SDR-Based Search and Rescue Communication System Using LPWAN Technology

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Declaration

This project is dedicated to Allah Almighty and Prophet Muhammad (P.B.U.H) and all those people who inspired us and motivated us through the journey. I declare that the work contained in this thesis is my own, except where explicitly stated otherwise. In addition, this work has not been submitted to obtain another degree or professional qualification.

Signed: ____________________

Date: ____________________

Acknowledgments

They said, “Glory be to You, we have no knowledge except that which You have taught us. Verily, it is You, the All-Knowledge, the All-Wise”. (Al Qur’an, 2.32)

All praises to Almighty Allah, the most Beneficent and the most Merciful, who bestowed us with the knowledge and strength to accomplish this project report.

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Our group would like to express their deep appreciation and indebtedness to our family and all others whose contribution and endless support made this project possible.

Commemorating the Guidance and Support of our

Cherished Parents and Mentors……

Table of Contents

List of Figures

SDR-Based Search and Rescue Communication System Using LPWAN Technology

Abstract

Current research is focused on the issue of through-wall human monitoring in a crowded setting. Through-wall sensing aims to inform people in situations when they must find, locate, and identify things or persons inside of structures. The information at the signal level contains a picture of the structure's layout as well as the position, speed, and motion path of important objects. Examples of applications include law enforcement, disaster response, terrorist attacks, mining, catastrophes, structural failure, and urban military operations. In this project, a radar system to transmit FMCW signal is designed using Software Defined Radio (SDR) or USRP N210, which offers a cost-effective high-bandwidth and high-dynamic range processing capabilities. After reaching the walls, the USRP transmitter signal is reflected and picked up by a second USRP receiver antenna hidden behind the wall. GNU Radio is used to generate the simulated FMCW transmitter and receiver graphs. Following a micro-doppler classification, the object in front of or behind the wall that is in the electromagnetic wave's path is identified. This information is then sent to other USRPs.

For through-the-wall detection, where a sophisticated communication system is an Important Factor, Internet of Things (IoT) technology is also employed to communicate with the Rescue Teams about the individual who is buried beneath the rubble. The Arduino IDE Environment is used to program the Lora HTCC AB01. The Lora HTCC AB01 file has been imported into GNU Radio. A reliable support vector machine (SVM)-based classifier and a successful feature extraction method that makes use of a time-frequency conversion are suggested to identify non-stationary micro-motion patterns.

Chapter 1

Introduction

A tectonic plate slips abruptly past another massive piece of the Earth's crust to cause an earthquake, a natural calamity that shook the ground. Without the progress in technology to promptly discover and rescue earthquake affects victims, thousands of lives that are trapped under earthquake debris and concrete slabs could be lost. Unknown building layouts could also put first responders in danger and make it more difficult for them to find people within structures with speed and accuracy. They might also put law enforcement agents in danger if they can't detect and follow criminals through building barriers.

The following scenario, which includes search and rescue operations, maritime rescue, and surveillance (anti-terrorism and law enforcement), all heavily involve through-wall radar. Ground Rescue, Mountain Rescue, Urban Rescue, Combat Rescue, and Maritime Rescue are all types of search and rescue operations.

On February 23, 2023, a mosque explosion in Peshawar, Pakistan's northwest city, claimed at least 61 lives and injured over 157 others. The explosion tore a portion of the roof off, and what was left quickly collapsed in, hurting many more. In order to get to worshippers who were buried under the rubble, rescuers had to clear mountains of debris.

Figure 1. Mosque explosion in Peshawar

The ability to detect targets through a lossy material and function in a high-clutter environment are important factors to take into account while designing through-the-wall radar. The composition of the wall affects the attenuation of electromagnetic waves; plasterboard, glass, and wood have low attenuation. Brick, cinder block, or concrete all significantly reduce the received power by the radar and create severe attenuation loss. In contrast to human movement, whether it be conscious or unconscious, the stationary item does not show the Doppler effect.

1.1 Effect of Micro-Doppler on the Radar

The radar sends out an electromagnetic signal and then, after some lag, it picks up the signal that was reflected. The difference in time between the emitted and received signals serves as a gauge for the object's range. Pulse radar and continuous wave radar are the two fundamental varieties of radar. The transmission of the signal is the primary distinction between these two radars. While continuous wave radar sends and receives a signal in the form of continuous waves, pulse radar sends and receives a signal in brief bursts. Basic pulse radar and moving indication radar are the other divisions of pulse radar.

Unmodulated and modulated continuous wave radar are the other two divisions of continuous wave radar.

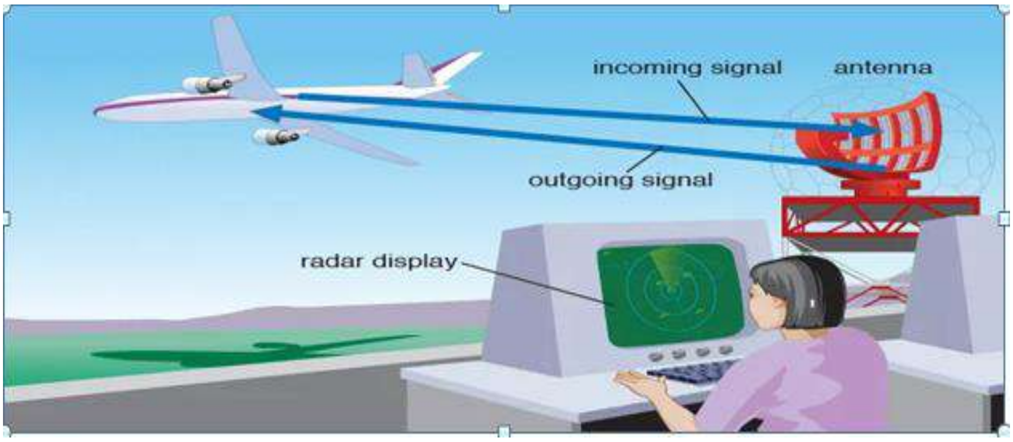


Figure 2. Radar working

The Doppler Effect in radar operation works by having a moving object emit a signal, which causes the received signal to have the transmitter signal's frequency altered. The Doppler frequency shift is used to calculate radial velocity, or the velocity component in the direction of the line of sight (LOS). Three different types of waves, including sound, light, and water waves, are affected by the Doppler effect. The Doppler Effect is used in many different contexts, including the horn of a passing car, bats searching for prey, police utilizing radar to measure the speed of moving cars, and meteorologists anticipating weather patterns.

Additionally, it was used to make medical diagnoses, including those made by echocardiograms, ultrasonography, fetal monitoring, blood pressure measurements, and the direction of blood flow in arteries and veins. The item experiencing the micromotion experiences the micro-Doppler effect. Any vibrational, oscillatory, or structural motion that results in an extra Doppler shift in addition to the buck translation of motion is referred to as micromotion. Micro-Doppler effect classification, recognition, and identification are necessary in order to extract the kinematics properties of the object, for instance, the rotating blades of a flying helicopter, the walking or swing arm of a person, birds flapping their wings, etc.

1.1.2 Micro-Doppler Effect in Radar

When an object, or a structural part of the object, vibrates or rotates, the object's micro-Doppler signature exhibits characteristics of the complex frequency modulations caused by the micromotion. To ascertain the kinematic characteristics of the item, extract elements of the object's movement, and identify the object of interest, micro-Doppler signatures are used.

1.1.3 Through-the-Wall Micro-Doppler Signatures

Due to the low frequency of through-wall radars, the micro-Doppler frequency shift can be rather small. As a result, items behind the wall can be detected by the radar. Radar can still identify human body motion, heartbeat, and even breathing with the help of cutting-edge signal decomposition and processing algorithms, which makes it useful for spotting and keeping an eye on human activity in the wake of an earthquake or explosion. The micro-Doppler signature's pattern is unaffected by the presence of walls. Depending on the wall's characteristics, the radar signals are only reflected or diminished by the wall. Radar is able to identify certain variations in the reflected radar signals from humans, such as heartbeats, thorax motion caused by breathing, and even laryngeal vibration.

1.2 FMCW RADAR

FMCW (frequency modulation continuous wave) radar transmits continuous electromagnetic radio wave that changes their frequency when reflected of the target and is known as Doppler radar. FMCW is used to measure range, velocity, and angle of arrival of target. FMCW transmits a sinusoidal signal known as chirp which is a straight line with a slope in the time-frequency plot as frequency changes linearly with time.

The bandwidth of the chirp in the frequency domain is determined by change in its frequency. FMCW radar has a range of 77-81 GHz. The synthesize in FMCW generates a chirp which is then transmitted by a transmitter antenna. The received signal is then mixed with the transmitted signal by the mixer and resulting signal is called an Intermediate frequency (IF) signal. The frequency of signal at the output of mixer is the difference of instantaneous frequency of transmitted and received signal. The distance is measured by comparing the frequency of the received signal isa delay version of the transmitted signal. The distance is measured by comparing the frequency of the received signal with the transmitted signal. A signal object produces an IF signal which is represented as a constant single tone. Multiple objects in front of the radar produces multiple reflected chirps and IF signal will also reveal multiple tones.

1.3 SDR-USRP-N210:

SDR equipment can fix faults in real time while communicating with a personal computer. Dynamic spectrum positioning, Opportunity Driven Multiple Access (ODMA), spectrum regulation, and cost reduction are some of the applications of SDR (some SDR implementations are less expensive than their analogue counterparts).[1] The Universal Software Radio Peripheral is simply known as USRP. The platforms Linux, MacOS, and Windows are supported. UHD is used by a number of frameworks, including GNU Radio, LabView, MATLAB, and Simulink. Software for USRP hardware drivers is referred to as UHD. USRP functions as a transceiver of RF signals over a broad frequency range with a bandwidth of up to 40 MHz.

The primary advantage of USRP is its capacity to conduct all analogue and digital communication experiments using a single piece of hardware, resulting in a significant reduction in overall cost. The suggested technique makes use of the USRPN210 with daughter board specification WBX, which operates between 400MHz and 4.4GHz, with an output power of 100mW and a bandwidth of 40MHz.[2]

1.4 Log periodic antenna:

Antennas are the fundamental components of modern communications systems. By definition, an antenna acts as a transducer between a guided wave in a transmission line and an electromagnetic wave in free space. It is considered as a basic component in wireless communication system

Log-periodic structure is introduced by DuHamel and IsBell in 1957 [2]. The lengths and spacing of the elements in a log periodic antenna increase logarithmically from one end to the other. Log-periodic directional antenna used in this paper is a PCB shielded LP0965 of frequency range 850-6500Mhz and at gain of 5-6dbi, which is shown in Fig. 2. These antennas are used in an application which needs more tuning frequencies and wider bandwidth without affecting its directivity and gain. SMA cable, which must pair with a USRP front-panel connector, is its compactable product.

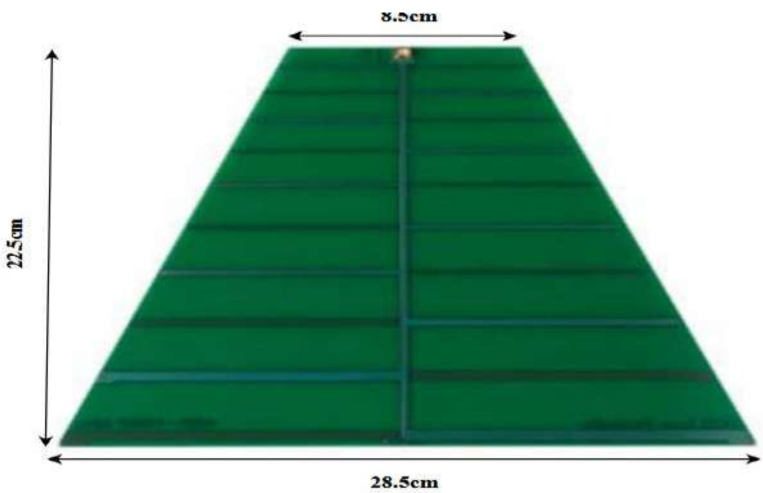


Figure 3. Log periodic antenna (850MHz-6.5GHz)

By contrasting it with the surroundings, we shall simulate a trapped person under debris in this project. An SDR, which functions as an FMCW RADAR, was used for the wireless communications. The RADAR will use micro-Doppler detection and classification to identify a variety of obstacles, including different types of wall materials, breathing people, vibrations coming from people, and more. to provide Target information to the receiver USRP. The following is the order of the remaining chapters. The report's literature review is found in Chapter 2. The Motivation and Problem Statement are highlighted in Chapter 3. The methodology is given in Chapter 4. Chapter 5 will finally wrap up the report.

Chapter 2

Motivations and Problem Statement

2.1 Motivation

To minimize casualties, search and rescue efforts are conducted during earthquakes and underground mining. Every person who is harmed or trapped in these situations poses a risk to their loved ones, friends, and society as a whole. By utilizing various strategies and tools, the rescue team hopes to reduce this loss and get the victims to safety as fast and effectively as possible. Additionally, as people band together to aid those in need, rescue operations save lives, increase morale, and develop a feeling of community spirit.

Modern technologies and techniques are required for the challenging and complex task of looking for life beneath the rubble. Using the SaR dog and equipment like axes, concrete saws, and bolt cutters, rescue crews have already filled in gaps inside collapsed structures. The technical approach involves the application of technologies that have shown promise in enhancing the detection of life beneath the rubble, including carbon dioxide detectors, DAR radar systems, unmanned aerial vehicles (UAVs), drones, thermal imaging cameras, acoustic sensors, fibre optic sensors, LiDAR, and machine learning algorithms. The creation of more dependable and successful techniques for finding survivors under the wreckage can aid rescue crews in more quickly finding and removing them, which could ultimately save lives.

We hope to develop a system that uses micro-doppler phenomena to identify a person through a wall with the evolution of search and rescue technologies.

2.2 Problem Statement

Through wall detection technology offers excellent opportunities for military and police applications, these applications are not limited to the military and police; they go beyond those applications to where detecting a target behind an obstacle is needed. With the ability to disclose the location and velocity of obscured targets, scientists' resort to electromagnetic wave propagation. Thus, through-the-wall radar (TWR) is a technology that propagates electromagnetic waves through a wall toward a target causing through-wall radar imaging (TWRI) a range of ambiguities in target characterization and detection. These ambiguities are related to the thickness and electric properties of walls. The mechanical and electric properties of the wall defocus the target image rendered by the radar. The focusing problem is displacing the target from its original location when the image is rendered. Thus, the operator of the TWR will have a wrong position, not the original position of the target. Focusing is not the only problem observed while the electromagnetic signals propagating through the wall but also target classification, wall modeling, and others are areas that need investigation.

Chapter 3

Literature Review

3.1 Detection of Life Under Rubble/Debris

The following techniques are used for the detection of human life under debris

3.1.1 Use of a CO_2 sensor, a thermal camera, and a microphone

While the thermal camera can validate the victim's precise location, the CO2 sensor is beneficial for efficiently reducing the potential worry area. Additionally, it is thought that the usage of microphones in conjunction with other sensors would significantly aid in the discovery of victims. An algorithm to identify voices or other potentially human audio hidden behind debris has also been created and tested in this study [2].

3.1.2 SaR Operation by Trained Sniffer Dog Sensing

In order to determine if there may be victims hidden beneath the wreckage, the current search strategy is based on survivors' testimonies.[2]
Due to their innate ability to hear and smell, search and rescue (SaR) dogs are a valuable tool in the hands of rescuers since they may find

a victim even when sight and sound are not accessible. However, canines are more likely to spot dead bodies than living individuals. In this study, 3-axis accelerometer data are used to train deep convolutional neural networks (CNNs) for activity identification and sound categorization. With an F1 score of 99% accuracy, a gyroscope and a wearable microphone that analyses the generated sensor data using DL algorithms, respectively, effectively find the victim and alert the rescue crew in real-time [10].

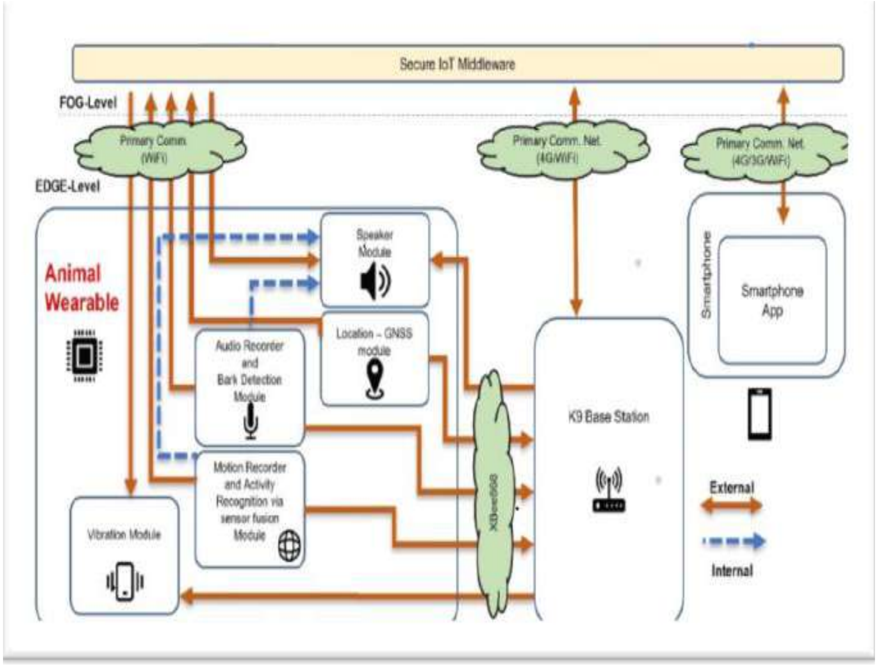


Figure 4. Dog wearable system architecture and communication flows for SaR operation

Before the created data is sent through the network in this article, it is processed in real-time using edge computing. In particular, when Wi-Fi is unavailable and the RF module is ineffective for providing streaming audio data due to the maximum data rate of 250 kbit/s for IMU signal transmission and 192 kbit/s for medium quality audio signal transmission for GPS coordinates. However, increasing the data transmission range causes the rate to drop below 10 kbit/s, making it impossible to send the produced raw signals [10].

3.1.3 Microphone

The Acoustic Life Detector uses audio signal processing to identify the low-frequency noises made by victims. However, when there is a lot of background noise, such as that created by pneumatic drills, breakers, automobiles, wind, electrical lines, and water flows, which might be present in a real situation, microphones used to identify speech, human-made noises, or environmental noise become less precise. The inability of auditory detection technologies to find people who are unconscious is another drawback [2].

3.1.4 Cameras

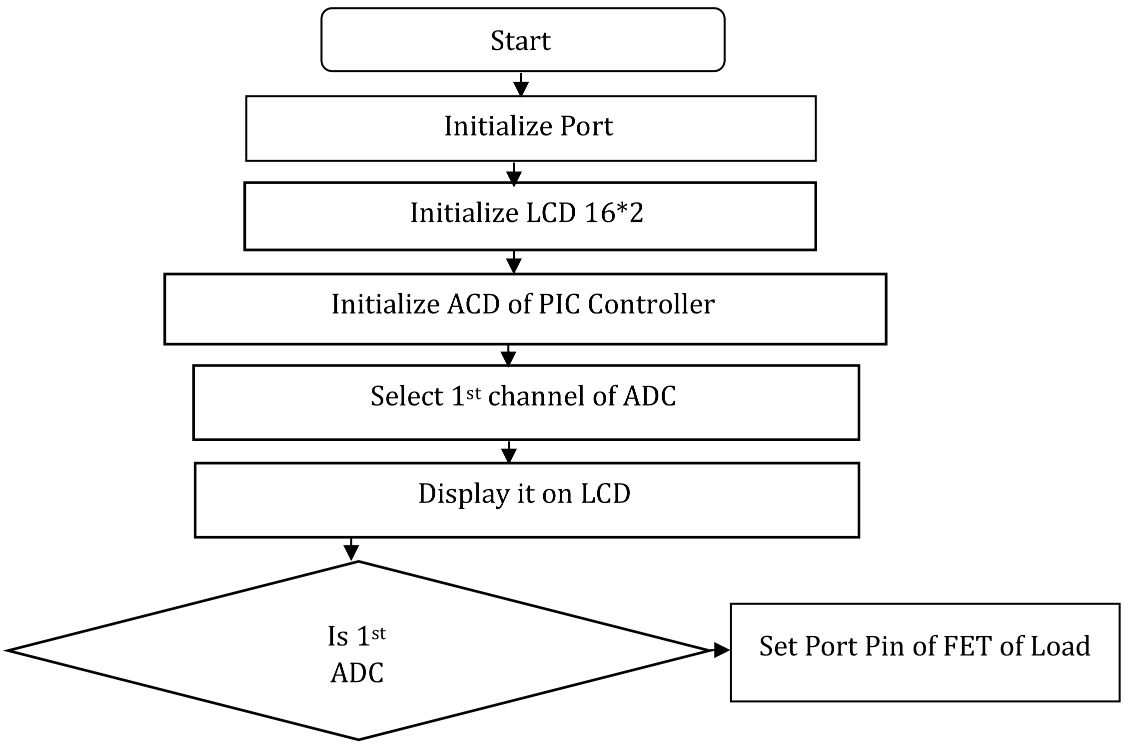
Since cameras are a useful interface for human rescue, they are frequently attached to mobile robots to explore hazardous and inaccessible regions. To solve the issues of poor visibility under the debris, several researchers recommended infrared cameras to find trapped persons. Cameras are an excellent way to find victims, although they are restricted in their ability because of their inherent narrow field of vision, the existence of barriers, and the typically poor visibility under the wreckage. In a real-world situation, quick localization and precise positioning assessment of the individual are essential for a successful rescue effort, yet photographs by themselves are insufficient to offer this information [11].

3.1.5 Doppler radar

Doppler radar is frequently employed in disaster rescue efforts because of its effectiveness in detecting movements behind obstructions. A few millimetre movements, such as a heartbeat or breathing, can be detected using the frequency or phase shift in a reflected radar signal. However, correct calibration is necessary for Doppler radar, and even minor environmental changes brought on by earthquakes and structural instability impair the system's performance. Additionally, this device is not appropriate for large disaster regions because to its narrow-angle vision [2][4].

3.1.6 Microwave Signal:

To find out if there are any survivors among the ruins, a microwave signal is delivered through the debris. This signal has the ability to cross obstacles and would bounce off of various objects, even people. A signal beam that strikes the body is reflected with extra modulation brought on by the beating of the heart and the breathing of the lungs. Receiving modulated signals reveals the existence of people moving towards life beneath the debris. Other signals, referred to as clutter signals, are reflected off of stationary objects. The microwave detection system may operate at many frequency ranges, including 2GH (L-band) and 10GHz (X-band). [8]



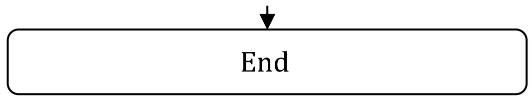


Figure 5. Microwave Signal in through wall detection architecture proteus simulation and flowchart

3.1.7 Ultrasonic Sensor based Camera

A low-cost camera is utilized to take pictures of the scene as needed and an ultrasonic sensor is used to identify any living people. The ultrasonic sensor turns on the camera to display a live image if it detects even the slightest indication of a living individual. Then the video is shown on the screen. With this strategy, the amount of data that must be collected and processed during the rescue operation is rather low. The detection is influenced by a number of variables, including body posture and ambient light levels [13].

3.1.8 Piezoelectric plate

In a disaster region, a piezoelectric plate is used to detect vibrations caused by trapped people. The microcontroller (PIC 16f877) linked to the plate collects the data and wirelessly transmits it to the data collecting unit (DCU). The data gathering device then sends the rescue crew a warning signal. The condition of the person beneath the trap may be easily determined by correct analysis of this vibration data, and utilising GPS, the position of the person under the debris can be found. Piezoelectric plates provide the input signals that signal conditioning machines use to amplify, filter, and isolate the signal [5][14][15].

3.1.9 GPR (Ground Penetrating Radar)

In disaster zones, GPR data can be manually gathered by first responders or obtained utilising UAVs and UGVs. Using GPR scans, it locates any possible voids beneath collapsed buildings. The real-time kinematic (RTK) global positioning system (GPS) that is combined with the GPR can provide the coordinates of the possible void [6].

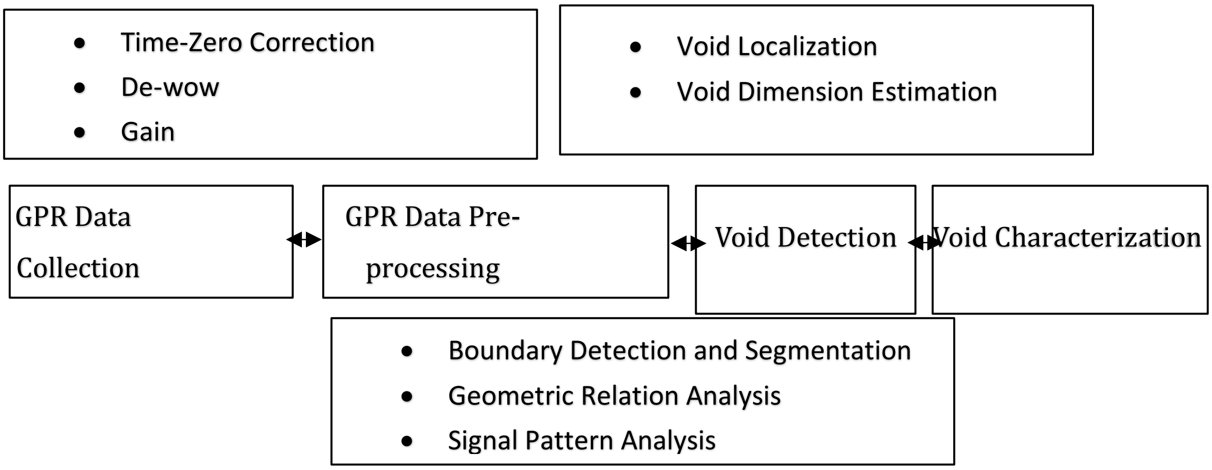


Figure 6. Mobile Rescue Robot semi-automatized

A mobile rescue robot with a PIR sensor that can locate living people in a disaster scene from a distance has been created. The semi-autonomous robot is controlled by a joystick, and it communicates with control stations using RF technology. A gas sensor is used to find gas leaks within the structure, and an ultrasonic sensor is used to identify obstacles in a robot's course of travel. The integration of IP cameras allows for the observation and analysis of circumstances that will most likely successfully enable human detection in a certain circumstance. The Figure. 6 shows the framework of mobile rescue robot semi-automatized with ground penetrating radar. [7].

3.2.0 **Human Micro-Doppler Through Wall Radar Classification Using Singular Value Decomposition Analysis**

In this study, a C-band radar system with a central frequency of 5.8 GHz is used to identify a person outside of a residential building at a radar standoff distance of about 0.5 meter without physically installing a single sensor. It is also used to detect multiple people moving around a room. To categorize aspects of whether individuals are walking freehand or with any object, a singular value decomposition signal processing approach is applied.

Modern radar systems frequently employ the linear FM waveform because it may attain high-range resolution by sweeping across a large bandwidth. However, it becomes challenging to conduct matched filtering or pulse compression in the digital domain when the bandwidth is on the order of hundreds of megahertz, or even gigahertz, since high-quality A/D converters are difficult to find at such data rates.

Stretch processing, also known as deramp, is a method that can be applied in such circumstances. The analogy domain is used for stretch processing [5].

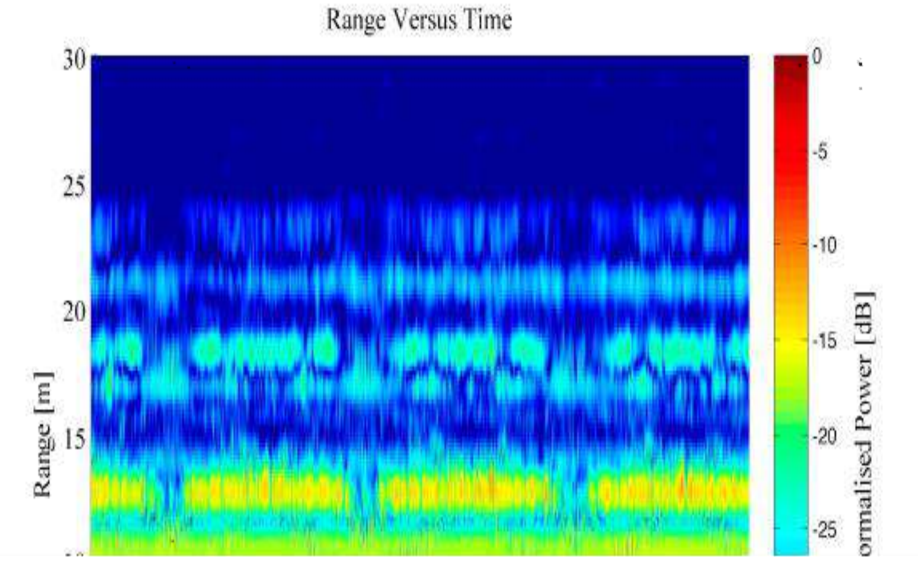


Figure 7. Individual walking with free hands, measured through the wall using a range-time intensity (RTI) plot.

This figure shows the person was walking free handed. The range values include the RF cabling lengths; hence, the target appears at a greater distance than the absolute straight-line distance from the antennas to the individual. The RTI shows that the person was detected within the scene, shown by the disturbance in the signatures at 2.5, 12 and 22.5 s close to the wall signature at 7 m. [9]

3.2.2 LORA IN TWD:

In recent years, contactless sensing has made substantial use of wireless signals. The sensing range is constrained by the weak target-directed signal's inherent limitations. For instance, although acoustic-based sensing is restricted to less than one meter, WiFi and RFID may attain sensing ranges of 3 to 6 meters. The new long-range communication technology, LoRa, created for Internet of Things communication.

Both conceptually and empirically, we investigate LoRa's sensing potential. In order to characterize the link between target movement and signal change, we build the sensing model. We also suggest unique methods for extending the LoRa sensing range for human respiration sensing to over 25 meters [6].

3.2.3 SDR TECHNOLOGY INTRODUCE IN TWD

In order to improve the coverage of survivors and rescuers in the disaster region, this study expands the FMN-based emergency networks (with and without base stations). In addition to the forwarding functionality, each peer making up the WMHN (FMN and MANET) is given a new duty to construct and maintain three RANs providing GSM, WiFi, and LoRa connections. These technologies were chosen because they have native support in smartphones. So, survivors and rescuers can join one of the RANs and the command post via the

WMHN. A smart phone application is suggested to manage RANs priorities in accordance with the exchanged kind of communication and an additional feature to improve quality of service for end users (survivors and rescuers).

Chapter 4

Methodology and Implementation

In this project we are making the system for the detection of the person through the wall and communicate the information through the LoraWan which informed the rescue person about who is lying under the rubble. We done our implementation on device called SDR. The SDR is programmed through two software which are GNU radio and MATLAB. The GNU radio is a user graphical interface where as MATLAB is programming and numerical computation platform, these both are compatible with SDR. The block diagram for micro-doppler acquisition, RADAR detection, and communication via a wall is display in Fig. 10. The Fig. 11 and Fig. 10 presents the through FMCW radar implementation in GNU radio using USRP and transmission of electromagnetic waves through USRP transmitter through the wall are then received at USRP receiving antenna, after this perform the signal processing on data extracted in MATLAB to form the desired waveform of the signal.

4.1 Hardware

The detail discussion of hardware that are used in our project are as follows:

4.1.1 SDR

The rapidly evolving technology of SDR is gaining immense gaining popularity and sparking a lot of interest in the radar sector. Radio communication systems can use SDR. SDR enables radio communication systems to be implemented entirely in software rather than modifying Hardware components each time. It is a platform which is flexible and allows low-cost wireless communication, implemented using software or firmware that is customizable and uses programmable processing methods. It is a wireless device equipped with sound card or other ADC converter, which commonly includes a personal computer and an FPGA or programmable system-on-chip (SoC) to perform digital functions. However, it is used to transmit and receive different frequencies from a single device. The SDR has ability to standardize air interfaces across world regions. The low frequency signals which are transmitted and received through the SDR that are processed IF signal inside the DSP. The regular updating is required in SDR of software it is regularly updated on the backhand to prevent it from becoming obsolete over time. Software defined radios has a significant use for the military and mobile phone services, both of which are required to cater in real time to a wide range of varying radio protocols and utilization USRP N210 The software defined radio (SDR) NI USRP N210 offers a conversion of RFs to digital and analog forms according to requirement in application. SDR has immense number of benefits in wireless communications like it can act as a mobile phone and can make it act as a GPS receiver. Due to latest advancements and increased usage of Drones and Long-Range wireless Modules its sustainability and usage is expected to increase in near Future. For implementation of this proposed project, we used Ettus Research NI USRP N210.

NI USRP N210

The NI USRP N210 is a software defined radio (SDR) that provides a configurable and flexible platform for prototyping, designing and deploying wireless communication systems. The device is designed to work with Implementing signal processing building blocks is made possible by the open-source software development toolkit GNU Radio.

software-defined radios. The National Instruments (NI) and Ettus Research are the two main companies which manufacture these SDR Models. The SDR manufactured by Ettus Research is USRP N210 and it is called as Radio peripheral with universal software definition (USRP). A USRP N210 being one of the high-end SDRs in market has the advantage of operating in a depending on the installed daughterboard, the frequency range for the device ranges from 10 MHz to 6 GHz. The device also features two daughterboard slots, which allow for the use of various daughter boards to support different frequency ranges and modulation schemes. In our setup, we used the SBX-40 daughterboard having the frequency range of 400-4400 MHz. The daughterboard also provides an instantaneous bandwidth of 40 MHz The USRP has a built-in FPGA Board: Xilinx Spartan 3A-DSP 3400, dual 400 MS per second, 16-bit DAC, and dual 100 MS per second, 14-bit ADC. A 1 gigabit per second Ethernet cable is used to stream data at a rate of 50 MS per second. The USRP also contains a MIMO Expansion port in order to perform MIMO Operations by synchronizing it with another USRP. The device is powered by DC Power supply of 6-18 V.

4.1.2 LPWAN

LPWAN Description

Low bandwidth, low bit rate, and low power communications across great distances are made possible by LPWAN’s, or low power wide area networks, so it is including a small number of devices with constrained processing power and energy budget because of small batteries, connected using a communication protocol. It is used in different IOT applications according to their available resources while machine learning embedded intelligence into IOT applications. LPWAN has a great contribution to IoT-based healthcare applications for monitoring vital indicators, and numerous services can be implemented using the information obtained. LPWAN devices are lower in cost and consume very low power which makes them power efficient and offers a long coverage range. The star topology used by the LPWAN network eliminates the complicated routing algorithms necessary for a mesh topology. and reduces power consumption to a greater extent. The Figure. 8 shows the architecture of LPWAN.

The centralized gateway may use machine learning algorithms to make the proper decisions while receiving the sensed physical parameters from the connected devices via LPWAN. LPWAN application holds a large capacity to support constrained devices such as smart grids, smart cities, smart metering, etc.,

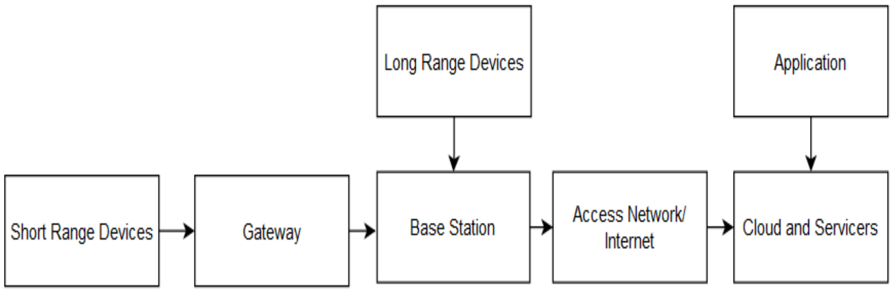


Figure 8. LPWAN technology is targeted at this emerging application and market. [1]

End Devices

The LPWAN network is used by two different kinds of equipment. The base station can be directly contacted by long-range devices (based on LoRa or NB-Fi). Short-range devices (based on Bluetooth or Zigbee)

Base Station (BS)

It joins end devices or gateways on one side and an access network or internet service provider on the other network. BS and cloud servers communicate via TCP/IP to carry out this task. To translate between application and Internet of Things protocols, BS is responsible. In IoT applications, MQTT and CoAP are often used protocols.

LPWAN Gateway

For short-range devices, the Gateway is utilized to offer network connectivity by often taking care of conversion- based radio technology and the associated protocols. Since Gateway must manage big end devices, it typically operates on a mains power source. In order to ensure end-to-end security, Gateway is additionally outfitted with encryption methods.

Cloud server and apps: Cloud storage is a service that allows for remote management, backup, and archival of user data. Customers can typically access the service online.

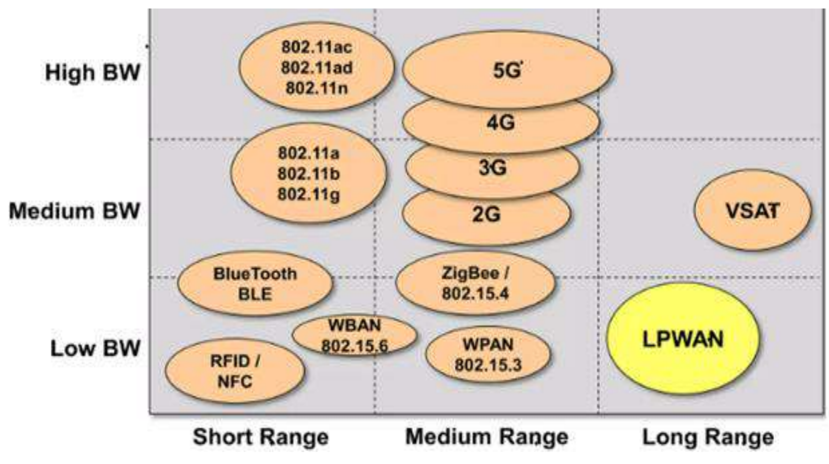


Figure 9 Compare of different IOT technology with LPWAN

In sensor-based applications, many wireless standards including IEEE 802.11 (WLANs), IEEE 802.15.2 (Bluetooth), and IEEE 802.15.4 (ZigBee, LR-WPANs) are employed. For networks needing high-speed data transfer, IEEE 802.11 and IEEE 802.15.2 were created, whilst IEEE 802.15.4 was created for low-speed data communication. The unlicensed spectrum is often used by network providers to build their wireless networks because cellular networks like 5G, 4G, 3G, and 2G are expensive, require a lot of power, and entail expensive gear and services. LPWAN technology is ideal for linking devices that must transmit modest amounts of data over a great distance while preserving a long battery life. Specification for LTE-M NB-IoT Open 3GPP Private Spectrum.

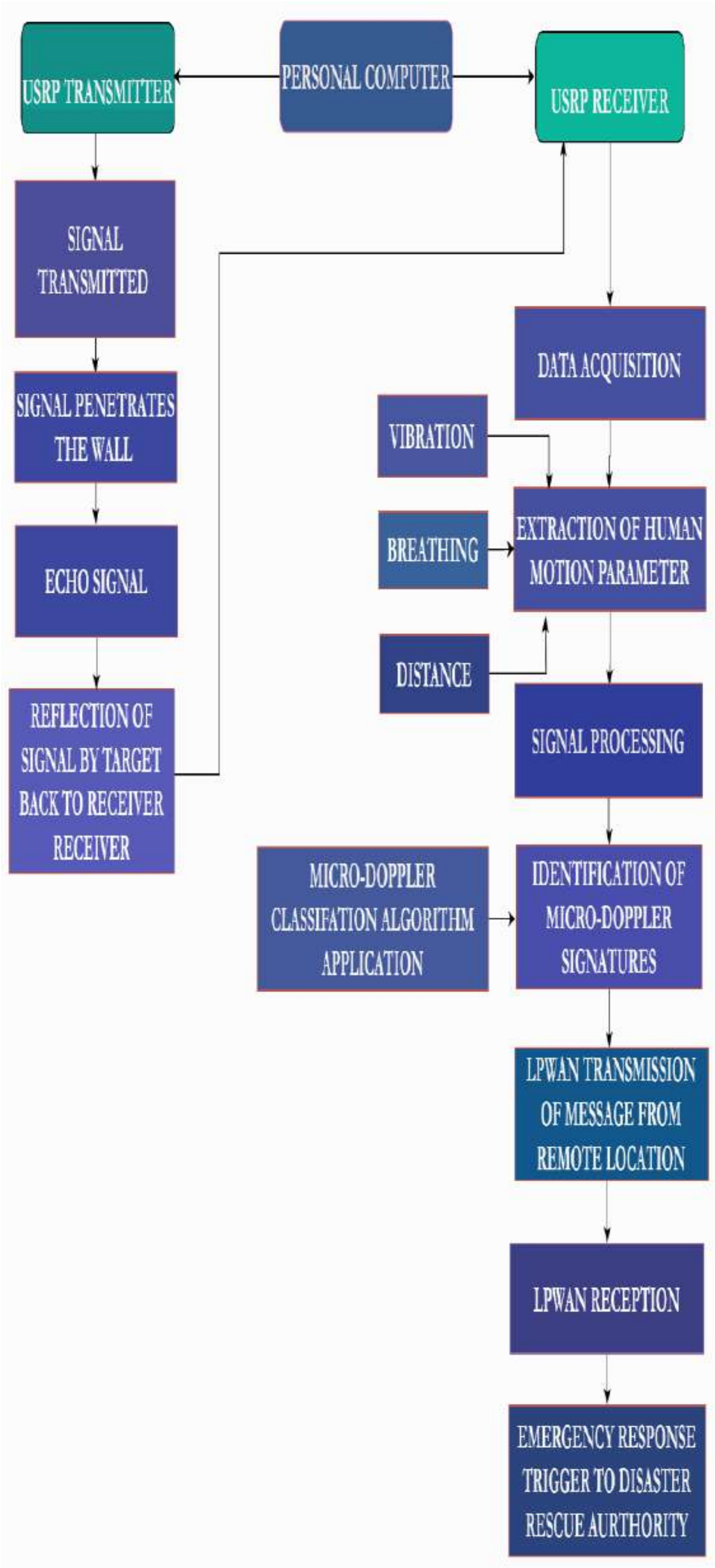


Figure 10. Illustration of way to carry out through wall survival detection

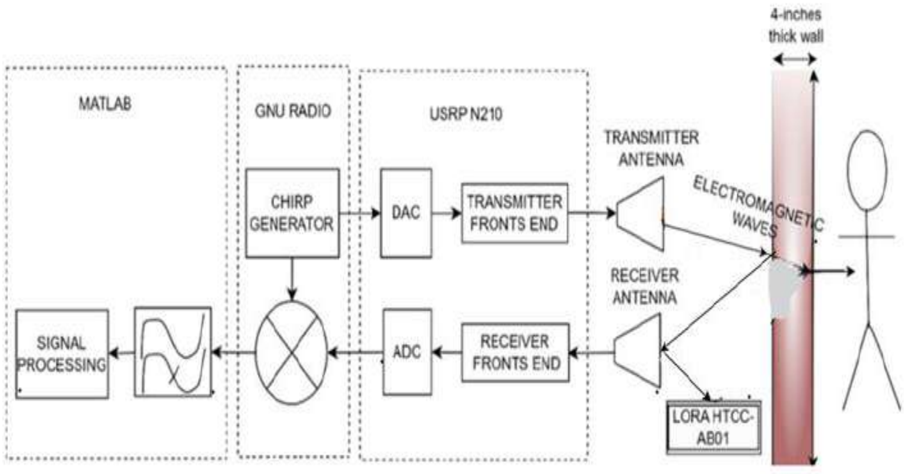


Figure 11. Implementation and method of through wall detection

4.2 Software

4.2.1 GNU Radio

A GNU Radio The free and open-source GNU Radio Companion platform was created to fulfil the functional needs for experiments relating to communication and signal processing along with creation of software radios It may be said that a software radio is a radio system that conducts the needed signal processing in software rather than doing reconfiguration of integrated circuits in hardware for each specific case. Due to the fact that GRC offers a graphical user interface with signal Numerous applications in the domains of control and monitoring are also made possible by the usage of this platform. processing steps, therefore it doesn't require a lot of programming knowledge. A single software defined radio can be usable in multiple applications, due to the ease of Software modification, by use of same hardware to produce several radios for a range of communication standards. Simple click and drag operations may be used to realize both simulation and real-world scenarios. At the back end, corresponding blocks will execute the Python and C++ code. GNU Radio has wide usage in industry, research, government, university, and hobbyist domains to support both real-world radio and wireless communications research. In every way, this configuration may be a replacement for a virtual instrument platform like LabView, but it is less user-friendly Popular SDR gear is supported by Matlab and Simulink, enabling communication with SDR platforms for radio-in-the-loop testing, prototyping, and hands-on education.

4.2.2 MATLAB

Matlab and Simulink support for popular SDR hardware, you can communicate with SDR platforms to perform radio-in-the-loop testing, prototyping, and hands-on learning. Matlab is a powerful software programming environment which allows the scientists and engineers to perform technical computing, create systems and algorithms, and data analysis. It provides a wide range of toolbox and functions for signal processing, image processing, machine learning, wireless communications, control systems and many more. Matlab being a high-level language that allows easy representation of data in form of array mathematics and matrix. Matlab is widely used in academic research, engineering, and industry for data analysis and modelling. Matlab provides a user-friendly interface that allows you to interactively explore and visualize your data. Matlab has pre-built applications and allows us to design customized applications. Matlab is easy to use, display live script findings, and code visualizations. You can also use Matlab plotting functions to create graphs and charts that illustrate your results and findings.

4.2.3 Arduino IDE

A software development environment called the Arduino IDE for LPWAN enables users to design and program low-power, wide-area network (LPWAN) applications for Arduino-compatible devices. For IoT devices and applications, LPWAN technology offers a long-range, low-power wireless communication option. The LoRaWAN, Sigfox, and NB-IoT LPWAN protocols are among those supported by the Arduino IDE for LPWAN.

For writing code and creating apps for Arduino boards, programmers often utilize the Arduino IDE (Integrated Development Environment). It offers a user-friendly interface and a condensed programming language that enable both novice and seasoned developers to use it. Due to their simplicity and adaptability, Arduino boards are frequently employed in the maker community and IoT (Internet of Things) projects.

A special kind of Arduino-compatible board made for the LPWAN CubeCell is an application for low-power wide-area networks (LPWAN) devices that require long-term battery operation should use LPWAN, a wireless communication technique that is optimized for long-range communication with low power consumption. We can create Internet of Things (IoT) applications that make use of LPWAN technology for long-range, low-power connectivity using the Arduino IDE and LPWAN CubeCell board. With this combination, projects based on LPWAN may be quickly and easily prototyped and deployed, allowing for energy-efficient connectivity and communication with a variety of IoT devices across long distances.

Overall, the Arduino IDE for LPWAN offers a strong toolkit for creating LPWAN applications, enabling developers to quickly produce creative IoT solutions.

4.3 Implementation

4.3.1 FMCW Transmitter

We simulated the FMCW Radar in order to detect Human Targets by transmitting and receiving Signals through rubble and storing the received echoes for Micro-Doppler Signature Extraction. The coding for the transmitter and receiver was simulated in GNU Radio to implement FMCW Radar. The FMCW transmitter code is depicted in Fig. 12.

As previously stated, GNU Radio use graphical programming, thus the code is in form of blocks. When a new window is created, the variable block and options block are already placed for parameter setting. The variable block is a block that allows you to create a user-defined variable that can be used in your flowgraph. The variable block is very useful when you need to create a value that is used multiple times in the flowgraph and you want to change that value in one place instead of searching and changing it in multiple blocks. The options block in GNU Radio is a graphical interface that allows users to set parameters for a block. The back-end programming of blocks in python is stored by the option Block. The Option block also provides us the Option to write name of code author. It provides a convenient way to modify settings without having to write code. The FMCW Transmitter blocks used in our code are explained as follows:

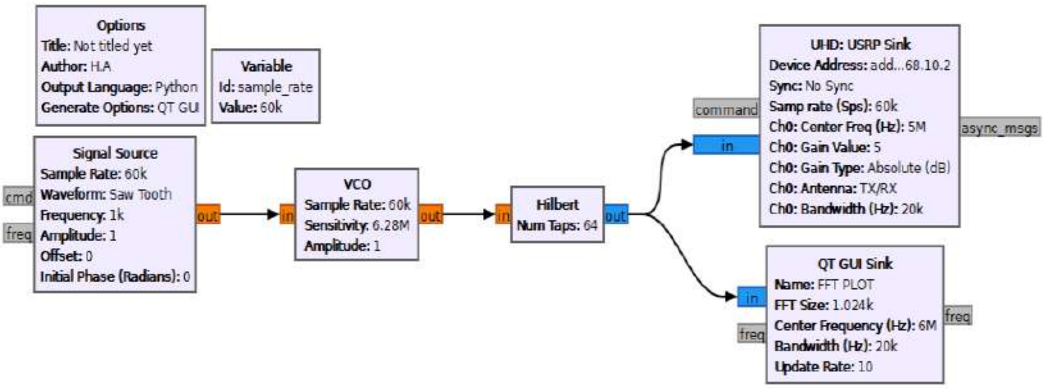


Figure 12. FMCW Radar Transmitter

Signal Source

A signal source generates a variety of continuous waveforms with a frequency that varies linearly over time. In our project, the signal source block generates a 1kHz Saw tooth waveform which is used for FMCW RADAR. A sampling rate of 60k samples per second was used. and the amplitude is set to 1 V. The signal source is a critical component of the FMCW radar transmitter, as it determines the accuracy and resolution of the radar system.

VCO

An oscillator with voltage control, or VCO, is employed to generate a continuous signal with a frequency that is continuously changing with time. VCO is used to generate a chirp which is a Frequency modulated waveform. The VCO acts as a carrier for the modulating signal which is the input frequency from the signal source. The VCO gives output which is the modulated signal. The VCO plays a critical role in generating a continuous and linearly varying frequency signal that enables accurate range and speed measurements in FMCW radar systems.

Hilbert

The Hilbert block is used in the transmitter to generate the modulated signal. The Hilbert block is used to generate the Quadrature (I/Q) signals that are required for the modulation. This block takes a real input signal from VCO and generates a complex output signal suitable for transmission. The block uses a Hilbert Transform to shift 90 degrees of the input signal's phase. The output the original signal's real and imaginary components are combined to create a complex signal as the phase-shifted signal.

QT GUI Sink

The QT GUI sink block in an FMCW transmitter using GNU Radio is used to view the transmitter's output waveform in real time. The block provides a graphical representation of the signal being transmitted, allowing you to easily monitor and analyze the output. It provides a timing, frequency, waterfall, and constellation graphs of the transmitted signal are displayed using a graphical user interface. It is a key component of any FMCW radar system.

UHD: USRP Sink

The UHD USRP Sink block in GNU Radio can be used as a part of an FMCW (Frequency Modulated Continuous Wave) transmitter to send a signal to a USRP (Universal Software Radio Peripheral) gadget for broadcast. The Gain is set at 5 dB and the centre frequency is set at 1 MHz.

4.3.2 FMCW Receiver

In order to receive the reflected echo of FMCW Radar, the same chirp which was transmitted is multiplied/mixed with the echo to obtain an IF frequency. An FMCW receiver is used to measure the distance and velocity of a target by transmitting and receiving a signal with a continuously varying frequency. A low beat frequency is created by combining the broadcast and received signals, and it is then filtered and amplified along with further signal processing to extract the distance and velocity information. The FMCW RADAR Receiver code is shown in Figure 4.4. The FMCW Receiver Blocks used in our code are elaborated as follows:

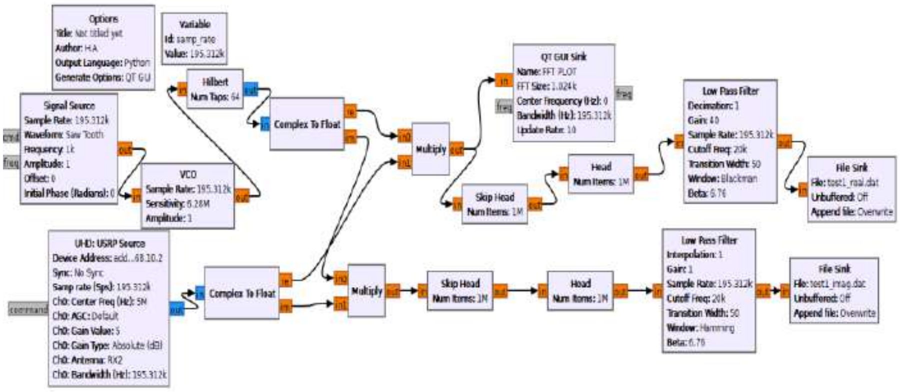


Figure 13 FMCW Radar Receiver

Multiply

The multiply block in an FMCW receiver is used to mix the received signal with a locally generated reference signal, which is then down converted to a lower frequency range for further processing. Basically, it mixes the real and imaginary components to obtain the IF signal.

Skip Head

The skip head is a technique used to remove the initial portion an undesired reflection from a nearby item is present in the signal that is received. It removes the storage of a specified number of samples specified from the beginning of the input stream. We used a value of 1M items. Hence our code will not store the initial 1M samples of received signal. It can improve the accuracy of our range measurements by removing unwanted reflections from nearby objects.

Head

The head block is used to limit the number of samples being stored in file sink block. the head of an FMCW receiver typically consists of a mixer, a bandpass filter, a phase-locked loop, a low-pass filter, and an analog-to-digital converter (ADC).

Complex to Float

The Complex to Float block takes in a complex input signal and outputs a float signal. The output of this block shows the actual and fictitious parts of the signal that was received as well as the chirp, which is then combined to produce the IF frequency.

File Sink

The File Sink block is used to save the received samples to a data file sample (.dat) format for further analysis. The real and imaginary samples are received in separate file sink for extraction of information about target.

4.3.3 MATLAB Processing

The RADAR Signatures acquired data obtained from GNU Radio, is processed in MATLAB to visualize our results. We used a Short Fourier Transform (STFT) to analyze our results. We cannot apply the Fast Fourier Transform (FFT) directly as obtained results are non-linear and constantly varying. The FFT is usually only applicable on Linear Time Invariant (LTI) systems. STFT is used to analyze non stationery objects by performing a windowing operation on the non-LTI signal multiple times. The portion of signal that is inside Hamming window becomes an LTI signal for that interval. Then the FFT of that signal is calculated which results in a time-frequency color map. A color map is a matrix that maps the data values to a range of colors obtained via time frequency analysis for micro-Doppler Acquisition. A color map is typically used to display a 2D image or a surface plot where each data point is assigned a color based on its value. Make a distinction between a human's motion, such as breathing, heartbeat, or other involuntary motions, and those of other items in the debris using the generated micro-Doppler signal.

The micro-Doppler signatures of various human motions are shown in the following figures.

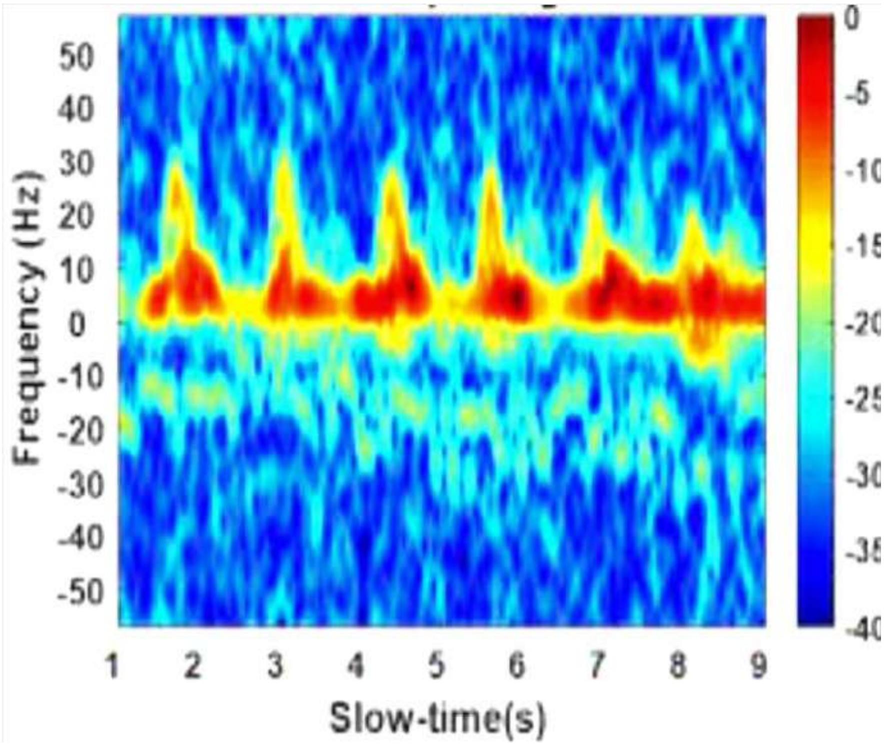


Figure 14. Spectrum in frequency time of slow-moving person.

The above Time frequency spectrogram depicts the signatures of a slow-moving man. The Time interval between the occurrence of frequency fluctuations is very less in this figure. Also, the red lines are classified as reflection from the human body. We notice that the slight Doppler shifts around 0 Hz shows us the reflection of the Main Body, while the motion of moving arms causes the frequency fluctuations to be produced which creates a micro-Doppler effect in the signature.

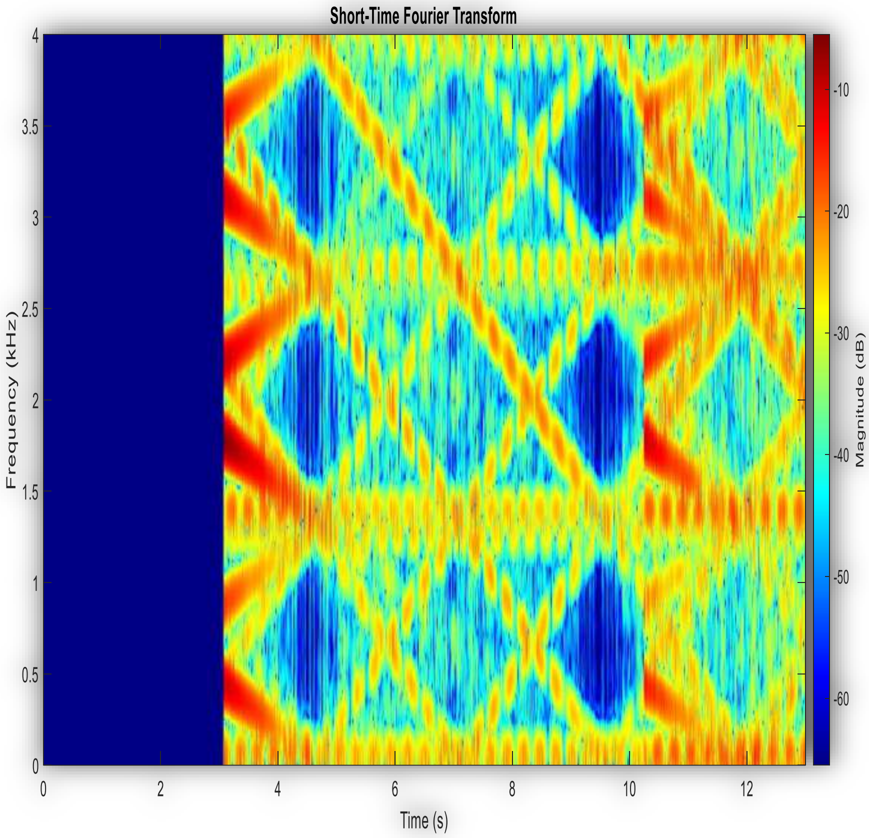


Figure 15. Frequency Time spectrogram of a Person Walking behind the wall.

The above Figure 15 shows the Fluctuations in Frequency that occurs multiple times in a short time interval that tells us why the Man is walking at a very fast pace. And the rapid fluctuations in the frequency shows that the arms are moving too fast in parallel to the main body which creates a difficult situation to read the micro-Doppler signature properly due to the overlapping of thousands of chirps at a time.

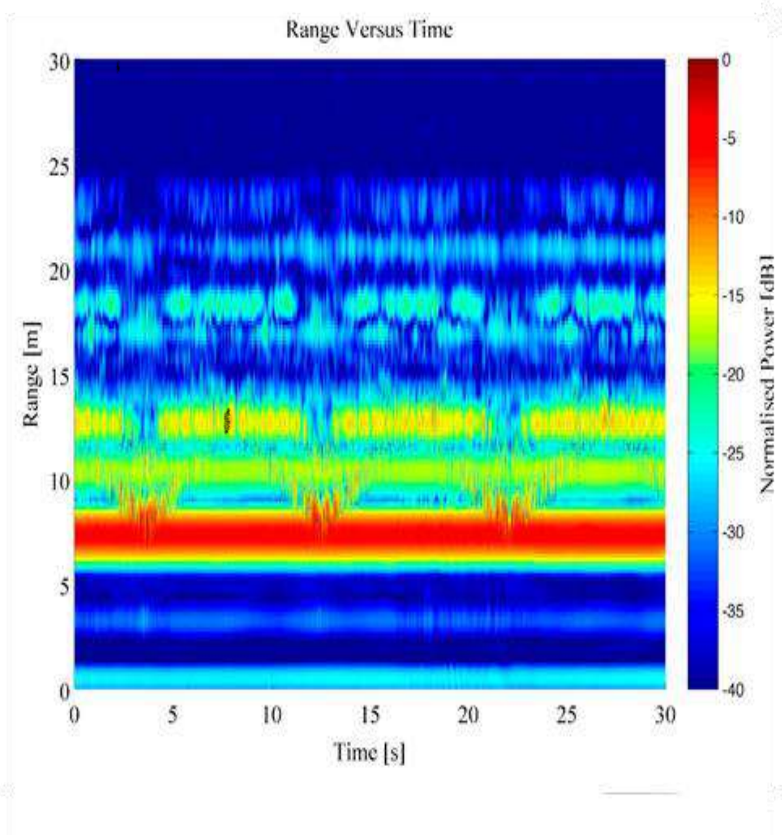


Figure 16. Individual walking with free hands, measured through the wall using a range-time intensity (RTI) plot.

The Figure 16 shows and RT that shows the person walking backwards and forwards within a room bounded by walls. The picture depicts a disturbance in signature at 2.5, 12, 22.5 seconds close to wall signature at a distance of 7 m.

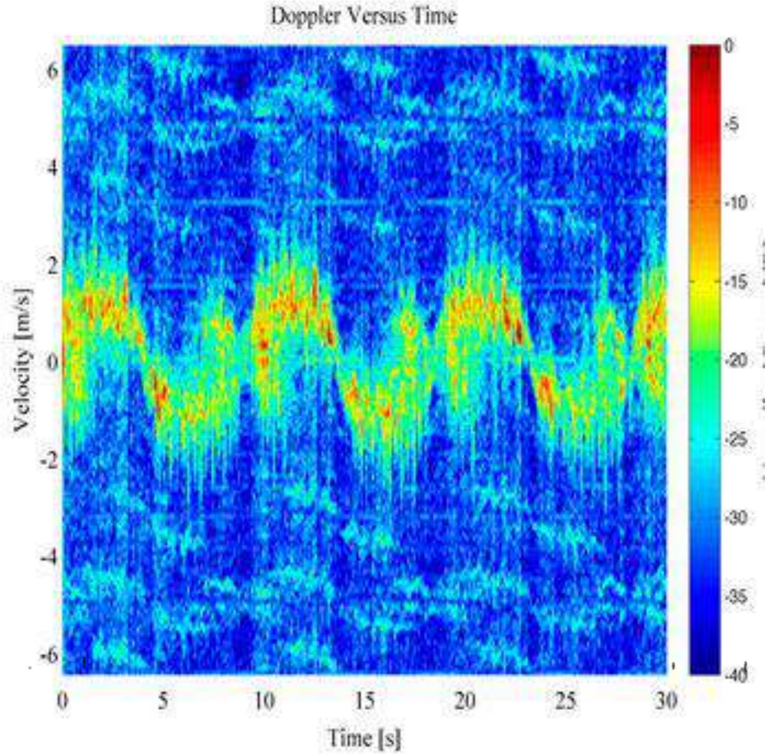


Figure 17. Individual walking with free hands-on Moving Target Indicator (MTI) plot taken through the wall.

The above Figure 17 shows the MTI plot of walking taken which has dominant zero frequency components removed which does not contain any motion characterization. Over the 30 seconds span, the picture shows the velocity of moving arms at the peaks of the sinusoids.

Chapter 5

Conclusion and Future Recommendation

We were able to get the conclusion that the LPWAN and SDR's contact with one another is crucial for search and rescue operations. Although SAR teams currently only have a few smart sensing devices, this project will significantly improve the security and efficiency of SAR operations. We have found that the key element of our technology that offers a dependable and effective means of communication between the rescue crew and Trapped individuals for greater chances of survival is TTW RADAR. The technology is simple to operate and deploy in disaster areas, improving cooperation and effectiveness. Through LPWAN, we also obtained the Micro-Doppler signatures of several target objects and simulated transmission data. In order to enhance computing power, LPWAN’s will also need to communicate at low power with the infrastructure and people in their immediate surroundings. The system's compatibility with current SAR tools and protocols makes it easier to implement the system in disaster areas. After acquiring the micro-Doppler signature from MATLAB, we constructed a dataset of various human movement spectra in order to categorize numerous objects in the area of interest. Disasters occur frequently; hence smart sensing is a newly developed technology. In order to identify, locate, and help locate imprisoned people more effectively, we will soon need to optimize the system parameters and merge the USRP N-210 with unmanned aerial vehicles (UAVs) and GPS.

Future improvements will increase the system's capabilities and turn it into a vital tool for rescue teams as they carry out the crucial mission of locating and maintaining the maximum level of individual safety and comfort. Additionally, a portable version of the system and accurate localization of the Target will make deployment and operation in disaster areas simple.

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