TECHNOLOGIES FOR SOLDIER SUPPORT

DRAW NO- 10

SOLDIER COMMAND AND CONTROL SOFTWARE

Introduction

Gesture recognition is a dynamic area of research in human-computer interfaces. New input methods, closer to the human nature, are searched for replacing the traditional ones. Communication through gestures is one of the essential and widely used modes of communication in military and is often used by the soldiers in situations where no other mode is possible. These include rescue operations and surgical strikes. Following are the two possible implementations of gesture recognition systems:

<u>SENSOR BASED GESTURE RECOGNITION</u>
Sensors like accelerometers and gyroscopes are employed for detecting the gestures. The data collected from various sensors is communicated to a computer where it is processed and classified into the correct gesture.
<u>VISION BASED GESTURE RECOGNITION</u>
This method uses image processing of the real-time data from the camera and uses various algorithms to classify them after extracting the portion of hand from the image.

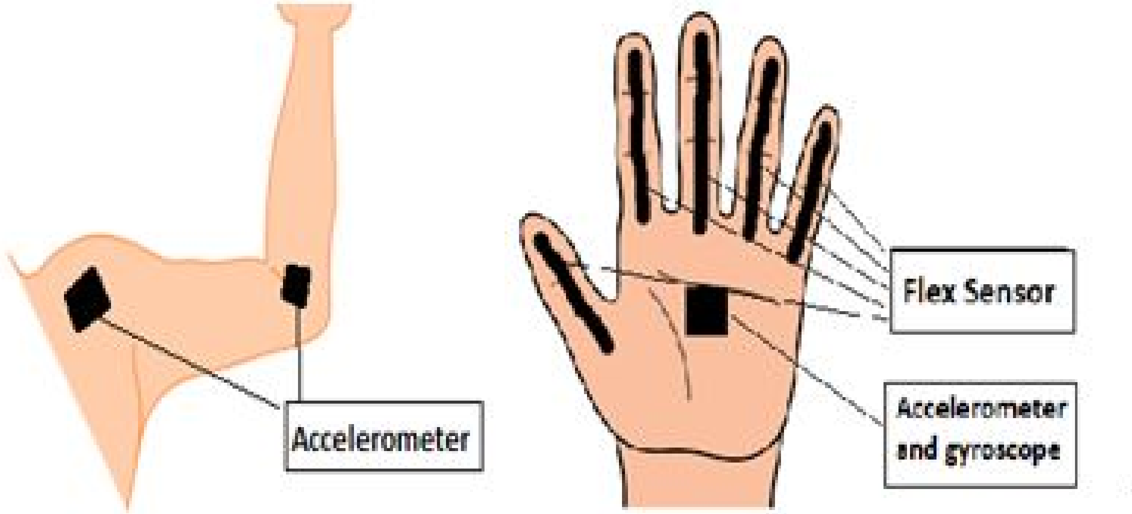
Our solution is based on sensor based gesture recognition and uses a neural network as a classifier. Using an accelerometer and gyroscopes has lower complexity and cost compared to camera-based gesture recognition. In addition, sensors worn on the hands provide better flexibility as the user does not need to face a particular direction as in the case with the camera and is also advantageous in case of areas with low visibility.

Hardware

FLEX (BEND) SENSORS : Many symbols differ in the sense that whether the fingers are partially/completely bend or kept straight. Flex sensors fixed in gloves of soldiers can detect the state of fingers without any hindrance to movement.
MPU 6050 : MPU 6050 contains MEMS Accelerometer and MEMS Gyroscope. Gyroscope is used to detect motion in any gesture.
3 AXIS ACCLEROMETER : This module is used to detect the tilt from the 3 axis and hence used to detect the orientation of hand.
MICROCONTROLLER : Arduino MEGA is used for collecting the data from various sensors and transmitting to another Arduino NANO which is connected to computer.
NRF MODULE (FOR DATA TRANSMISSION) : Not only cheap, this module is also high speed (2Mbps), consumes less power (1uA at standby mode) and has a decent communication range as well.

Positioning of Sensors

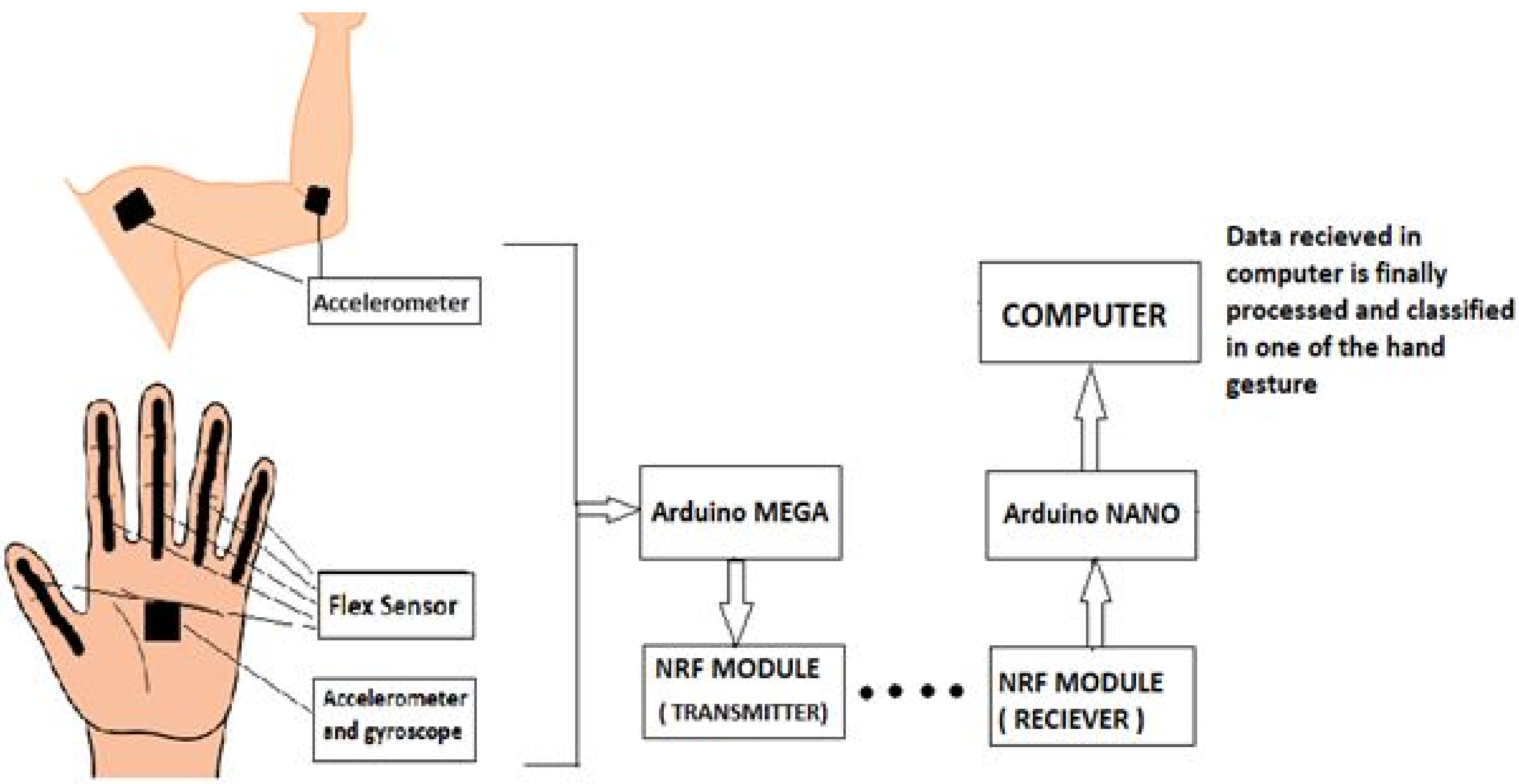
Bend Sensors are placed on each finger and thumb to figure out whether the fingers are bent or not, MPU 6050 (which contains MEMS Accelerometer and MEMS Gyroscope) on palm to know orientation of palm and an Accelerometer on shoulder to know the orientation of hand.

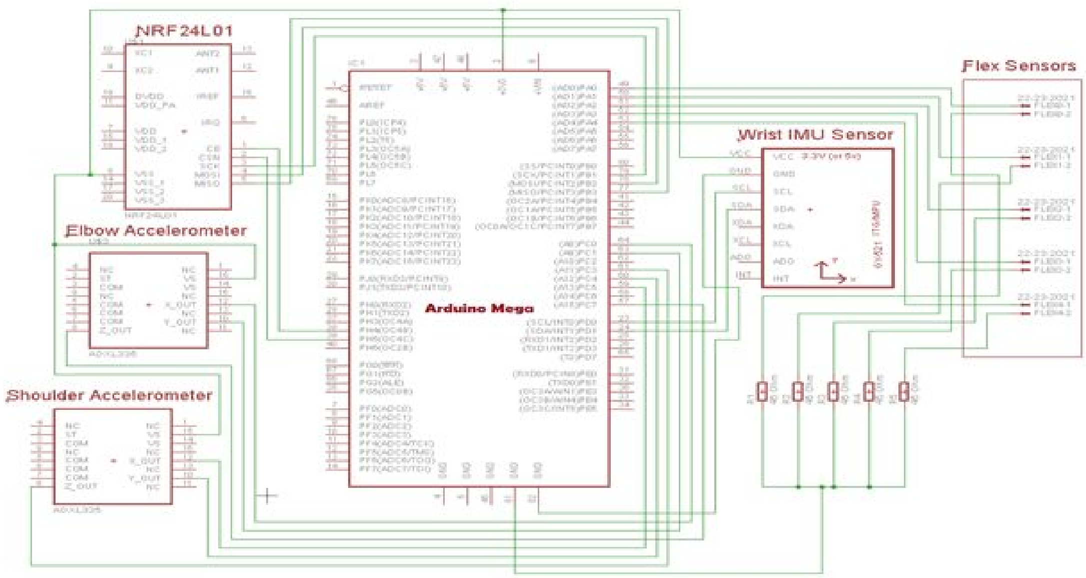


Working

All the data collected from the sensors is sent from Arduino MEGA to Arduino NANO through NRF24L01 Module. The computer connected to Arduino NANO reads the data through Pyserial and processes it.

An average of 10 readings is taken which forms 1 data entry. This data is classified into one of the 43 hand gestures using neural network as a classifier. The final output image of the gesture is shown on the screen





Algorithm

A neural network is used as a classifier for the problem statement. A neural network consists of units (neurons), arranged in layers, which convert an input vector into some output. Each unit takes an input, applies a (often nonlinear) function to it and then passes the output on to the next layer.

LEARNING MODEL

Supervised learning is most suitable for pattern recognition, so it is also used for gesture recognition.
Supervised learning is simply a formalization of the idea of learning from ex- supervised samples. In supervised learning, the learner (typically, a computer program) is learning provided with two sets of data, a training set and a test set. The idea is for the learner to “learn” from a set of labeled examples in the training set so that it can identify unlabeled examples in the test set with the highest possible accuracy. That is, the goal of the learner is to develop a rule, a program, or a procedure that classifies new examples (in the test set) by analyzing examples it has been given that already have a class label.

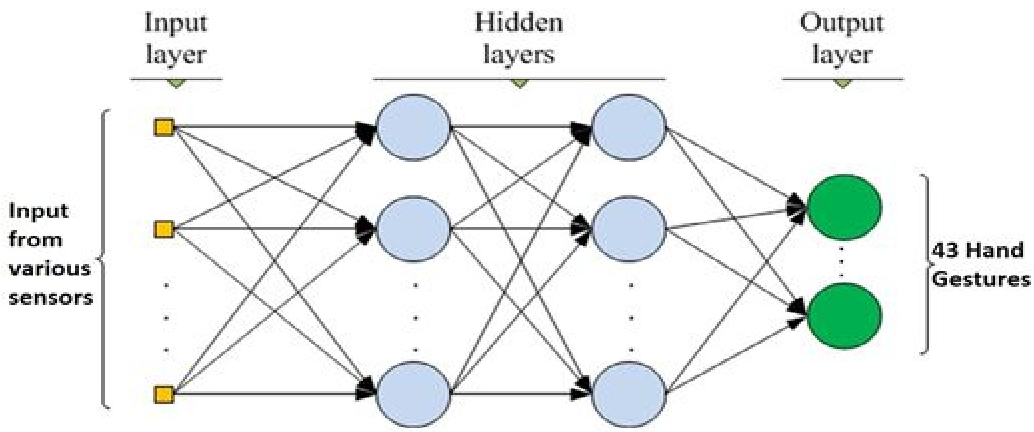
The goal is for the learner to develop a rule that can identify the elements in the test set. There are many different approaches that attempt to build the best possible method of classifying examples of the test set by using the data given in the training set. We will discuss a few of these in this document, after defining supervised learning more formally. In supervised learning, the training set consists of n ordered pairs (x_1, y_1), (x_2, y_2), ... , (x_n, y_n), where each x_i is some measurement or set of measurements of a single example data point, and y_i is the label for that data point. For our model, x_i is a vector of measurements from all the sensors. The corresponding y_i is the vector of classification of the gestures. The test data in supervised learning is another set of m measurements without labels: $(x_{n+1}, x_{n+2}, ..., x_{n+m})$. As described above, the goal is to make educated guesses about the labels for the test set by drawing inferences from the training set.
The model was trained beforehand with 300 data entries for each symbol giving total 43 * 300 = 12900 data entries.

BACK PROPAGATION

The weight updates of Back Propagation can be done via ***stochastic gradient descent*** using the following equation.

$$w_{ij}(t+1) = w_{ij}(t) + \eta \frac{\partial C}{\partial w_{ij}} \cdot$$

Where C is the cost function (mean squared error) and η is the learning rate.



A fully connected neural network with 2 hidden layers and 300 neurons in each layer with Back Propagation algorithm and Adam Optimizer is used in this case which takes input from various sensors and gives an output as one of the hand gesture. The neural network was trained beforehand with the data output for all the symbols.

Results

We have tested the model on a testing dataset of 50*43 = 2150 data entries.We have been attaining a maximum of 95% accuracy in detecting the symbols with the proposed model.

Cost Analysis

Component	Price	Quantity	Cost
Arduino Mega	Rs-750	1	Rs.750
MPU-6050	Rs-280	1	Rs.280
ADXL-335	Rs-300	2	Rs-300
Flex Sensor	Rs-380	5	Rs-1900
Manufacturing	Rs-300	-	Rs-300
Total			Rs-3530

TECHNOLOGIES FOR SOLDIER SUPPORT

DRAW NO- 10

MEMS SENSORS FOR PHYSIOLOGICAL SIGNAL DETECTION AND CONDITIONING

INTER IIT TECH MEET 2018

Introduction

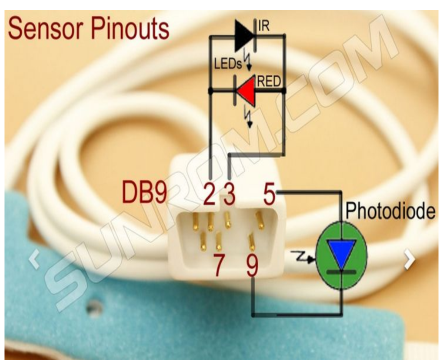
Fast development of electronics, radio communication systems and also textile industry enables modern technologies to be employed for the safety secure at workplaces to save life and health of workers. Various systems of wearable technologies and active clothing, which integrate electronic and control components into textile materials or wearable equipments, are being developed to this end. The main aim of those systems – enable human physiological parameters to be registered and analyzed continuously during his work activities. Proper evaluation of those parameters would let us immediately know about sudden health state changes or an accidental injury. It's still rather new field of application and most of prototypes of the system are still under investigation stage.

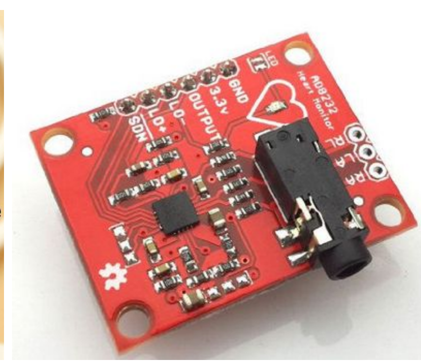
This report describes our efforts towards making some low-cost wearable technologies which can be used to extract and analyze some physiological parameters vital for health monitoring.

Hardware

Temperature sensor (DS18B20) - It has been used to calculate the body temperature as well as the respiratory rate

ECG Module (AD8232) - This module is used to calculate the ECG values using three electrodes placed on the chest. SpO2 sensor probes for pulse oximetry - These contain a pair of Infra-Red and Red LEDs and a photodiode. Pulse oximetery is done on the basis of absorption of both the rays by the photodiode.





DS18B20 SpO2 sensor probe AD8232

Positioning of sensors

Pulse Oximeter probes have been placed across a finger, three ECG sensor electrodes have been placed on the chest and two temperature sensors have been used, one is placed in the armpit and another is placed in the respiratory mask worn to sense the temperature changes while inhalation and exhalation.

Parameter extraction and analysis

Body Temperature

The DS18B20 digital thermometer provides 9-bit to 12-bit Celsius temperature measurements. The DS18B20 communicates over a 1-Wire bus that by definition requires only one data line (and ground) for communication with a central micro-processor. In addition, the DS18B20 can derive power directly from the data line ("parasite power"), eliminating the need for an external power supply. It has been positioned in the armpit and provides very accurate temperature readings in the range of 10°C to +85°C with an error of ±0.5°C.

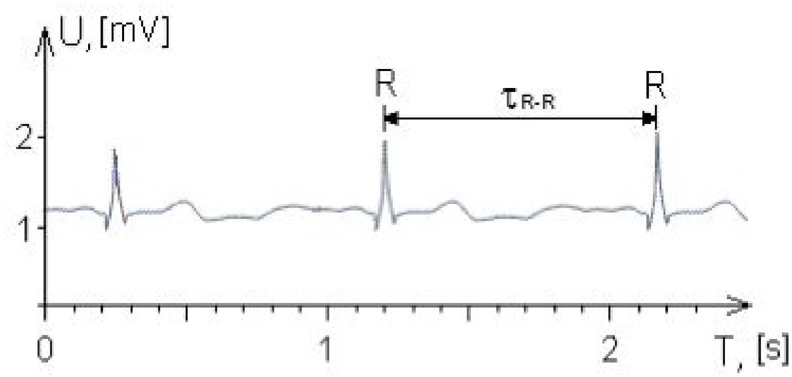
Respiration Rate

DS18B20 has been placed in the respiratory mask to calculate the change in temperature during inhalation and exhalation. The temp of air during exhalation is higher compared to the temperature of air during inhalation. The temperature readings from the mask are analysed to find the minimas and thus the rate of respiration is calculated.

Heart beat rate

ECG signals are analysed to calculate the R-peaks during each ECG wave which represents a single heart-beat. Thus, the heart rate can be calculated using the time difference between two consecutive R peaks which are a characteristic of each ecg signal.

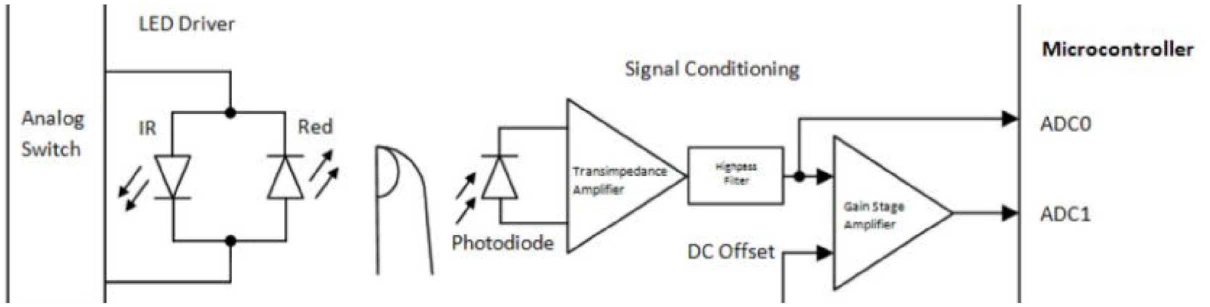
$$pulse = \frac{60}{\tau_{R-R}} \quad \left[\min^{-1}\right].$$



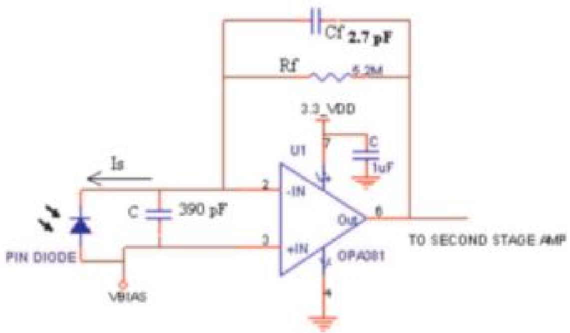
Blood oxygen saturation

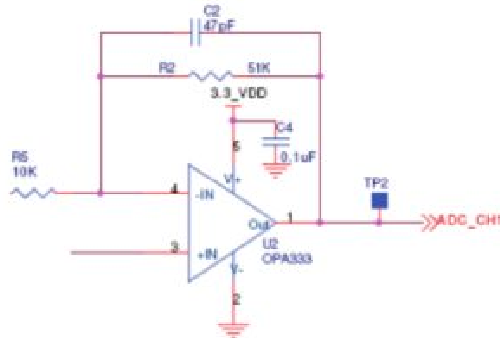
The current signal obtained from the pulse oximetry probes is passed through a transimpedance amplifier to convert it into a voltage signal which is further passed through a gain amplifier and a low pass filter and read using ADC in the Arduino Nano in every 1ms interrupt.

The resulting Infra-Red and Red signals are then sent to the central node using a nrf where it is processed using a FIR hamming window low-pass filter to remove the high-frequency noise signals and an IIR filter for DC removal.



Block Diagram for pulse oximetry





Transimpedance Amplifier

Gain Amplifier

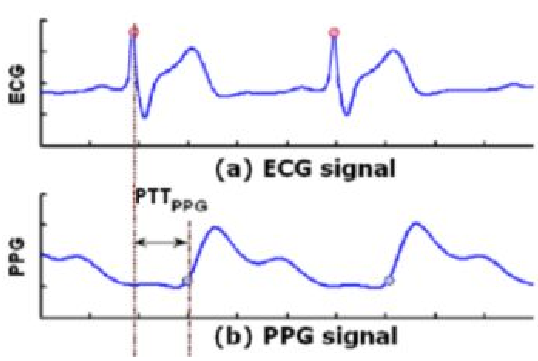
From the AC sample values obtained for the R and IR signals, the RMS values for the IR and R signals are detected. The RMS values are passed through a square root algorithm providing a value proportional to the peak-to-peak signal. The ratio of R and IR signals are calculated and its relation with oxygen saturation is used to calculate the percentage of oxygen in the blood.

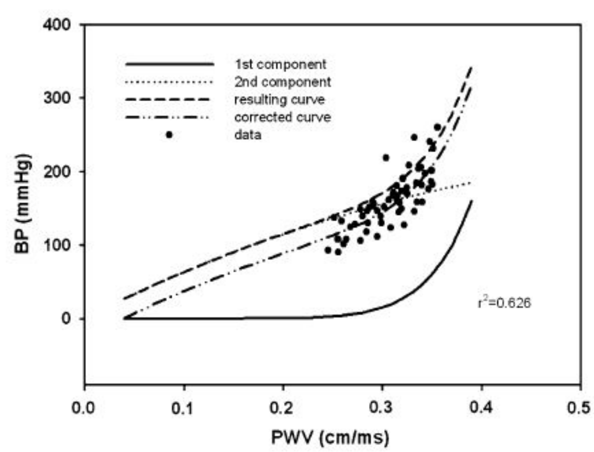
Blood Pressure using Non-invasive Technique

The Infra-Red and Red signals obtained earlier are superimposed to get the PPG signal and pulse transit time(PTT) is calculated which is the time difference between the R peak of the ECG signal and the characteristic point of the PPG signal. Pulse wave velocity is calculated from the PTT using Davies and Struthers formula given below. A PWV - BP relation model was used to find the systolic blood pressure.

$$\text{PWV (cm/ms)} = \frac{\text{BDC} \times \text{height (cm)}}{\text{PTT (ms)}}$$

$$\text{BP}_{\text{PTT}} = P1 \times \text{PWV} \times e^{(P3 \times \text{PWV})} + P2 \times \text{PWV}^{P4}$$





Cost Analysis

Component	Rate	Quantity	Cost
AD8232	1729	1	1729
DS18B20	165	2	330
SpO2 sensor probe	800	1	800
Arduino Nano	230	1	230
NRF24L01	99	2	198
Raspberry Pi zero	750	1	750
MIscellaneous	-	-	300
Total	-	-	4337

TECHNOLOGIES FOR SOLDIER SUPPORT

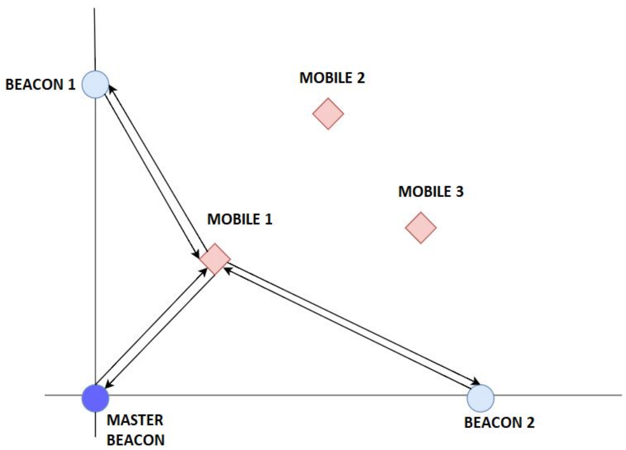
DRAW NO- 10

SOLDIER AD-HOC WIRELESS NETWORK

INTER IIT TECH MEET 2018

Introduction

Indoor Localisation has transformed the way people navigate indoors in the same way GPS transformed the navigation outdoors. Real Time Location Systems (RTLS) describes the class of systems that provides information in real time about the location of the objects, people etc. To determine the absolute position of the tagged objects, the Mobiles, we need to find how far it is away from a number of known points denoted as Beacons. The two major schemes for implementing RTLS are as follows:



- Received Signal Strength Indication (RSSI) based schemes: These scheme allows measuring the signal strength of the received signal at the receiver.Knowing the power of the signal transmitted, the propagation characteristics (Channel) and some prior knowledge of the environment it is possible to calculate the approximate location of the Transmitter. In general these schemes are not that accurate and are required to be augmented with additional technologies to obtain adequate accuracy.

- Time Based Schemes: These schemes involves measurement of the time the radio signal takes to travel between the transmitter and receiver through various techniques and then knowing the speed of light the distance can be calculated.

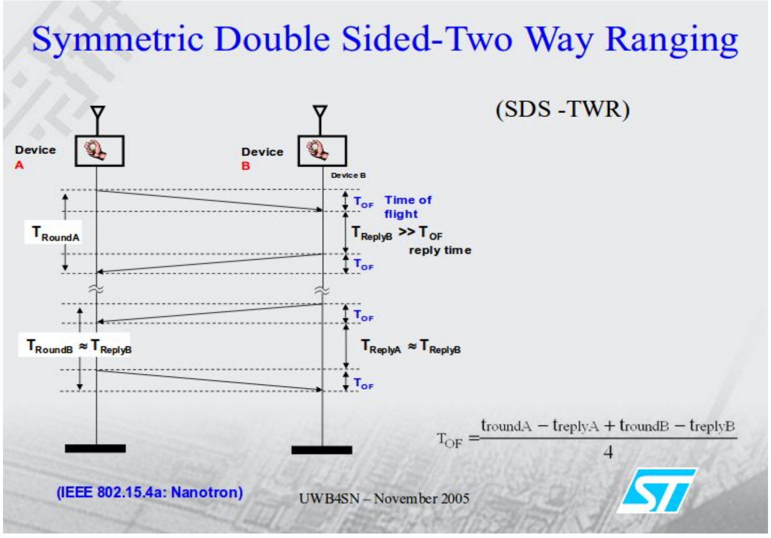
Ultra Wide Band (UWB) (ranging from 3.1 Ghz to 10.6 Ghz) radios have emerged as one of the major breakthrough hardware based approaches in indoor localisation. The UWB radios generally rely on two way ranging, i.e the process of estimating the distance between two devices: one that needs to be localised and one of the custom hardware devices that have been pre-installed in known location. The distance estimation is achieved by accurately timestamping the transmission and reception of wireless signals exchanged between the participating devices. UWB signals consists of very narrow pulses transmitted over a large bandwidth, usually in the order of gigahertz. Even though they overlap with multiple frequencies, no interference is created, as the transmission power at each frequency is very low. UWB transmission require the Tx and Rx to be coordinated to send and receive pulses. The advantage of the UWB transmissions in Indoor localization application lies in their ability to very accurately timestamp the wireless transmissions. Conventional RF signals reflects in indoor environment structures, resulting in distortions to the direct path signal, which in turn makes accurate timestamping challenging.However, because of the pulses being very narrow, it is now easier to differentiate the direct path pulse from the reflected ones. As a result, UWB signals can measure distances with accuracies as low as a few centimeters.

Embedded System Design

The complete embedded system consists of UWB radio Decawave DW1000,Atmega 328P (Arduino Nano) microcontroller, Raspberry Pi on the Beacons, LM2596 DC-DC Buck Converters and two TTL to CMOS logic converters.The detailed description of the modules are as follows:

Decawave DW1000

The DW1000 is a fully integrated low power, single chip CMOS radio transceiver IC compliant with the IEEE 802.15.4-2011 UWB standard. It facilitates proximity detection to accuracy of +/- 10 cm using two-way ranging time-of-flight (TOF) measurements. We implemented Symmetric Double-Sided Two-Way Ranging (SDS-TWR) which overcomes the various physical effects such as clock drift etc. The Two way ranging(TWR) involves following steps:-



1. The mobile transmit a message to the tag and records the time the message left its antenna (say t1).
2. The beacon receives the message and sends back a reply.
3. The mobile records the time it receives the reply (say t2).
4. The mobile then calculates the time difference Tr=t2-t1
5. The mobile the calculates the distance using the formula d=c*Tr/2, where c is the speed of light.

The SDS-TWR scheme is an advanced version of TWR which needs four instead of two messages. Also an additional message is generally needed to send measurements from one side to the other. The DW1000 module ranging reading can be calibrated according to the modes used through crystal trimming, Transmit output power spectrum and antenna delay. We used antenna delay refinements for the ranging calibration.

Atmega 328P (Arduino Nano)

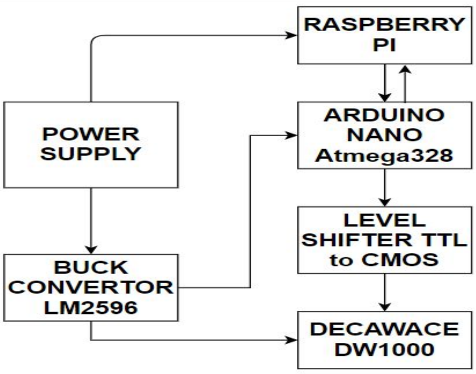
The DW1000 module has an Serial-Peripheral Interface (SPI). The Arduino Nano used acts as a master in the SPI communication with the DW1000 which acts as a slave and thus can be used to access the registers and calculate the ranging data. Moreover, Nano writes the obtained ranging data on the USB serial of the microprocessor for further processing.

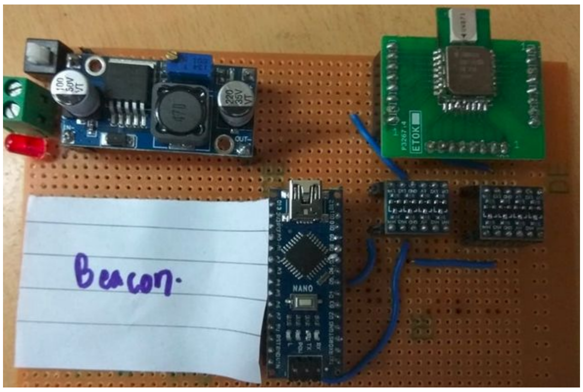
Raspberry Pi

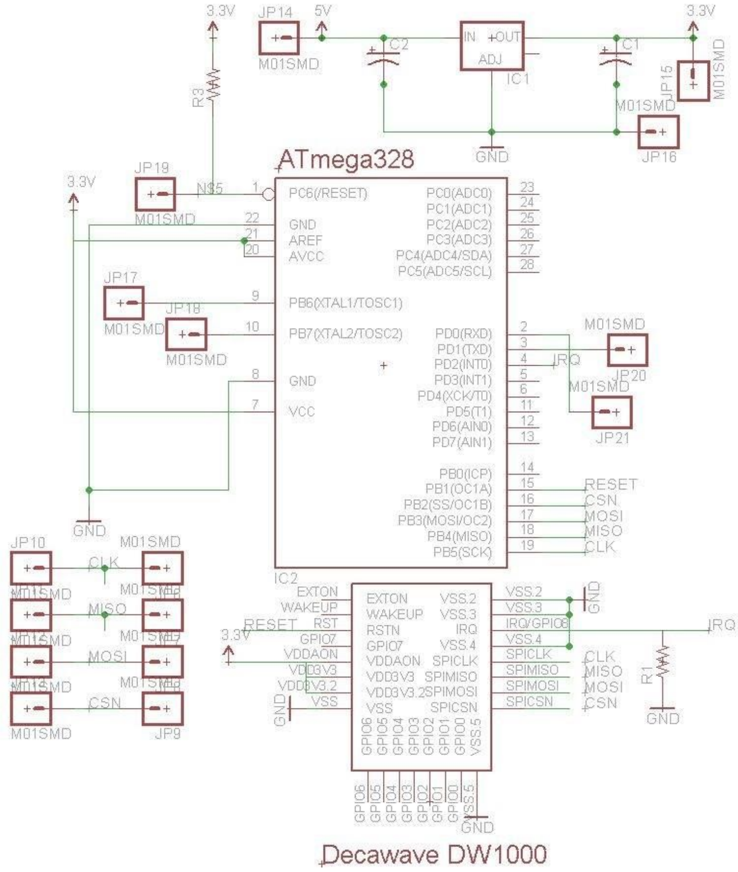
The data obtained from the USB-Serial on the Beacon after applying filter is sent to the Master Beacon using Wifi Sockets (TCP/IP). The Master Beacon schedules the ranging process for the other Beacons and finally calculates the coordinates of the Mobiles present.

The Decawave DW1000 works on the CMOS logic and the Arduino Nano works on the CMOS logic so we need logic shifters to serve the purpose. The DW1000 current consumption can go upto 300mA so it cannot be used with the Nano’s 3.3V pins and hence we need external power supply which is regulated by the LM2596.

The detailed block diagram, designed circuit and schematic of the module is as follows:-







Localization algorithm

We obtain several (5-50) measurements for each beacon-mobile combination. This is organized by a time preemptive scheduling among the beacons and the mobiles. Each beacon is allotted a fixed amount of time to range all the mobiles and each mobile is allotted a fixed amount of time to connect with a certain beacon. They switch and go idle once their time window gets over. The beacon and mobile connect with each other in an ad-hoc manner. The error in measurements follow a gaussian distribution as shown in the figure (src: DW1000 datasheet). However, a few spurious readings are often detected which are off by several magnitudes. Also the number of readings is not deterministic. Therefore, we choose the median of all readings obtained as the estimator of the beacon-mobile range. Simultaneously, the estimated ranges are communicated to a master beacon over a hotspot network. At the master beacon, the 2D coordinates of the soldier are calculated using a linearized least square (LLS) localization algorithm.

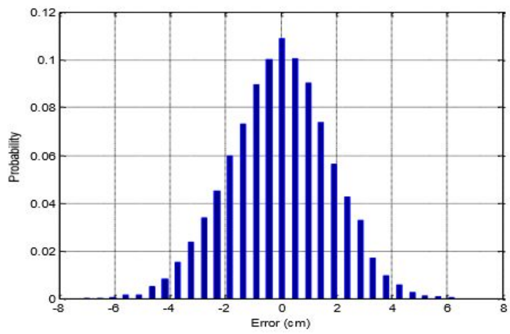


Figure 11: Typical probability distribution of Line of Sight 2-way ranging performance

Consider a mobile. In order to locate it we have it's range from all(n) the beacons say r_i. If the beacon as coordinates as x_i, y_i, The coordinates of the mobile are thus a solution of the equation: $(x-x_i)^2 + (y-y_i)^2 = r_i^2$. The number of such equations is same as number of beacons. We can linearize the equation with respect to a different beacon resulting in a system of n-1 linear equations as given in [4]. The linear system is easily written in matrix form as $\mathbf{A}x=b$. Where A is the matrix made of x and y coordinate vectors of remaining n-1 beacons with respect to the reference beacon. x is the vector of mobile coordinates with respect to the reference beacon. b is vector with kth element being $[r_i^2 - r_k^2 + d_{ki}^2]/2$. Here ith beacon is the reference and d_{ki} is the distance between kth and ith beacon. The solution for x that minimizes the squared error between $\mathbf{A}x$ and b is given as: $x=(\mathbf{A}^T\mathbf{A})^{-1}\mathbf{A}^T b$.

The decision to choose the algorithm is supported by the simulations done using the the LS2 simulation engine in [5] and [6]. It can be noticed that for only 3 beacons and non-enclosed coverage by beacons, LLS algorithm's performance is comparable or better than that of others. An example of the simulation can be seen in the figure. The dark points indicate the beacon locations. The red and yellow regions have localization error lesser than the ranging error. The white-grey-black regions have localization error ranging from 100% to 300% of the range measurement error. As can be seen LLS is shown to have better accuracy than other standard algorithms like NLLS, AML etc.

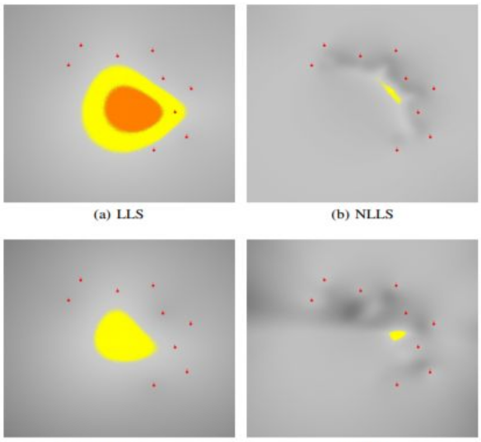


Fig. 1. Spatial distribution of the position error with four different algorithms (average case).

Cost Analysis

Components	Price	Quantity for Mobile	Cost for Mobile	Quantity for Beacon	Cost for Beacon
DWM1000	$ 19	1	$ 19	1	$ 19
Microcontroller Nano	$ 2.15	1	$ 2.15	1	$ 2.15
Level shifters	$ 0.2	2	$ 0.4	2	$ 0.4
Power supply unit	$ 5	1	$ 5	1	$ 5
RPi (zero)	$ 5	0	0	1	$ 5
Total			**$ 26.45**		**$ 31.45**

References

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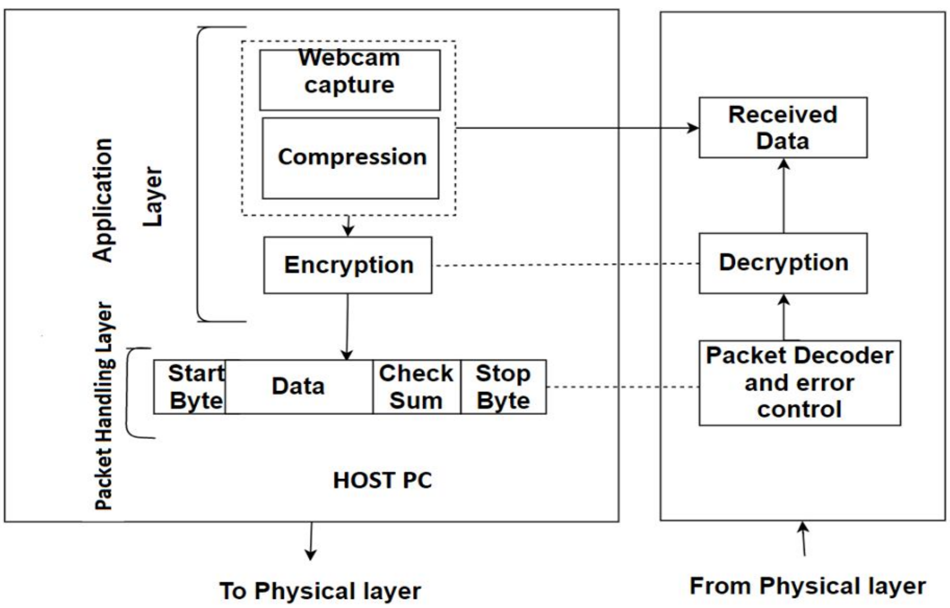
Draw No-10

IMAGE AND VIDEO STREAMING OVER V/UHF RADIO

Introduction

A point-to-point communication protocol for Image and Video transmission over UHF band has been proposed and implemented. The application layer of the protocol has been designed keeping in mind the security of data transmission and any potential loss of data during transmission. The physical layer of the protocol has been optimized with respect to the constraints of BER and spectral efficiency.

Protocol Overview



1. Packetisation and Headers- The protocol uses data packets of size 128 bytes. The header of the protocol consists of start byte and stop byte for identification of the packet and checksum for error detection.

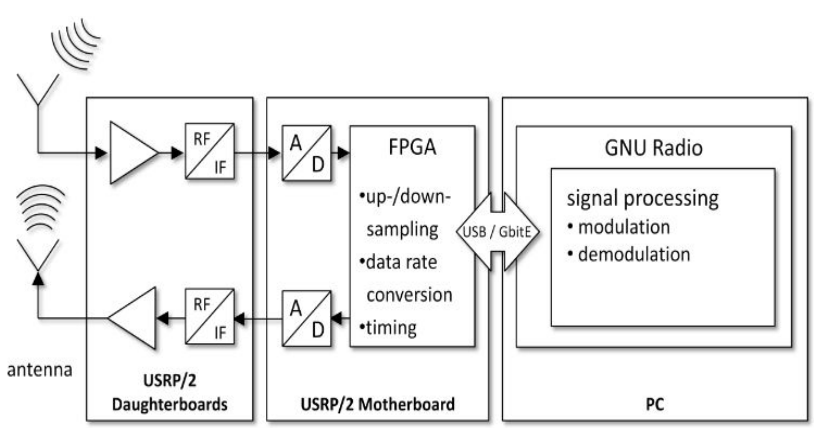


Figure 2: Software-Defined Radio block diagram

2. Compression- The image has been compressed in JPG format for minimizing the data usage and improving the bandwidth efficiency.
3. Encryption- Packets of the protocol have been secured using 128-bit AES encryption method. This has been implemented by pycrypto library.
4. Error Checking - For the purpose of detecting faulty packets, an error check mechanism has been developed in the

receiver, using checksum, which drops the packet upon the reception of erroneous data.

5. Connection initiation- For initiating the connection between transmitter and receiver, the transmitter sends a predefined byte sequence which is acknowledged by the receiver the completing the handshake process. This block has been setup inside the GNU radio.

Hardwares and Softwares Description

The physical layer of the protocol has been implemented using GNU Radio software and Amitec SDR-04 Hardware. Baseband processing like modulation and demodulation blocks are performed using the GNU blocks while up-down sampling and RF chain are implemented inside the SDR04.

1. SDR04 Amitec

Amitec SDR04 is the highest performing class of the programmable transceiver family of products. Its USB 3.0 interface serves as the connection between the SDR and the host computer. This enables the user to realize 120MS/s of real-time bandwidth in both transmit and receive directions simultaneously (full duplex). Its Features are-

1. RF ASIC Architecture : Operation range - 400KHz-4GHz, LNA, PA driver, RX/TX Filters, Synthesizers, RX Gain control, TX power control
2. FPGA programmable transmission and reception for high performance. Altera Cyclone FPGA with single cycle access memory, 18x18 multipliers for dedicated DSP and programmable general logic elements.
3. 200MHz ARM9 with single cycle access memory.
4. Mixed Processing at FPGA/Host Computer for maximum flexibility
5. Modulation Bandwidth programmable upto 60MHz.
6. Completely Shielded Auto-Calibrated Radio with very High SNR.
7. Dual 40 MS/s, 12-bit ADC
8. Dual 40MS/s, 12 bit DAC.

2. GNU Radio

GNU Radio is a free & open-source software development toolkit that provides signal processing blocks to implement software radios. Transmission & reception of the image and video signal has been implemented by using python blocks of GNU Radio software. This has been achieved by varying data rates at different band of frequencies. It can also find the RF frequency and packet error rate of received signal and try to reduce packet error by reconfiguration of transmission gain. SDR system provides flexibility to development of video transmission using GNU Radio software and Amitec SDR04 hardware.

Power, bandwidth and Modulation Specifications

Specifications of Amitec SDR04 are :-

1. TRX RF Frequency range 400KHz-4GHz
2. Baseband bandwidth<1-30MHz
3. Frequency Resolution <3 Hz

4. Maximum RF output power +5dBm
5. Receiver sensitivity -100dBm
6. Transmit Gain control Range upto 50dB

Free space Loss(in dB) = 32.45 + 20*log(D) + 20*log(f) where D is the distance in KM and f is the frequency in MHz. For our chosen carrier frequency=1.234 GHz and the desired distance 5-10Km, Path loss will be in between 108dB-114dB. According to the receiver sensitivity of -100dBm, we are keeping a safe link margin through incorporating the path loss by increasing the antenna gain of SDR.

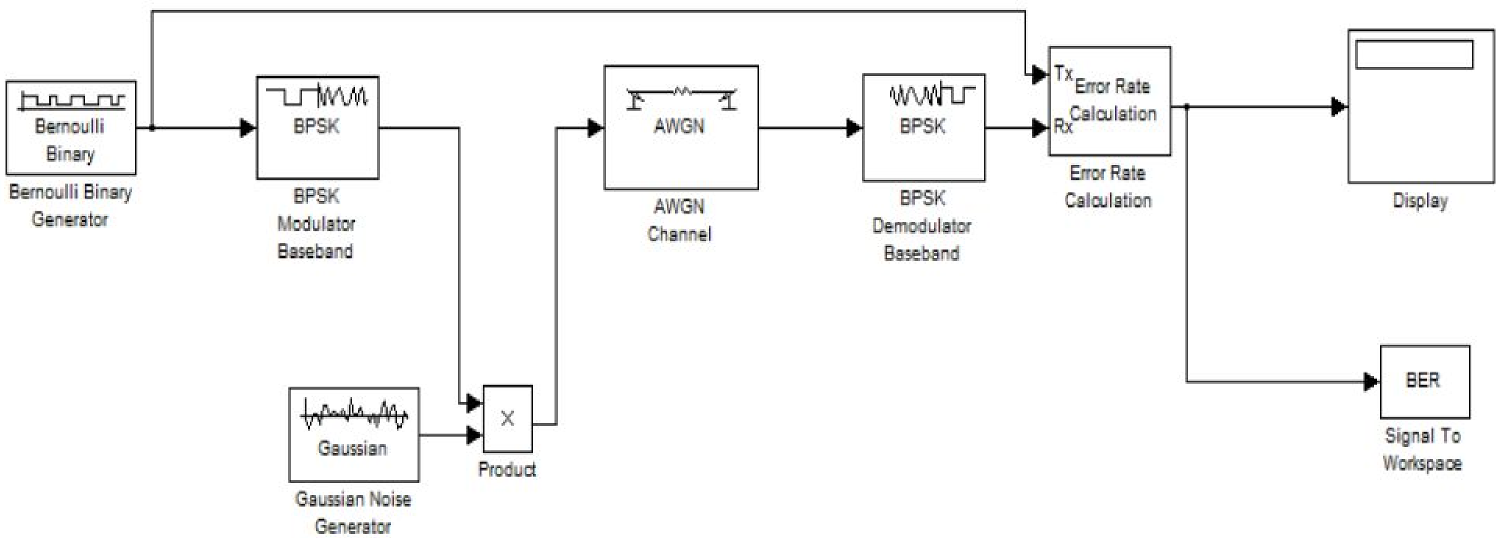


Fig:-Block Diagram for calculating BER of BPSK Modulation

Analytical studies of various digital modulation techniques such as BPSK, FSK, MSK and DBPSK have been done. A simulation environment in MATLAB has been designed with various configurations of OFDM technique. The Bit Error Rate has been measured with different modulation schemes and different configuration which achieve better utilization of bandwidth. We have studied existing configurations with digital modulation techniques and compared the results. Multi-data bits per signal modulation techniques have better bandwidth efficiency but poor BER and signal power performance. So considering Bandwidth, Power and Spectral performance, BER and spectral efficiency as key parameters we have chosen GMSK for Image and Video Transmission.

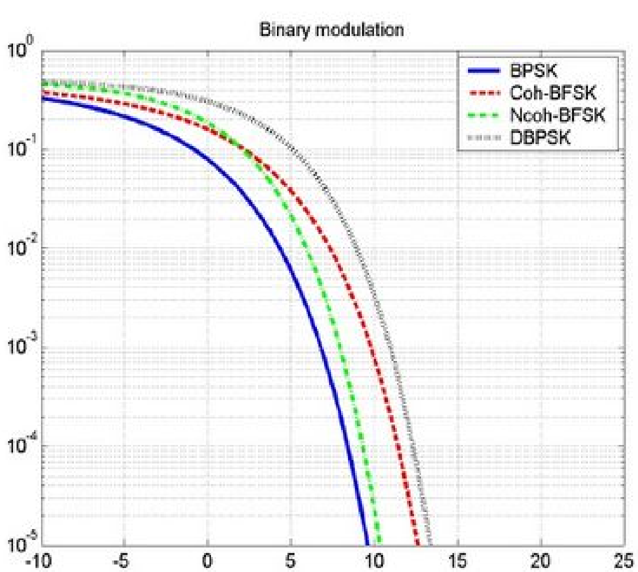


Fig:- BER Performance of Different Modulation Techniques

Image and Video Transmission using GMSK Modulation

GMSK is a popular form of modulation technique which is used in digital radio communication systems. It is phase frequency shift keying which provides constant envelope and phase is changed between the symbols. It is also used as alternative of QPSK. GMSK modulation is mostly used in GSM technology and it is based on the minimum shift keying. In GMSK, Gaussian low pass filter is used to reduce the effect of sideband power. The bandwidth of the GMSK modulation system in GSM technology is BT=0.3, in which B is the pre modulation filter bandwidth and T is the bit period. We have set the BT as per our requirement.

The mathematical expressions of the resulting signal is represented by following equation:

$S (t) = a1 (t) \cos (\pi t/2T) \cos (2 \pi fct) - aQ (t) \sin (2 \pi fct)$

This equation can be rewritten in a form of phase and frequency modulation.

$S (t) = \cos [2 \pi fc (t) + bk (t) \ \pi t/2T + \Phi k$

So the signal is modulated in the form of phase and frequency and the phase changes continuously.

Setups and Libraries-

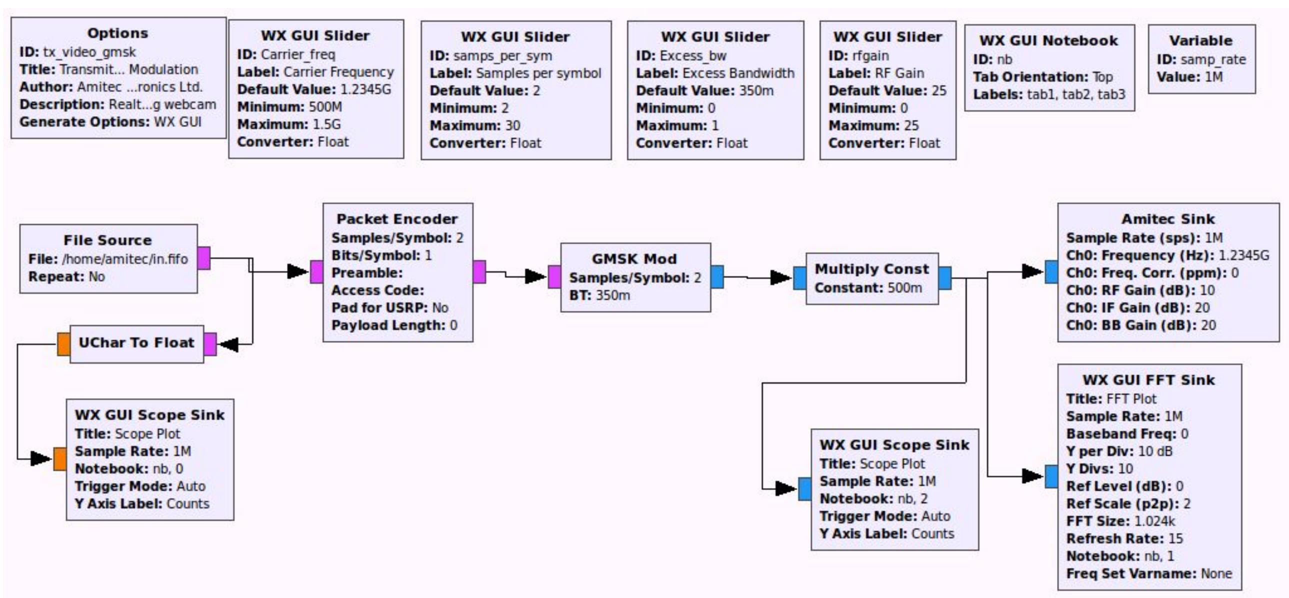


Fig:- GRC block Diagram for Transmitter

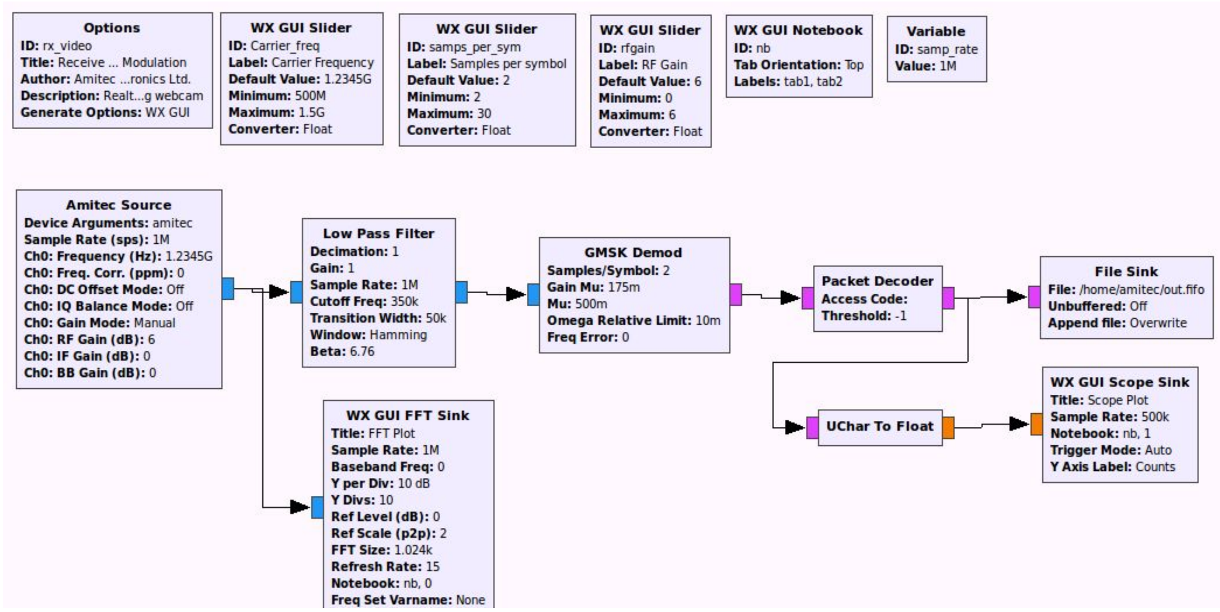


Fig:- GRC block Diagram for Receiver

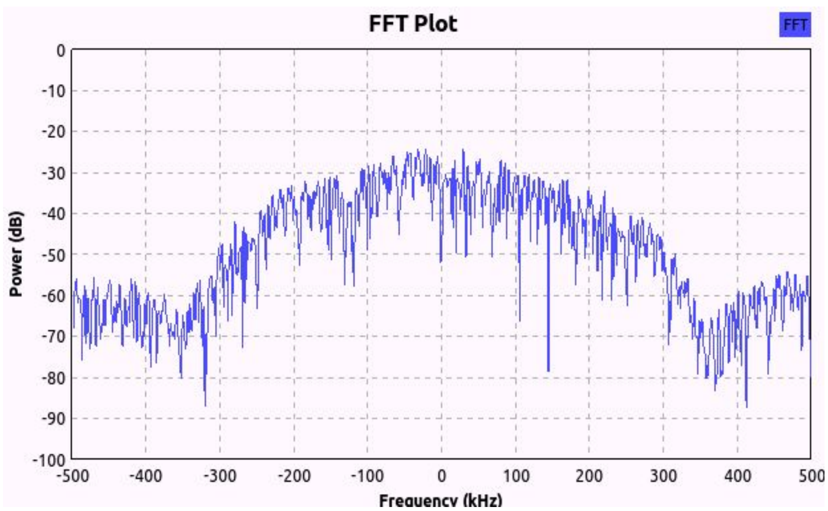


Fig:- FFT Plot for the transmitter

Future Goals

Future goals of the project will be to develop a system-on-Module for the purpose of Image/Video transmission. The upper layers of the protocol will be implemented in the processor and the baseband processing will be performed in the FPGA. As a result of this, the bottleneck of the system between the processor and FPGA for high-speed intra-modular data communication will be greatly diminished. High-performance tasks like compression will be performed with HW/SW partitioning of the task.