Finger Gesture Detection Experiment using Software Defined Radio Radar

Edwar[1*], Erfansyah Ali [2], Rizkia Feriska [3], Ikhwan Muzzaki[4]
[1,2,3,4] School of Electrical Engineering, Telkom University
Bandung, Indonesia
edwarm@telkomuniversity.ac.id[1*], erfansyahali@telkomuniversity.ac.id[2], rizkiaaf @student.telkomuniversity.ac.id[3], ikhwanmuzzaki@student.telkomuniversity.ac.id[4]

Abstract – *Human gesture detection for Human to Machine (H2M) Communication is usually done by using a camera. However, this device has a dependency of light illumination. To overcome this limitation, a radar can be utilized to read the finger gesture because it uses electromagnetic wave that is independent of the light appereance. Radar device is usually complicated and consists of components. In this research, a Software Defined Radio (SDR) was used to simplify the radar device circuit. The SDR generated the continuous wave (CW) signal that is suitable for detecting moving object such as finger gesture. The radar was working on 2.4 GHz of frequency. The results of the CW radar system using SDR shows that each gesture has a different reflected signal pattern, amplitude, and phases so we can conclude that each gesture has a character that can be distinguished through the characterization of reflected electromagnetic waves. This promising result can be the future application such as H2M) communication.*

Keywords*: Radar, Human to Machine Communication, SDR, continuous wave signal, Finger Gestures.*

1. Introduction

Human to Machine (H2M) communication research is growing as the interaction between human and devices have been established frequently. In this field, optical-based devices are often used to interprete human motions into some specific commands. However, this device will not work in the absence of light. There is an available option to overcome this problem, which is using radar. Radar is a device that can detect the object by using electromagnetic wave. It does not depend on the availability of light source. Radar device used to have a big size and a complex system. Thanks to the advanced of semiconductor technology, the dimension and complexity of radar device has been shrunk down significantly in these recent years. For the example, [1] has developed a compact radar set for education purpose. Furthermore, some manufacturers also have developed pocket size radar devices which are cheap and easily configured [2-3].

The possibility of radar usage to provide H2M communication has been investigated in [4] and [7]. Both has done single and multiple hand gesture detection subsequently. However, the hand movements detection is limited in the number of variations. A reseach done by [5] has done a different approach by detecting fingers movement instead of hands. Fingers can make more gestures or signs so it is able to produce more specific ‘language’ that can be translated by the machine. However, that research requires a high computational device to implement it. Another approach has also been done by [6] which was using a higher frequency to increase the gesture detection probability. However, it was working on a shorter distance.

In this paper, an experiment to detect finger gesture using radar has been conducted. The fingers were selected as the object due to it is able to create a variation of gestures or signs. To simplify the radar device circuitry, an SDR has been chosen. This radar setup was working on 2.4 GHz of frequency. The radar signal waveform was CW. It has a good sensitivity to detect a moving target. The experiment result shows that every finger gesture has its own pattern and it is unique one to the other.

2. Research Method

The methodology used for this research is experimental method. The experimental setup consists of an SDR, a pair of antennas, and a computer.

2.1. BladeRF SDR Module

Radar device usually consists of several components, such as signal generator, oscillator, filter, amplifiers, and antenna, as shown by Figure 1. It makes a radar device complicated to be develop. In this research, some of the components were replaced by the SDR. The SDR was required to work at 2.4 GHz. The BladeRF x40 SDR module was selected for this research, as shown in Figure 2. The bladeRF x40 is a low-cost USB 3.0 Software Defined Radio. This module operating frequency is from 300MHz to 3.8GHz which covers the radar frequency center for this research. This module can be powered and program through a USB cable. This SDR can be configure using GNU Radio, an RF simulation software [8].

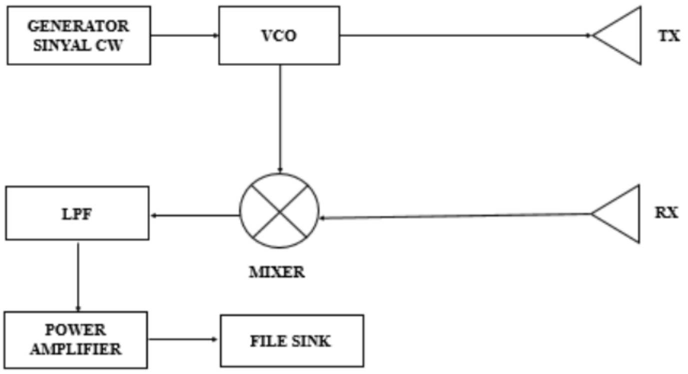


Figure 1. Radar block system.

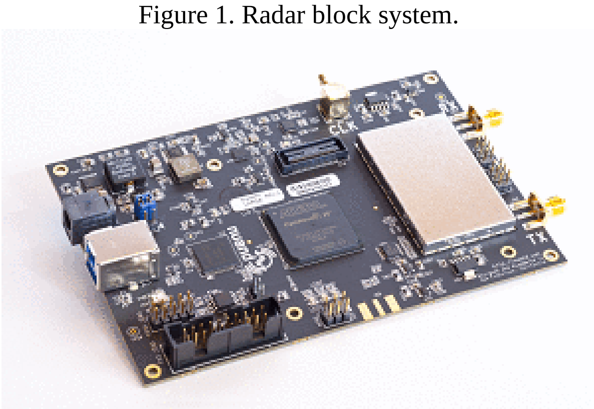


Figure 2. BladeRF X40.

2.2. GNU Radio System Design

GNU Radio system design is using to run the system radar. The simulation start after the system design is finished. The specification of system design can be found in Table 1, and the CW Radar system design can be found in Figure 3.

Table 1. Radar system specification.

Parameter	Specification
Frequency of system	2.4 GHz
Sample rate	5 MHz
Cut-off frequency	150 KHz

ISSN (e): 2540-9123
ISSN (p): 2502-1982

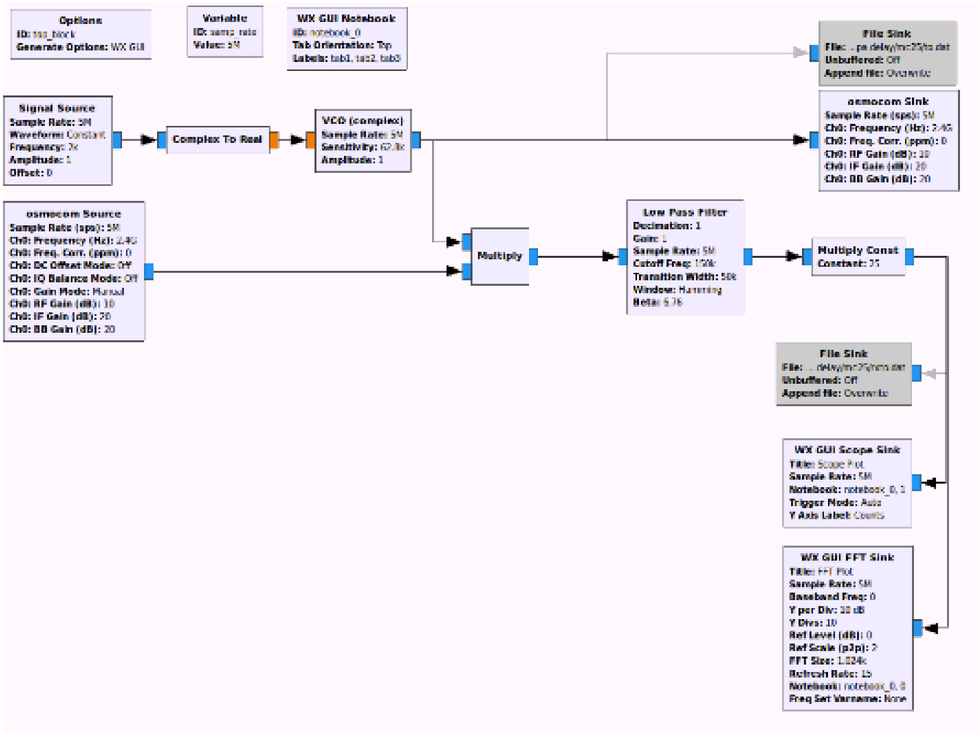


Figure 3. GNU Radio radar system design.

Each block from the system radar has a different function. Signal source block works to create the shape of signal, frequency modulated, and the amplitude of signal. Complex to real block works to convert the complex value to real value. The VCO block will create a sinusoidal frequency based on the amplitude. In CW radar system, the sensitivity and amplitude are selected to create the CW signal. The function of the Osmocom blocks is for interface GNU Radio to BladeRF. This system used Low Pass Filter (LPF) to filter the signal with cut-off frequency at 150 KHz. The function of multiply const blocks is for amplify the signal. WX GUI scope sink will show the result in time domain and WX GUI FFT sink will show the result in frequency domain. The result of this system design will be saved in file sink. The data from file sink will be processed in signal processing.

2.3. Continuous Wave Radar

Continuous wave radar or CW radar will emit the signal continuously, therefore the CW radar needs at least two antennas with transmitter and receiver are separated. The transmitter will emit the signal and the receiver will receive the echo. CW radar works by using the principle of Doppler effect. The weakness of CW radar is spillover or signal leakage from transmitter to the receiver. The equation for CW signal transmission shows in (1).

$$x(t) = A \cos 2\pi f_0 t \tag{1}$$

where A is amplitude of the signal, $f_0$is the transmitted frequency and t is time. This equation applies in time domain. The output from time domain signal shows in Figure 4[9].

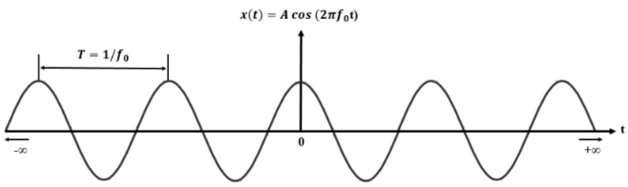


Figure 4. Continuous wave signal in time domain.

ISSN (e): 2540-9123
ISSN (p): 2502-1982

The continuous wave signal consists of two impulse functions, there are f_0 and -f_0. This impulse can be seen by using Euleur's equation as shows in (2)[9].

$$x(t) = A\cos 2\pi f_0 t = \frac{A}{2}\left\{e^{j2\pi f_0 t} + e^{-j2\pi f_0 t}\right\} \quad (2)$$

To see the signal in frequency domain, fourier transforms must be done on (2) so the equation for signal in frequency domain shows in (3)[9].

$$X(f) = \frac{A}{2}[\delta_D(f - f_0) + \delta_D(f + f_0)] \quad (3)$$

The result of frequency domain can be seen in Figure 5[9].

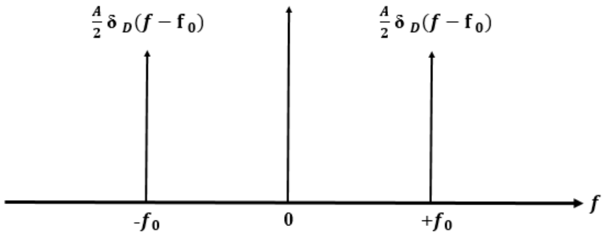


Figure 5. CW signal in frequency domain.

2.4. Hardware Configuration

CW radar system used three devices. Those are laptop with GNU Radio installed, BladeRF X40, and cantenna. The laptop is connected with BladeRF X40 by using USB cable and the BladeRF X40 is connected with Cantenna by using SMA cable. Figure 6 shows the topology of this system.

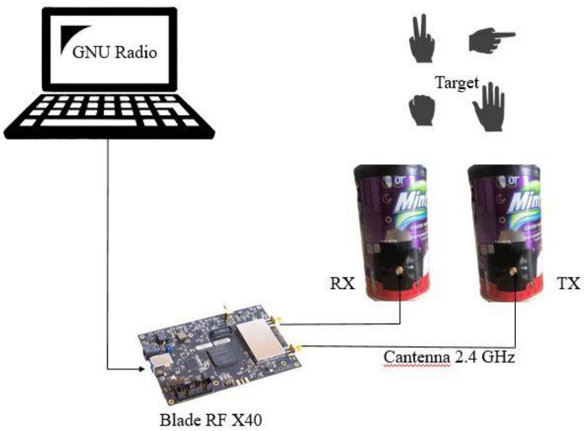


Figure 6. Topology system design.

3. Result and Discussion

3.1. Experiment Result

At the beginning of this research, radar was recording the received signal without target. The purpose of this activity was to observe any interference recorded in the received signal. This interference might be a false alarm during the experiment. The no-target receiver signal was relatively free from interference. It can be seen on Figure 7 that there is no significant peak on the observation window.

There are four different finger gestures that have been tested. Those are shown by Figure 8. As a reference, the radar has been operated without object at the beginning. The first gesture is open and close the hand. The second gesture is bending the fingers by 90°. The third is open and

ISSN (e): 2540-9123
ISSN (p): 2502-1982

close the finger. The fourth gesture is close the finger start from the little one finger. Figure 8 (a) shows the first gesture image which is a wide-fingers opening gesture. Figure 8 (b) shows the second gesture image which is similar to the first gesture but the fingers are on a thighter position. Figure 8 (c) shows the third gesture image which is the opening of a curled fingers. Figure 8 (d) show the fourth gesture image which is a closing gesture, finger by finger.

The result in time domain shows that every gesture has a different response. In this research, the characteristic of every reflected signal from each gesture has been observed.

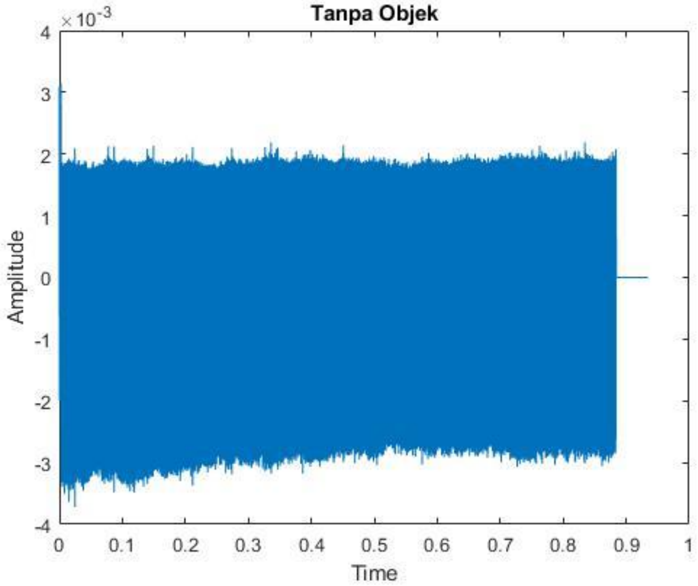


Figure 7. Result without using object.

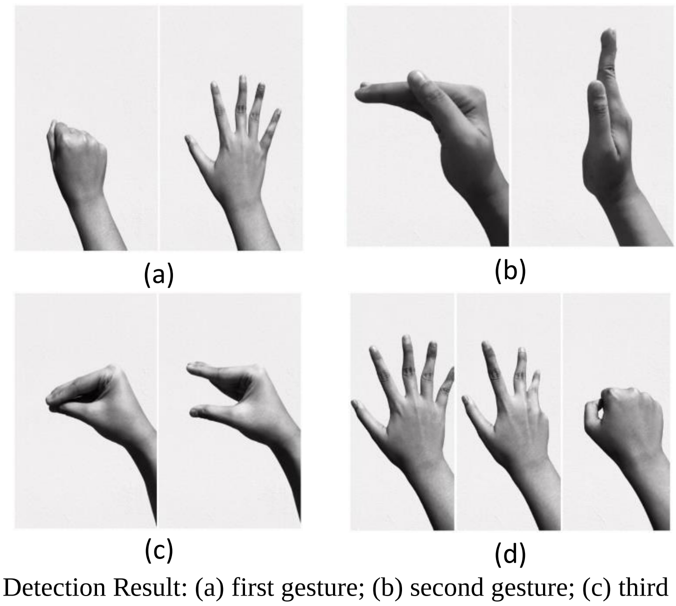


Figure 8. Gesture Detection Result: (a) first gesture; (b) second gesture; (c) third gesture; (d) fourth gesture.

Table 2 (a) shows the result for the first gesture. The amplitude shows a shallow ramp up wdue to the finger movement. It shows that the target cross section is getting bigger as the fingers is opening. Its movement creates doppler effect that slowly increase the echo amplitude.

Table 2 (b) shows the result for the second gesture. It shows a significant peak compared to the first gesture. It because the fingers position is thighter and forms a solid cross section that is

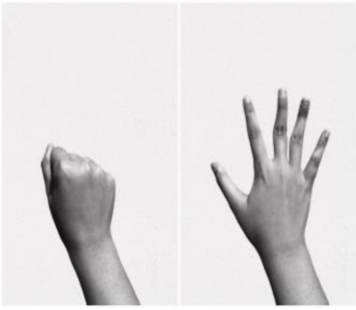
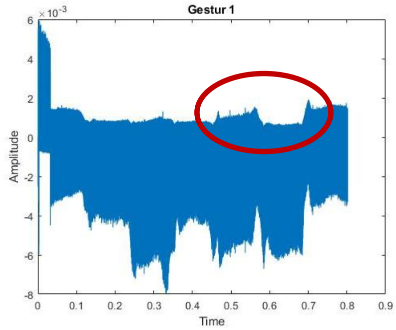
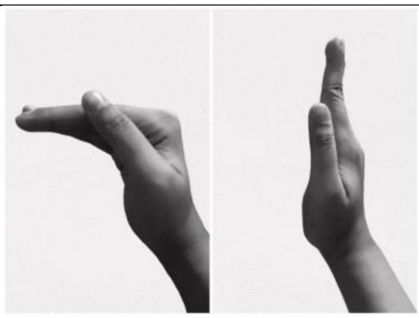
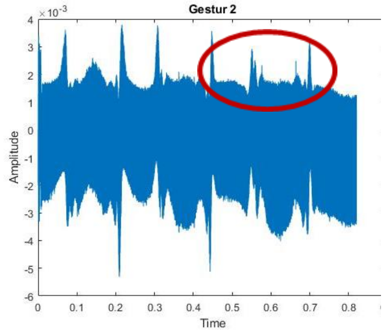
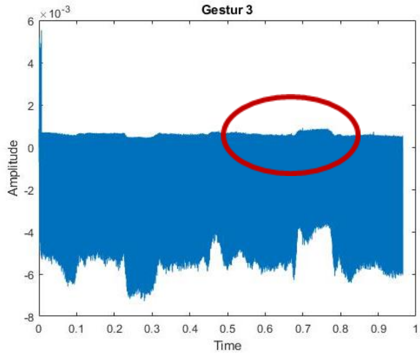
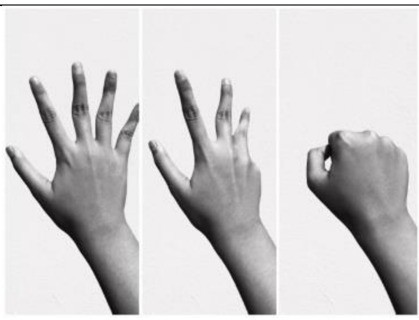
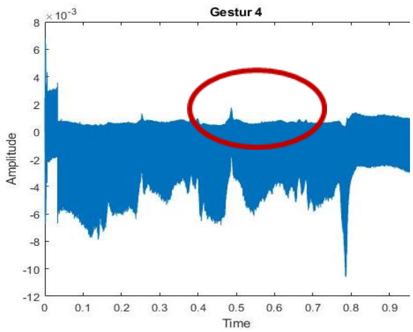
ISSN (e): 2540-9123
ISSN (p): 2502-1982

much bigger than the signal wavelength. Hence, the doppler response become significantly jump up.

The third gesture result is shown by Table 2 (c). It makes small constant increase due to the movement distance is not significant. It makes the target cross section is smaller from the radar point of view. This gives small changes to the doppler effect of the echo signal.

Table 2 (d) shows the result for the gesture of Figure 8(d). The signal makes a small spike such as gesture (a) and (b). When the fingers slowly go down finger by finger, there is a small ramp that shows that the target's cross section becomes smaller gently.

Table 2. Gesture Detection Result: (a) first gesture result; (b) second gesture result; (c) third gesture result; (d) fourth gesture result.

(a)		
(b)		
(c)		
(d)		

The result in phase shift analysis has a small change its because the movement of the gesture is small. There are shift between transmitted and received signal because the Doppler effect is working in this experiment. Figure 10 shows the phase shift of all experiment.

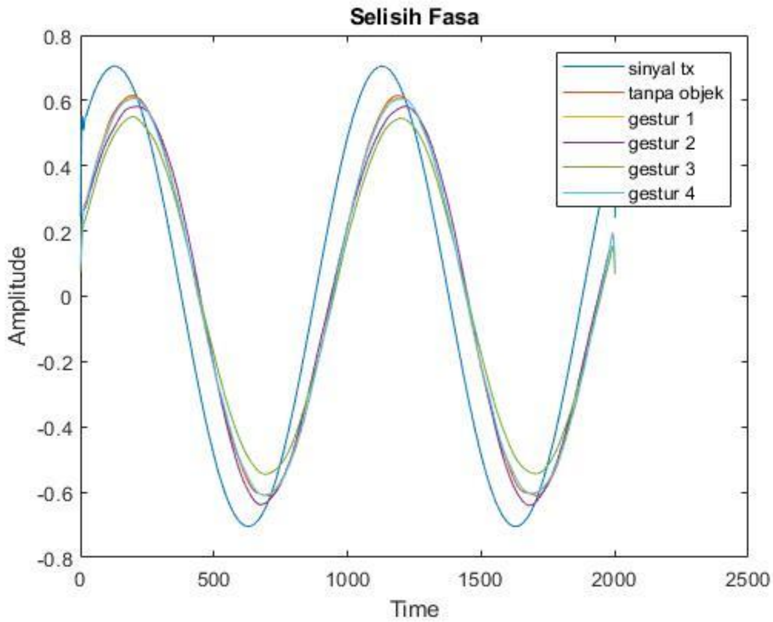


Figure 10. Phase shift from all experiment.

4. Conclusion

The investigation to finger gesture detection using software defined radio and continuous wave radar has been done in this work. The result from time domain analysis and phase shift analysis show that each gesture has a different and unique response. In phase shift analysis show that the shift betweel all measurement have a small difference because each gesture has a small movement. The ability of this system reading different finger gestures make the H2C communication using radar will be possible to be implemented. In the future, experiment using cost-of-the-self (COTS) radar module will be conducted to simplify the module from the size and the cost.

Referensi

[1] G. L. Charvat, A. J. Fenn and B. T. Perry, "The MIT IAP radar course: Build a small radar system capable of sensing range, Doppler, and synthetic aperture (SAR) imaging," 2012 IEEE Radar Conference, 2012.

[2] https://www.smart-prototyping.com/HB100-Doppler-Module [Accessed April 2, 2022].

[3] https://www.amazon.com/Akozon-CDM324-Induction-Channel-Microwave/dp/B07FMQ37L7 [Accessed April 2, 2022].

[4] Edwar, A. A. Pramudita, and E. Ali, "Gesture Motion Interpretation Using CW Radar for H2M Communication," Proc. - 2019 Int. Conf. Radar, Antenna, Microwave, Electron. Telecommun. ICRAMET 2019.

[5] Y. Xu and Y. Lu, "Touchless Control by Hand Gesture Sensing with Radar Sensor and Machine Learning," 2021 IEEE 10th Global Conference on Consumer Electronics (GCCE), 2021.

[6] G. Zhang, S. Lan, K. Zhang and L. Ye, "Temporal-Range-Doppler Features Interpretation and Recognition of Hand Gestures Using mmW FMCW Radar Sensors,"

ISSN (e): 2540-9123
ISSN (p): 2502-1982

2020 14th European Conference on Antennas and Propagation (EuCAP), 2020.
[7] D. Rodrigues and C. Li, "Hand Gesture Recognition Using FMCW Radar in Multi-Person Scenario," 2021 IEEE Topical Conference on Wireless Sensors and Sensor Networks (WiSNeT), 2021.
[8] https://www.nuand.com/product/bladerf-x40/, [Accessed April 2, 2022].
[9] M. Skolnik, Radar Handbook, 3rd ed., vol. 53, no. 9, New York: McGraw-Hill Book, 2008.

ISSN (e): 2540-9123
ISSN (p): 2502-1982