5529 Launchpad

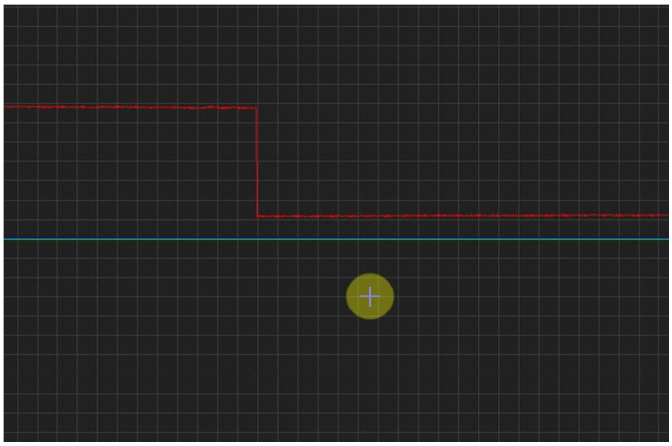
Flowchart for this is as under:





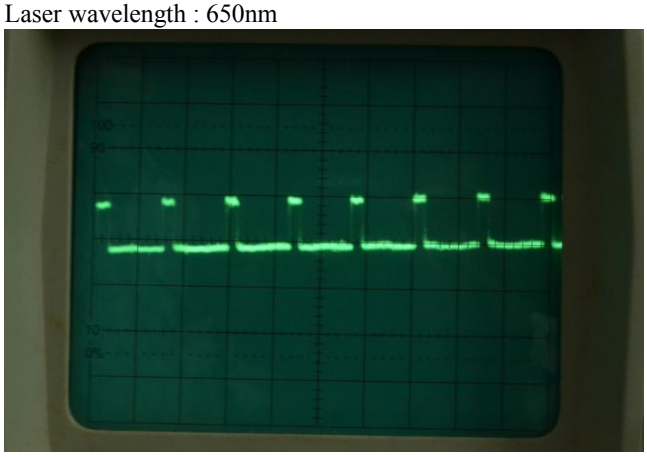


Also we used serial oscilloscope program to determine the value of the threshold for the detector circuit to work flawless.

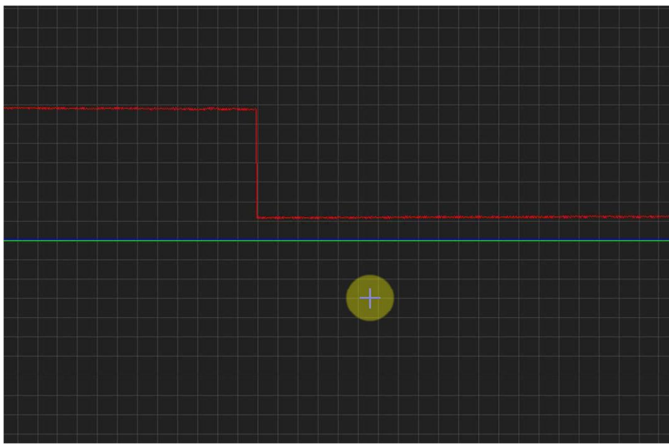


IV. RESULTS

The pulse width of the laser was set to 10% duty cycle and 100Hz
Laser wavelength : 650nm



The detector circuit output:
1. 1.24mV + 5% error when switched ON
2. 550mV in OFF state



V. CONCLUSIONS

We had set our goal to detection and localization of the faults on railway tracks using optical fiber. We were successful in detection of fault in railway tracks but due to time constrain and other limitations we could not complete the localization part. Although we could achieve our goal partially, we strongly belief that with proper setup and expert guidance, our proposal can be implemented in real time to serve the people. This will remain a part of the future scope of the project for us. Also our project can be well integrated with internet of things to determine the trains that are going to be affected because of the fault and send them signal simultaneously and decide an alternate part for them to prevent blockage.

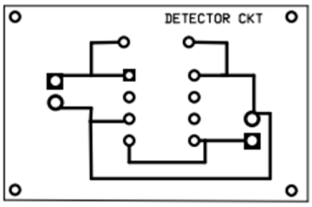
ACKNOWLEDGMENTS

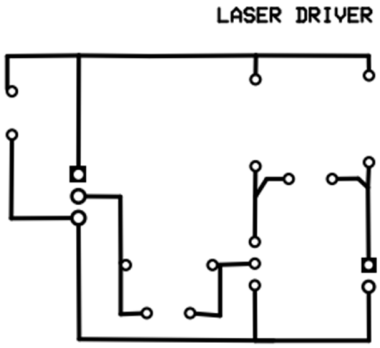
We would that this opportunity to thank our mentor, Dr. B S Umre sir, for providing the necessary boost when our enthusiasm went low. Also we would like pay our sincere gratitude to Dr. Joydeep Sengupta for providing us the necessary technical knowhow required in this field. And lastly Dr. Pazare, esteemed alumnae for our college for helping us with the various optical components and guiding us all the way through.

REFERENCES

All publications, technical reports or other past works your project is based on
1) Sorin W. and D. Baney,"Measurement of Rayleigh backscatter at 1.55 µm with 32 µm spatial resolution" IEEE Photonics.vol.4,pp. 374-376 Apr. 1992.
2) Jones D., "Introduction to Fiber Optics" Naval Education A. T. Sep.1998
3) Von der Weid J.P. and R. Passy , " Return Loss Measurements of WDM Filters with Tunable Coherent Optical Frequency-Domain Reflectometry "IEEE Photonics,Vol.9,pp.1508-1510,Nov.1997
4) Sorin W. and D. Baney,"Measurement of Rayleigh backscatter at 1.55 µm with 32 µm spatial resolution" IEEE Photonics.vol.4,pp. 374-376 Apr. 1992.
5)Jihong Geng and Christine Spiegelberg ," Narrow Linewidth Fiber Laser for 100-km Optical Frequency Domain Reflectometry " IEEE Photonics T.,Vol.17,pp.1827-1829,Sep.2005.
6) Marcuse D. "Loss analysis of single-mode fiber splices",Tech.J., V.56,pp.703-718,Jun. 1977.
Web Links:
1) http://www.satp.org/satporgtp/countries/india/database/railwayattack.htm
2) http://en.wikipedia.org/wiki/List_of_Indian_rail_incidents
3) http://www.newport.com/Fiber-Optic-Basics/978863/1033/content.aspx
4) http://www.thefoa.org/tech/ref/testing/test/reflectance.html
5) http://physics-animations.com/sensors/English/interf.htm

APPENDIX A





APPENDIX B

PWM CODE

```
#define pwm p2_2

boolean ledstate = 0;

 int interval_On =1; // set the value of ON time
 int interval_Off =9;// set the value of OFF Time
 int t = 0;

unsigned long currentTime = 0;

unsigned long prevTime = 0;

void setup()
{
 // put your setup code here, to run once:


 pinMode(pwm, OUTPUT); // PWM OUTPUT

 digitalWrite(pwm, LOW);
 t = interval_Off; // initialize

}

void loop()
{
 // put your main code here, to run repeatedly:
  currentTime = millis();
  //if(t == interval_Off)

  if((currentTime - prevTime)> t){

   prevTime = currentTime;
   //led state change start
   if(ledstate ==0)
   {
    digitalWrite(pwm, HIGH);
    ledstate =1;
    t = interval_On;
   }
   else{
    digitalWrite(pwm, LOW);
    ledstate = 0;
    t = interval_Off;
   }
   // led state chnge over


  }

}
```

DETECTOR

```
int threshHold = 0;
int sensorValue = 0;
long avg= 0;
int avg_final=0;
int i=0;
int count =0;
#define LED RED_LED
#define LED1 GREEN_LED

void setup()
{
 // put your setup code here, to run once:
 Serial.begin(9600);
 Serial1.begin(9600);
 pinMode(LED, OUTPUT);
 pinMode(LED1, OUTPUT);


 digitalWrite(LED, LOW);
 digitalWrite(LED1, HIGH);
```




```
}

void loop(){

 // once the fault detected no need to go inside loop
 while (count==0){
   avg =0;
 // put your main code here, to run repeatedly:
  for(i = 0; i<500; i++){
      sensorValue= analogRead(A5);
      avg += sensorValue;
      }
   // i = 0;
    avg_final = avg/500;
    Serial.println(avg_final);
    if(avg_final< threshHold)
    {
     // Transmit signal to RF receiver

     while(!Serial1.available()) {// Confirm the reciption of
data
       Serial1.write("X");
     }

     digitalWrite(LED, HIGH);   // turn the LED on (HIGH
is the voltage level)
     digitalWrite(LED1, LOW);

     count =1;

    }


 }

}
```

RECEIVER

```
char phone_no[]="xxxxxxxxxx      ;
int count =0;
#define LED RED_LED
#define LED1 GREEN_LED
void setup()
{
 // put your setup code here, to run once:
 Serial.begin(9600);
 Serial1.begin(9600);

 pinMode(LED, OUTPUT);
 pinMode(LED1, OUTPUT);

 digitalWrite(LED, LOW);
 digitalWrite(LED1, HIGH);
}

void loop(){
while(count ==0){
 // put your main code here, to run repeatedly:
 if(Serial1.available()){
   char e = Serial1.read();
   Serial1.write(e);
   // fault msg confirmed

   digitalWrite(LED, HIGH);   // turn the LED on (HIGH is
the voltage level)
   digitalWrite(LED1, LOW);
   //gsm code starts
   //-----------------------------------------------------
    Serial.println("AT+CMGF=1");
    delay(1500);
    Serial.print("AT+CMGS=\"");
    Serial.print(phone_no);
    Serial.print("\"");
    Serial.println("");

    while(Serial.read()!='>');
    {
     Serial.print("Test Message from Tiva
GSM.....Helloo...!!!");
      delay(500);
      Serial.write(0x1A);
      Serial.write(0x0D);
      Serial.write(0x0A);
   // gsm code ends
   //-----------------------------------------------------
   count =1;
 }
}

}
```

APPENDIX C – BILL OF MATERIALS

Give a table which shows the name of the hardware/software component, number of components in the project, cost per component, whether the component is a TI/non-TI component, total cost of the component, and the total cost of all components.

	Component	Manufacturer	Cost per component	Quantity	Total cost of component	TI Supplied / Purchased
1	**CC2500RF MODULE**	**TI**	**700**	**2**	**1400**	**NO**
2	**GSM MODULE**		**1200**	**1**	**1200**	**NO**
3	**OPTICAL SPLITTER**		**1200**	**1**	**1200**	**NO**
4	**FC /SC CONNECTO**		**100**	**2**	**200**	**NO**



	R					
	OPTICAL FIBRE		**2000**	**1**	**2000**	**NO**
	MSP430F5529	**TI**		**2**		**YES**
	TIVA C SERIES	**TI**		**1**		**YES**
	LM741	**TI**		**1**		**YES**
	OPT101	**TI**		**1**		**YES**
				Total Cost of the Project	**6000**	