Uluslararası İleri Doğa Bilimleri ve Mühendislik Araştırmaları Dergisi
Sayı 7, S. 72-80, 3, 2023

Araştırma Makalesi

IJANSER
https://as-proceeding.com/index.php/ijanser
ISSN: 2980-0811

International Journal of Advanced Natural Sciences and Engineering Researches
Volume 7, pp. 72-80, 3, 2023

Research Article

Sense through Wall Human Detection using ADALM-Pluto AD9361

Abdul Haseeb[*1], Rabia Taseen[1], Mumtaz Majeed[1], Farhan Ullah Khan[1] and Ayesha Shabbir[1]

[1]*Department of Electrical Engineering, University of Engineering and Technology Taxila, Pakistan*

[*]*Abdul.Haseeb@students.uettaxila.edu.pk Email of the corresponding author*

(Received: 28 March 2023, Accepted: 03 April 2023)

(2nd International Conference on Engineering, Natural and Social Sciences ICENSOS 2023, April 4 - 6, 2023)

ATIF/REFERENCE: Haseeb, A., Taseen, R., Majeed, M., Khan, F. U. & Shabbir, A. (2023). Sense through Wall Human Detection using ADALM-Pluto AD9361. *International Journal of Advanced Natural Sciences and Engineering Researches*, 7(3), 72-80.

Abstract – The research describes the development of an interior target identification system that uses ultra-wideband radars to locate one or more targets in a cluttered environment. The device can gather information about target distances from radar, which can be used to localize and follow one or more targets in real time. One of the most crucial tools for the present wireless transmission system is software-defined radio's (SDR). An SDR is a radio that uses re-configurable hardware and robust software to apply various modulation and demodulation schemes as well as different standards in the same device, allowing it to tune to any frequency range. In our research Radio Detection and Ranging (RADAR) was used for detection with ultra-wideband frequencies. We can predict the locations and shapes of the targeting object behind the wall because of the ultra-wideband (UWB) radar technology. It is very useful, particularly for uses involving security and relief. We're moving to SDR, the analog device (AD) we used is ADALM-Pluto AD9361, because of UWB. In this experiment, various frequency bands are sent and either captured with or without objects. We create a comparison method that is like autocorrelation after various findings. The research outcomes proved that the program surpassed one without segmentation. With this strategy, UWB radars have an advantage over narrow-band (NB) radars in terms of enhanced data processing flexibility, and as a result, they will be utilized more efficiently and effectively in applications in the real world. Additionally, they demonstrated that it is possible to quickly identify humans using only a brief amount of data. The tools used for experimental setup are GNU Radio, the signal processing block, and Python for Out-of-Tree Module (O-TM).

Keywords – Software Define Radio's (SDR), Radio Detection and Ranging (RADAR), Ultra-wide Band (UWB), Analog Devices (AD), Narrow Band (NW) and Out-of-Tree Module (O-TM).

I. INTRODUCTION

With recent technological advancements, intelligent robots such as domestic, nursing, and emergency robots will become commonplace soon. The need for security technology to safeguard people from crime and terrorists is growing, however, as the security situation in society has gotten worse since the turn of the twenty-first century. For these reasons, surveillance and tracking systems are common today in places like cities, homes, stores, and hospitals. These devices must be able to detect individuals and other things. One potential use for surveillance systems is the automated and real-time detection of malicious users [1].

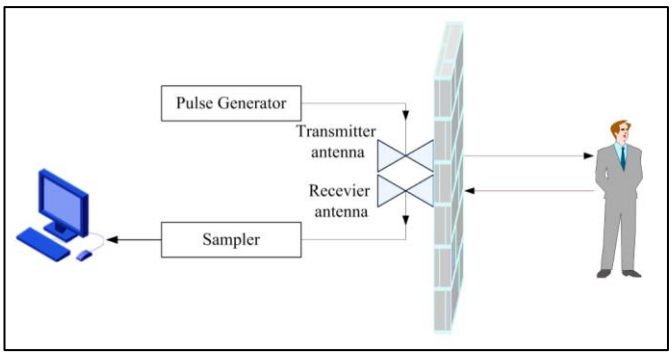

Fig. 1 Human Detection through Wall [1]

Many applications depend on the ability to recognize human targets through the wall. The defense industry might use it in situations involving prisoner recovery. In such circumstances, the location of people inside a building is crucial because the rescues may face risks due to the new design of the structure and the proximity of furnished people. UWB development has become one of the most popular options for these uses because of its amazing range goal and exceptional invasion through the majority of building materials. The high frequency of UWB radar has a delayed effect on long-range objectives, which aids in more effective target separation.

SDR is a radio correspondence framework that has truly been executed in equipment (for example blenders, channels, speakers, modulators/demodulators, locators, and so on.) as opposed to utilizing programming on a PC or installed framework.

The fundamental SDR framework may comprise of a PC outfitted with a sound card, or of a further simple to-computerized converter went before by some type of RF front end. Critical measures of sign preparing are moved to the universally useful processor instead of to specific reason equipment. Such an arrangement makes a radio which can get and impart comprehensively uncommon radio shows subject to the item used [2].

A. *Basic Principle*

The recipient's favoured answer is to join the ADC to the getting wire. The serious sign processor would scrutinize the converter, and afterward, its item would change over the data stream from the converter to some other structure that the application requires.

An ideal transmitter would be similar. A DSP would make a flood of numbers. These inevitably sent to a serious to basic converter related to a radio gathering device. The ideal arrangement isn't possible because of the current farthest reaches of advancement. The key issue in the two different ways is the difficulty of change between the mechanized and basic territories at an adequately high rate and an adequately high accuracy all the while, and without relying on physical cycles like impedance and electromagnetic resonation for help [2].

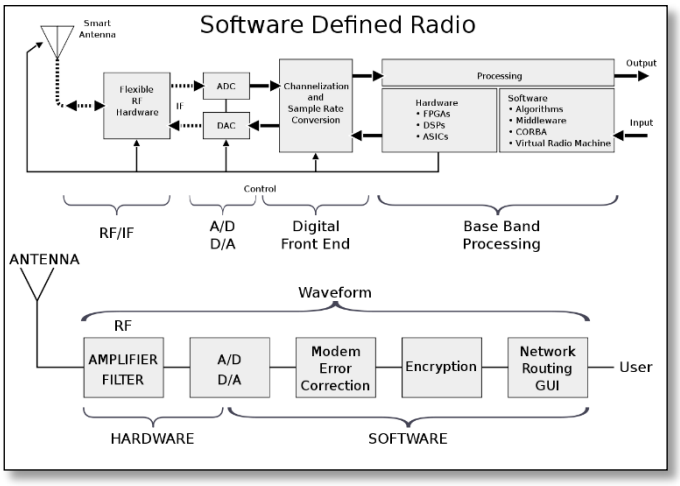

Fig. 2 Software Defined Radio Basic Principle [2]

B. *Ultra-Wideband*

UWB is a radio development that can use an incredibly low imperativeness level for short-go, high-information move limit trades over a huge piece of the radio range. UWB has ordinary applications in non-supportive radar imaging. Most recent applications target sensor data collection, precision finding, and following applications [3].

UWB short-run far off correspondence isn't exactly equivalent to an ordinary carrier wave system. UWB waveforms are short period of time length and have some genuinely stand-out properties [4].

As per the Electromagnetic theory, lower frequencies have better-invading properties. UWB radar uses a tremendous range in the blend in with lower frequencies which makes it sensible for applications, for instance, ground-entering radar, and foliage penetrating radar. This infiltration property is likewise critical for indoor area frameworks. Shorter frequency utilizes littler elements of get and sends reception apparatuses. Then again, an expansion in an inside frequency of the sign is attractive for improving the entering capacity of electromagnetic waves through dividers.

Some of the applications are;

- Communication Systems

Using UWB methodology and the open huge RF bandwidths, UWB correspondence joins have gotten commonsense. The remarkably colossal available bandwidth is used as the purpose behind a short-go distant neighborhood with data rates advancing toward gigabits consistently [4].

- Radar System

For radar applications, these short pulses give extraordinarily fine range objective and exactness partition and arranging assessment capacities. The incredibly huge exchange speed changes over into an eminent radar objective, which can isolate between immovably scattered targets. This significant standard is procured even through, for instance, foliage, soil, and divider, and floor of the structures. Various inclinations of UWB short pulses are protection from inert impedance (deluge, fog, jumble, vaporizers, etc.) and the ability to recognize languid or fixed targets [5].

The transmitter produces the powerful sign that is emanated by the radio wire. In a sense, a radio wire goes about as a "transducer" to couple electromagnetic vitality from the transmission line to radiation in space, and the other way around. The duplexer grants substitute transmission and gathering with a similar radio wire; essentially, it is a quick acting switch that shields the touchy recipient from the high intensity of the transmitter [6].

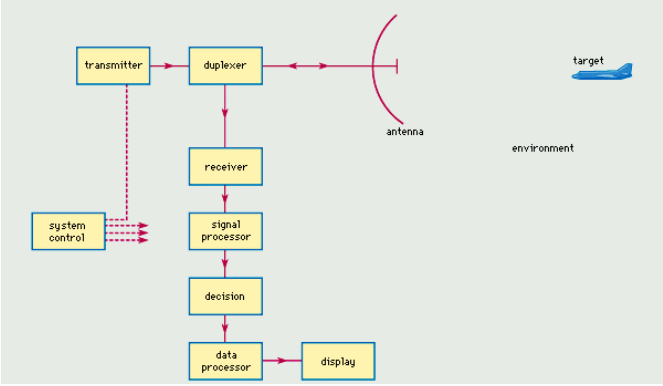

Fig. 3 Basic of RADAR [6]

C. *Pulse-Wave Radar*

Short and innovative heartbeats are transmitted by heartbeat radar, which receives echo signals during calm periods. In contrast to constant wave radar, the emitter is smashed before the calculation is completed. Radar rhythms illustrate this method. Huge heartbeat pauses T>> τ, also referred to as the accepting period, are interspersed between the transmit beats. With the incentive for specific separations stored in an information base, runtime estimation of the reflecting items is regulated by investigation of the significant variations of the Doppler range [7].

$$s(t) = A(t).sin[2\pi f(t).t + \varphi(t)] \quad (1)$$

The capacity A(t) is a variety of the sufficiency in the capacity of time t - for example an adequacy tweak. In the easiest case, the transmitter is for a brief timeframe turned on (for the time τ) and stays in the remainder of the time in the "off position". A (t) is then in the transmission case = 1, in any case = 0. The capacity of time is then dictated by the beat reiteration recurrence and the obligation cycle. Since the radar returns are dependent upon different misfortunes, a real plentifulness balance looks bad aside from simply this exchanging capacity [7].

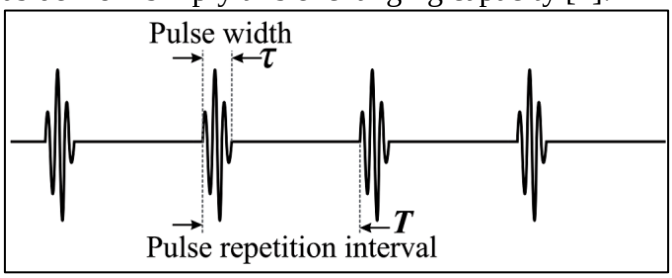

Fig. 4 Pulse Wave Radar [7]

D. *Continuous-Wave Radar*

Continuous Wave Radar (CW radar) sets convey a high-repeat signal continually. The resonation signal is gotten and taken care of for eternity. One needs to decide two issues with this standard, forestall an immediate association of the sent vitality into the beneficiary (criticism association) and dole out the got echoes to a period framework to have the option to do run time estimations [7].

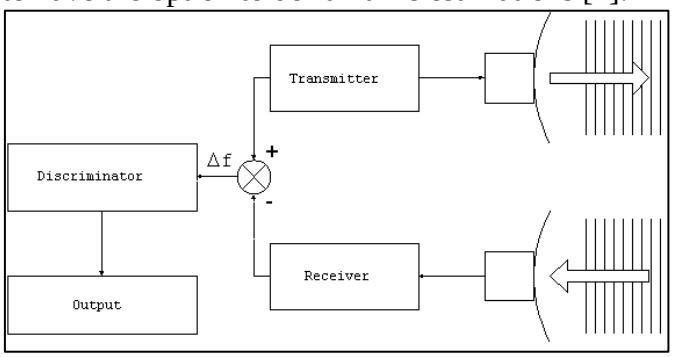

Fig. 5 Block Diagram Continuous Wave Radar [7]

E. *Doppler Radar*

An unmodulated ceaseless wave radar radiates a consistent repeat with predictable abundancy. The got resonation signal either has the same repeat, or

the resonation signal is moved by the Doppler repeat (with a reflector moving at an extended speed). CW radars that speak to extensive expert in assessing this Doppler repeat are called Doppler radars. A runtime assessment isn't major at all with a Doppler radar for speed assessment since no detachment confirmation is finished. If a runtime assessment is to be finished, by then a period reference of the got resonation to the sent sign can be set up by directing the conveyed signal. This equalization, for instance, the certified time at which the sent sign changes in repeat or abundancy, can be enrolled in the beneficiary after the concede time and along these lines makes time assessment possible. Such change, nevertheless, achieves other radar classes, which consequently use remarkable assessment norms. Adequacy balance at 100% parity is moreover conceivable and would provoke a heartbeat radar. A radar that communicates an unmodulated faltering can simply recognize the speed of a thing by methods for the Doppler Effect. It is incomprehensible to hope to choose to isolates or perceive different concentrations likewise [7].

The nonstop wave radar surveys the stage qualification φ between the imparted signal and the got signal. The significance of this stage differentiate is the extent of the partition passed by the electromagnetic wave to the frequency of the conveyed signal, expanded by the degree division of the full circle (2π). The size of this stage differentiate is the extent of the frequency of the imparted sign to the detachment traveled. On the off chance that the separation to the reflector doesn't change, at that point it is steady and is determined by:

$$\varphi = -2\pi \frac{2r}{\lambda} \qquad (2)$$

Where;

Φ: Phase difference

r : Distance of the reflector to the antenna

λ: Wavelength of the transmitted signal

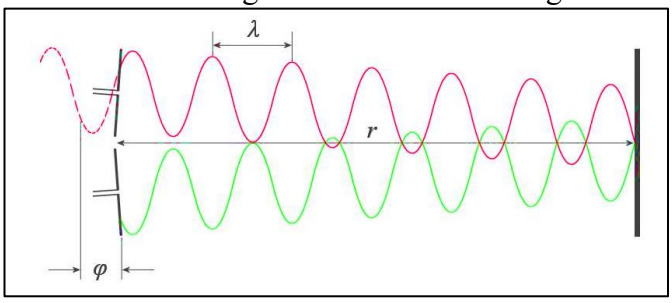

Fig. 6 Visual Represenation of Doppler Radar

If the separation to the reflector isn't consistent however changes, for instance, with a moderately steady speed to the sending radio wire, the stage distinction additionally changes as a component of time:

$$\varphi = -4\pi \frac{r(t)}{\lambda} \qquad (2)$$

II. PRELIMINARIES

As we know sense through wall human detection has many applications in new era. So our project has mainly two parts; one is detection of human body and other is localization of human body with the help of image processing. And further we can make the changes in transmitting power to detect the vital sign of human body like respiration and movement of chest.

A. *Fourier Transform*

The Fourier Transform (FT) breaks down a limit into its constituent frequencies. An outstanding case is the assertion of the melodic concordance to the extent the volumes and frequencies of its constituent notes. The term Fourier change insinuates both the repeat region depiction and the mathematical action that relates the repeat space depiction to a component of time. The Fourier change of a component of time is itself a complex-regarded limit of repeat, whose size addresses the proportion of that repeat present in the principal limit, and whose dispute is the stage adjusted of the fundamental sinusoid in that repeat. The Fourier change isn't confined to components of time, yet the zone of the main limit is typically suggested as the time-space. There is furthermore a contrary Fourier change that mathematically coordinates the main limit from its repeat space depiction [8].

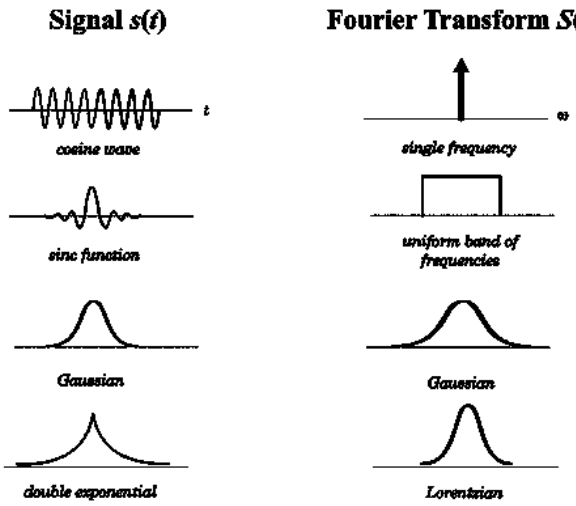

Fig. 7 Representation of Fourier Transform [8]

B. *Methodology*

But our focus is detection of human body movement through wall, so for this we mainly require data acquisition and removing of error. But first of all we need such a hardware to detect human or such a sense which capture the change of frequency in minimum amount of time. So we have the following sketch that we follow in our project.

- Structuring a recognizing framework for indoor conditions.
- Composing information securing programming.
- Pre-handling and sifting the got signal.

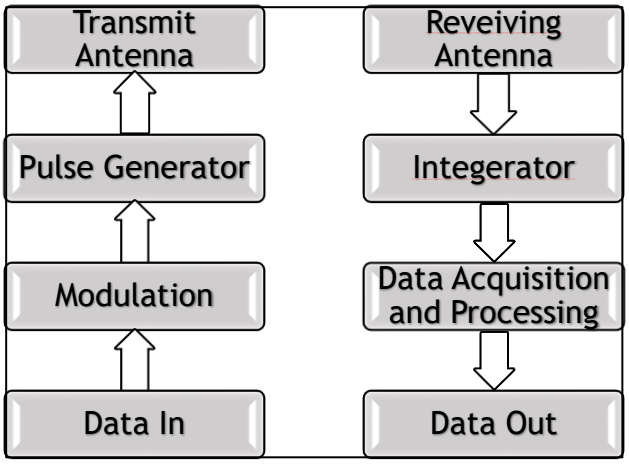

Fig. 8 Flow Diagram of Problem

C. *ADALM-Pluto*

The simple to utilize ADALM-PLUTO dynamic learning module (PlutoSDR) acquaints electrical designing understudies with the essentials of programming characterized radio (SDR), radio recurrence (RF), and remote correspondences. Intended for understudies at all levels and from all foundations, the module can be utilized for both teacher drove and self-guided figuring out how to assist understudies with building up an establishment in certifiable RF and correspondences that they can expand on as they seek after science, innovation, or science degrees [9].

Fig. 9 ADALM-Pluto [9]

The ADALM-Pluto has just talked about that it is a simple gadget, the fundamental reason for this gadget to interlink among hypothetical and useful works. Basically what are the impediment in useful when investigations performed? It can without much of a stretch be utilized to present software defined radio, radio frequency, or communications in reality.

This device comes with mainly two evaluation boards, AD9361/AD9364 and AD9363. This basic difference between two boards is the range of transmitting frequencies. The following table give quick idea what's the difference between AD9363 and AD9361 board. Further we discuss only one of board for more understanding.

Table 1. Comparison of AD9363 and AD9361

Parameters	AD9363	AD9361
RF Coverage	325 MHz to 3.8 GHz	70 MHz to 6.0 GHz
Bandwidth	20 MHz	56 MHz
Sampling Rate	30 MHz	61.44 MHz

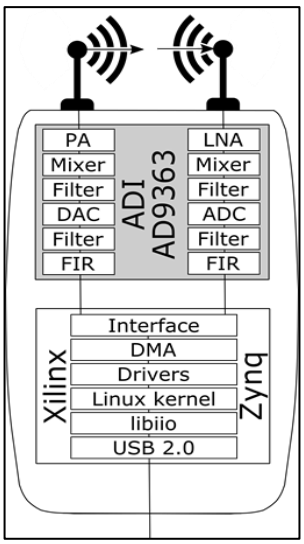

Fig. 10 ADALM-Pluto Basic Block Diagram [10]

As shown in the figure of ADALM-Pluto it is AD9363, but we are used in our research AD9361. If we see the block diagram we see chain between different blocks, this means that information is send from one block to another but in different means. We discuss shortly about each block.

- USB 2.0
  As we know this is USB interface through your personal system to main path of send or receive instructions. 2.0 shows the speed of data transfer in computer each port has specific number like 2.0, 3.0 or 3.1.
- Libiio
  This is the internal library of device. To connect through personal system the related library of analog devices must be installed to give access RF signals in environment.
- Linux kernel and Drivers
  The analog devices are usually interface with Linux operating system. And in Linux we installed specific drivers to give permission. We also installed in Windows, but we have done many changes and we cannot openly do changes in device.
- DMA
  Direct Memory Access, to transfer the data from RAM or memory unit to another part of computer without any processing unit is Direct Memory Access because if processing unit involve in analog devices the speed of work is effective even it is 1μ seconds.
- FIR
  Finite Impulse Response, If you put in an impulse, that is, a solitary "1" example followed by many "0" examples, zeroes will come out after the "1" example has cleared its path through the postpone line of the channel. In any case, the FIR channel has a burden additionally in light of the fact that it takes more memory during handling.
- Filter
  We have main two filters one in transmitting side to clear the side lobes as possible for exact band transfer and we also have amplifier place to enhance the signal by auto-scale or manually. And other filter is place in receiving side to firstly remove the noise from received signal line Low Noise Amplifier.
- DAC/ADC
  Digital to Analog or Analog to Digital Convertor, they are different specification according to analog devices.

III. Data Acquisition

Data acquisition is a way of testing the signals and manipulated the results. In which we take the response or signal of a physical system and converting into the digital system that can be solved by a personal computer (PC).

A. Transmit and Receive Signal

We can transmit a continuous wave of signal with different frequencies and receive it. But for this, we have checked our device by sent a signal frequency of single value along with fixed bandwidth. We observe difference between transmitting and receiving signals.

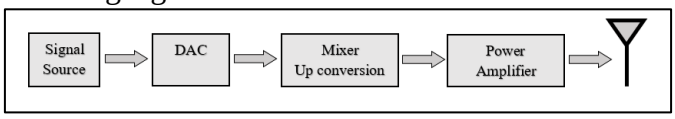

Fig. 11 Transmitting Side

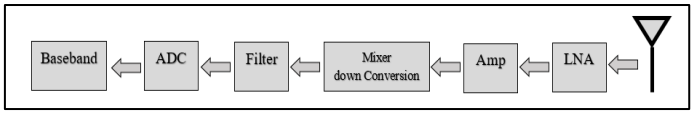

Fig. 12 Receiving Side

Table 2. ADALM-Pluto Sink

Parameters	Values
Device URI	192.168.2.1
LO frequency	70M
Sample Rate	1M
RF Bandwidth	45M
Buffer Size	32.768k
Attenuation (dB)	10dB

Table 3. Signal Source

Parameters	Values
Sample rate	200k
Waveform	Sine
Frequency	1G
Amplitude	1

B. *Transmit and Receive Continuous Signal using Out -of-Tree Module*

The final phase is to implement over research phase to transmit a continuous signal and receive it with a target as well as an obstacle. We can ignore the clutter effect because as it is an indoor project so for our testing or prototype, we cannot face such issues. For continuous signal, we need some additional block to make a loop which can transmit a signal like a sweep generator from lower frequency value to higher frequency values. For this additional block, we used the out of tree module method which discusses below.

An out of tree module is the process of making additional block in GNU Radio, in which you can add you code which you want to implement in the simulation. According to our requirement, we make the block that works in the loop. The following steps are used to create a block.

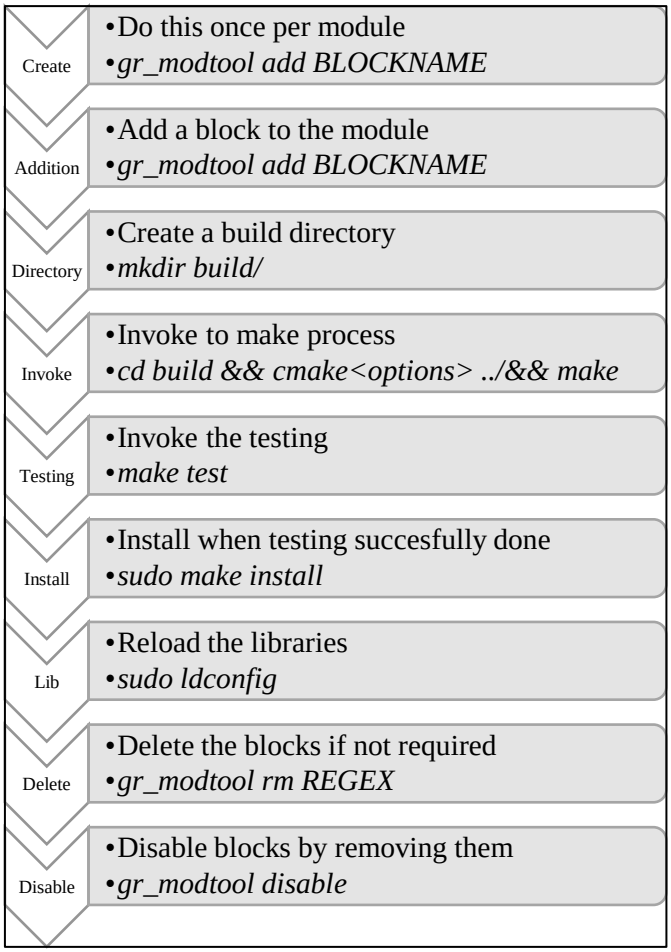

Fig. 13 Creating a Out-of-Tree Module

C. *Brief Visualization of Autocorrelation*

There are two basic concept taken from block diagram one is direct take autocorrelation of continuous signal, and the other one is that first to take FFT of signal, find the time delay then shift the signal and take difference of transmitting signal and receiving signal.

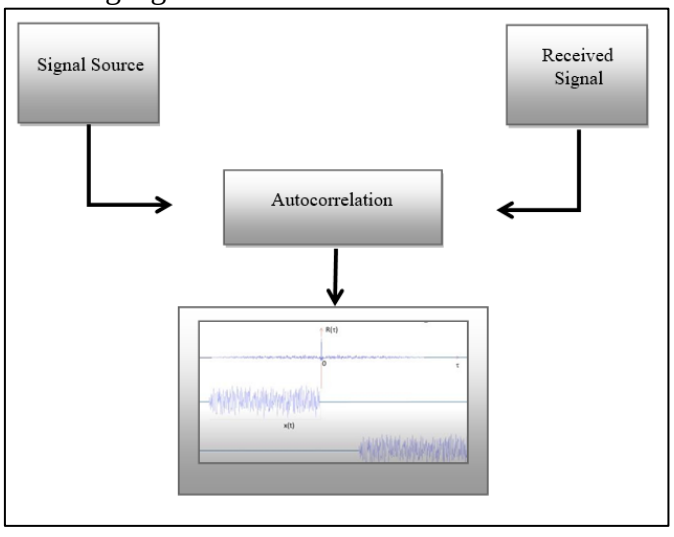

Fig. 14 Autocorrelation General Diagram

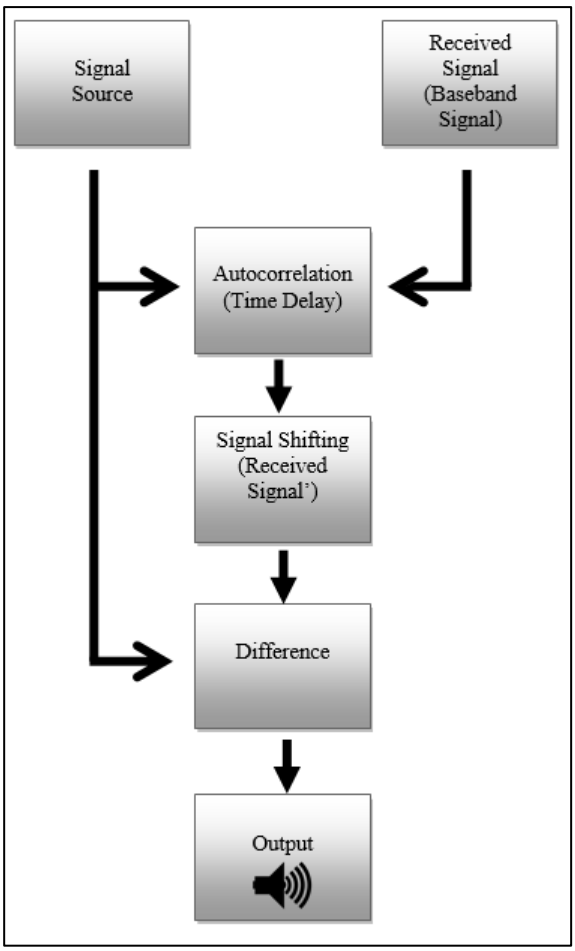

Fig. 15 Autocorrelation Proposed Block Diagram

IV. Results and Discussions

First, we transmit the sweep of signals to check at which frequencies the response of human thing is good or observable. For this, we create a module by using the Out-of-Tree module.The range of frequencies that is quite easier to observe is 900 MHz to 3GHz. So we set these parameters to achieve a better result. The best range without any obstacle is almost 3m. And with an obstacle, it's almost 1m (due to transmitting power is a drop). You can save the files of transmitting signals and receiving signals by using the block of File Sink. And further, this save files used for other purposes like Autocorrelation or any other algorithms by using the block of Import.

As we already discussed the problem of AGC, so we need to interface the controller at the receiving side. Which compares the transmitting and receiving signals, to show the difference and detect if somebody enters in zone.

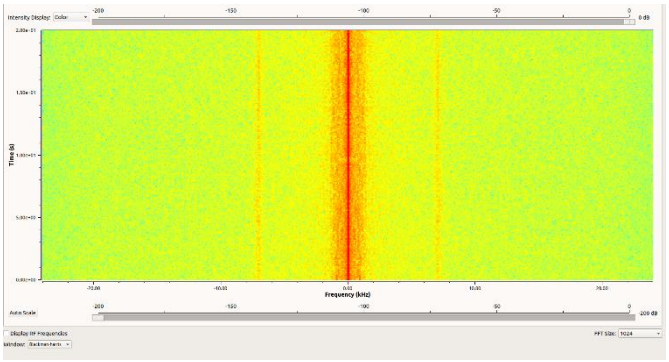

Fig. 16 Water Fall display without Target.

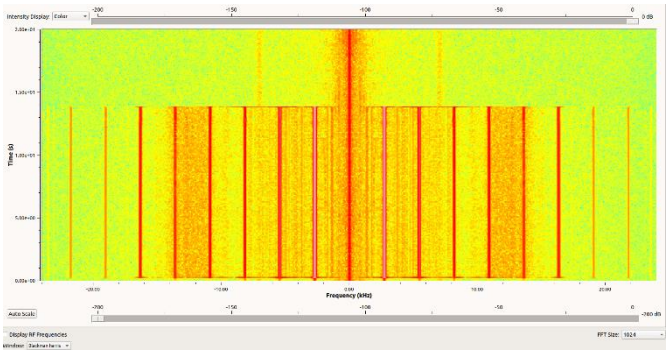

Fig. 17 Water Fall display with Target.

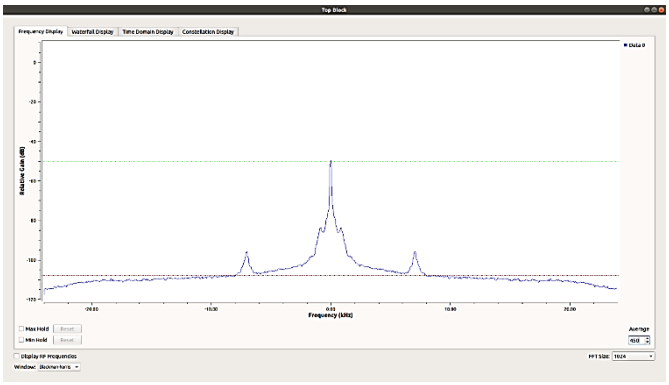

Fig. 18 Frequency Display without Target.

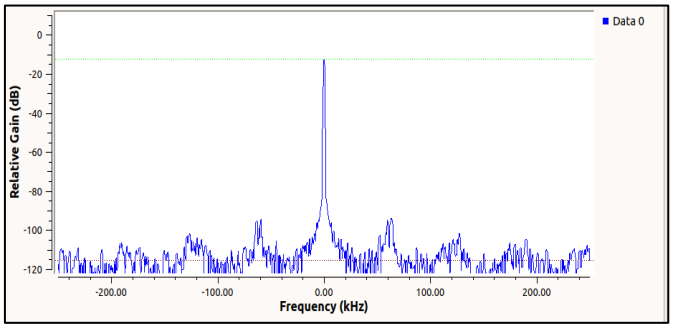

Fig. 19 Frequency Display of Target with Clutter

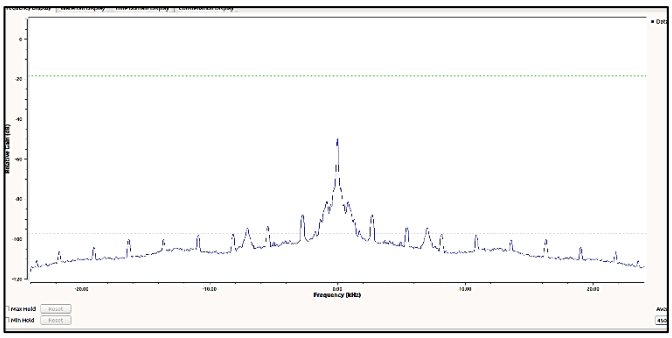

Fig. 20 Frequency Display of Target without Clutter

V. Conclusion and Future Work

As we already discussed in this research detection of the human body through the wall. Which has many applications in real-world special in military purposes or in case of any natural disaster in which the human body buried under broken houses? We work on real signals and focus on how to transmit and receive signals. What are the attenuation factors affect signals badly and how the device is working in different scenarios.

We also judge some other related work that also done by this ADALM-Pluto that in any indoor environment how we secretly transmit over the information in other PC. And we also Hack other information signals and decode the information. Because the range of frequencies is about almost 70MHz to 6GHz.

In the future, we hope to upgrade this research by introducing a sketch of the human person in your person window and locate the position of a person.

One other important thing we introduce in it that to detect weapons also by specific frequency directly reflect by the metals.

References

[1] K. Saho, T. Sakamoto, T. Sato, and K. Inoue et. al., "Experimental study of real-time human imaging using UWB Dopplar radar interferometry," *2012 6th European Conference on Antennas and Propagation (EUCAP)*, IEEE, 26-30 March 2012, pp. 3495-3499.

[2] The Wikipedia website. [Online]. Available: https://en.wikipedia.org/wiki/Software-defined_radio

[3] The Wikipedia website. [Online]. Available: https://en.wikipedia.org/wiki/Ultra-wideband

[4] U. Ozkaya, H. Duysak and E. Yiğit, "Efficient multitask learning analyses on grain silo measurement" Journal of Applied Remote Sensing, 2021 15(3), 038505-038505.

[5] R.J. Fontana, "Recent system applications of short-pulse ultra-wideband (UWB) technology", *IEEE Transactions on microwave theory and techniques*¸vol. 52, no. 9, pp. 2087-2104, 2004.

[6] The Britannica website. [Online]. Available: https://www.britannica.com/technology/radar

[7] The radartutorial.eu website. [Online]. Available: https://www.radartutorial.eu/02.basics/Pulse%20Radar.en.html

[8] The Wikipedia website. [Online]. Available: https://en.wikipedia.org/wiki/Fourier_transform

[9] The Analog Devices website. [Online]. Available: https://www.analog.com/en/design-center/evaluation-hardware-and-software/evaluation-boards-kits/adalm-pluto.html

[10] The Analog Devices website. [Online]. Available: https://www.analog.com/en/design-center/evaluation-hardware-and-software/evaluation-boards-kits/adalm-pluto.html#eb-overview

[11] The GNURadio website. [Online]. Available: https://wiki.gnuradio.org/index.php/UbuntuInstall#Building_GNU_Radio_on_Ubuntu_Linux

[12] The Analog Devices website. [Online]. Available: https://wiki.analog.com/resources/tools-software/linux-software/gnuradio

[13] S. Lian and Y. Zhang, "Handbook of research on secure multimedia distribution," *IGI Global*, 2009.

[14] The Oracle website. [Online]. Available: https://docs.oracle.com/cd/E19120-01/open.solaris/819-7761/fwmxi/index.html

[15] The Digibirds side website. [Online]. Available: https://digibird1.wordpress.com/a-gnu-radio-source-block-for-the-ft232h-usb-2-0-controller/