Ultra-Wide Band Software Defined Pulse-Doppler Radar
For Presence Detection

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Presence detection systems use a variety of methods to detect the presence of human targets. However, these systems produce either limited or no information about such targets. The aim of this project is to create a presence detection system that uses pulse-Doppler radar to provide dynamic information to the user by utilising software defined radio technology to conduct signal processing. Pulse-Doppler Radar is a detection method which, due to its complexity, is not used by detection systems but can provide additional information about a target such as speed or distance. Software Defined Radio enables real physical components of an electrical circuit to be emulated, avoiding the need for the real circuits to exist. The pulse-Doppler radar designed for this project is demonstrated to detect a single moving target and measure its speed and distance relative to the radar in real time using software defined radar.

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Annex A. A1

Nomenclature

Variables:

\[ f_t \quad = \quad \text{Frequency Transmitted} \]
\[ f_d \quad = \quad \text{Doppler Frequency} \]

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I. Introduction

Since the 1920s and earlier, radar has continued to grow and evolve to become an essential part of the modern world. It has been adapted to many uses including military as well as civilian use. Even from as early on as the 1940s, radar techniques such as pulse, Continuous Wave (CW), Frequency Modulated Continuous Wave (FM-CW) and pulse-Doppler radar were under development by different countries all around the world [1]. Even as radar techniques matured, they only operated with fixed circuit boards [2]. This meant that the radars were relatively inflexible. A Software Defined Radar (SDRadar) is a system whereby the conventional components included in a radar system, such as mixers and filters, have been replaced by a digital processing unit, with all signal generation and processing being done digitally. This enables greater flexibility in signal generation and processing. The radar is still restricted by the antenna properties, as well as the processing power provided to it. For SDRadar, most of the advanced abilities exist through digital signal processing (DSP) where the received signals can be processed using different methods, thus producing different outputs. Over the last 10 years, SDRadars have steadily improved [3] due to the increased computing power available enabling them to become smaller, known as System on Chip (SOC) radars. SOC radars are “nanoscale wireless low-power technology” [4] and contain all of the relevant processing and components needed for basic functions, such as transmission and reception. SOC radars are primarily used for FM-CW radars. The only external requirement is a computer or other processing device. An example of the size of these radars can be seen in figure 1. Note that figure 1 is the whole system except external processing including the antenna. As these SOC radars have such high resolution and are so small, this enables them to be used in smaller scale purposes such as presence detection.

A presence detection system can be defined as a method or technology that is used to determine the presence of a human being. There are many different technologies that can be used in this application such as radars, cameras, thermal imaging, inertial sensors, lasers and more. Each of these methods has their own physical strengths and weaknesses that determine the spatiotemporal properties they will demonstrate. The spatiotemporal properties are the following [6]:

a. Presence detection – The detection method being able to determine if a human is present
b. Count – The number of human targets that the detection system can resolve in the environment
c. Location – The location of the human targets in the environment
d. Track – Updating the location of the targets in the environment
e. Identity – Aspects of the target that can be determined, such as if they are running or have their hands in their pockets.

Each of these properties identify an aspect of space and time with the aim of providing the user with as much information about the area the system is working in as possible. Starting at presence detection and moving through until identity, each property requires more information to be available for processing and has a higher computational load. They are also dependent on each other, such as tracking not being possible without the location and number of targets being known or even counting the number targets present without first knowing a target is present.

II. Project Aim

The aim of this project is to use pulse-Doppler radar as a presence detection method that is able to provide the user with the distance and relative velocity of a single human target utilising SDRadar by programming a SOC radar sensor module into the pulse-Doppler radar.

III. Project Scope

SDRadar and DSP are both software related processes that enable the cross over between tangible and intangible operation of a radar system. This project end goal is to create a presence detection system that uses pulse-Doppler DSP as its method of detection. This pulse-Doppler method will be created from utilising SDRadar technology and DSP techniques to convert a basic SOC pulse radar into a pulse-Doppler radar that is capable of doing this process in real time. The radar will initially only be able to complete basic functions such as transmission and reception, and the production of baseband or radio frequency signals for analysis.

The results of the pulse-Doppler processing will be compared against other methods of presence detection such as infrared and other radar methods.
IV. Literature Review

This literature review has been broken down into the major contributing sections of the project. They are Software Defined Radar, Presence Detection Systems and Signal Processing. Each section will explore the topic explaining relative information pertinent to the project and previous research into that topic.

A. Software Defined Radar

Radar is an acronym for RAadio Detection And Ranging, which describes systems capable of detecting distant targets, either natural or manmade, and determining their characteristics using electromagnetic radiation [7]. The basic principle behind Radar is that a transmitter will emit electromagnetic energy of a given wavelength outwards. The energy will then propagate until it encounters an object, at which point it is reflected. It then propagates back to a receiver, which will process the signal and display any relevant information to the user [7]. The two methods for propagating the waves are sending pulses or CW. The focus for this project will be on pulse-based radar as this is the type of radar required for pulse-Doppler radar.

Conventionally, the processing of the returned signal is completed using analogue electronics. These are purpose built circuitry for their given function in a circuit. Due to serving one singular purpose, they are very fast and efficient at completing their function, resulting in fast processing of the signal. The trade-off for the speed is their flexibility. Analogue systems are not flexible, only being able to function to support its given design. An example is that the pulse modulator must be set to a given frequency, thus restricting the radar to only that frequency. The solution to this is the digital generation or processing of signals called Software Defined Radio (SDR).

SDRadar stems from SDR which, like SDRadar, performs many large portions of conventional signal processing through software over specialized hardware. The use of software for signal processing and analysis offers many advantages [11,101]. These include:

a. Ability to use different modulation schemes with the same piece of hardware
b. Adapтивely choosing operating parameters for the given conditions
c. Ability to update algorithms with newer and more efficient versions
d. Provides possibility for universal connectivity between devices
e. Eliminates need for large amount of physical hardware and resulting cost
f. Carries multiple protocols and switches between them at any given time
g. Faster and easier design process

Theoretically, this would enable a single platform to exist that can be configured in whatever way to meet the user’s requirement and be updated or changed as desired. One catch to these SDR devices is that the required bandwidth needs be very large, and thus is more susceptible to interference [11]. Another catch is that in order to transmit or receive information, the device will remain limited by its physical properties, such as the antenna or bandwidth. An example being if the user wanted to narrow a radars beam width, it could only be done by changing the antenna and not through the software.

B. Presence Detection Systems

An increasing requirement of general commercial products is to contain a presence detection device, be it either for improving energy efficiency such as automatic lights or doors to save on power and heating costs; or to be used for security purposes such as building protection. The purpose is to create an environment where devices are seamlessly aware and responsive to humans interacting with them. In order to accommodate this seamless environment of presence detection, the application and method of detection must overcome various challenges. The challengers are as follows [6]:

a. Noise – Noise is the most common problem to overcome, regardless of the method used in detection. Due to the use of low power radar, overcoming noise is very important for the radar.

b. Environmental variations – Environmental variations can alter the performance of a detection system by generating false positives or changing the operating parameters of the environment. An example is Passive infrared (PIR) sensors, which can be affected by convection caused by heaters which is perceived as movement and the radar failing to operate due to rain or fog.

c. Similarity to background signal – Distinguishing the target from the background signal is a challenge for particular types of detection systems that attempt to detect static as well as moving objects. If only moving targets are considered, the problem can be much easier to overcome. However multipath effects and other timing issues can still occur.

d. Appearance variability and unpredictability – When people are present, they move in unpredictable ways and wear a variety of clothing which can give off inconsistent returns. This
can make tracking difficult. For this project, an example is if the person has no relative velocity either towards or away from the radar, then they will not be detected.

e. Similarity to other people – Attempting to count, track and identify people can be very difficult due to the high degree of similarity between people. This can be due to their proximity to each other or physical attributes.

f. Active deception – In an environment such as a security system, people may try to jam or fool the system which can be as simple as moving slow enough that a motion detector is unable to register the movement.

Each of these challenges can be overcome by different detection techniques, as each technique has its advantages and disadvantages.

PIR detectors are the most common type of presence detection system. This is due to being inexpensive and having a simple detection method [10]. A PIR sensor exploits a living beings infrared radiation to detect changes in the amount of radiation in the environment it can observe. It will convert this into a voltage which is then compared to a threshold voltage to give a binary output [10]. To gather more tracking or identifiable information about the person’s movements, active infrared cameras, otherwise known as thermal imaging, need to be used. To extract the additional information, the image will need to be processed, which makes the system considerably more complex and expensive in terms of resources and money. Pulse-based radar for presence detection initially used the same technique as PIR detectors. The radar would find the difference between the amplitude of two pulses and then compare the result to a threshold. An alternative radar method is to use CW radar and, exploiting the Doppler Effect, find if a target is present and what their relative velocity is. When compared to PIR detectors, historically the radar systems were too complex, and for pulse-based systems, used too much power, thus were not used widely. However unlike PIR detectors, the extra information, such as movement speed and range, are all contained in returned pulses. With the inclusion of DSP, this makes pulse radar now the cheaper and simpler alternative to PIR detectors. An additional ergonomical advantage includes being able to operate from behind walls, which assists in the building of a seamless, aware and responsive environment. CW radars are still used; however need to include a frequency modulator to measure the distance, thus increasing cost and complexity.

C. Signal Processing

As this project is focusing on pulse-based radar, the only processing techniques that will be reviewed are applicable for pulse radar systems. These processing techniques include distance calculations, moving target indicators and pulse-Doppler processing. Calculating the distance from the radar is done by finding the difference between the transmission and reception of a pulse. It is then multiplied by the speed of light over two. This accounts for the travel time to and from the target. This is the method used to calculate range for all pulse radar systems.

Moving Target Indicator (MTI) is a basic process to eliminate static objects and clutter from the returned signals and highlight any moving targets. The elimination is a result of finding the difference between the two pulses. Any static objects in the returned pulses will be the same between the two, thus when compared against each other these will cancel out and any moving targets will generate a difference. To implement this into analogue radar, a delay line is added to the circuit. For digital circuits, the same principle applies by holding a returned signal, then comparing it to the most recently returned signal. The advantages of this process are that it is simple and easy to implement in both analogue and digital systems. The disadvantage of this method is that it is unable to demonstrate the five desirable properties. MTI can determine presence, count, location and track, but to a limited extent. In order to meet these properties, thresholding must be introduced into its processes. If the threshold is met, the number of targets and their distances can be recorded and updated, thus meeting the properties requirements. However, the threshold is an issue because for slow moving targets, the difference found between pulses is small and could potentially fall short of the required threshold. The opposite could also occur, whereby a target moves so fast that when the difference is found, it appears to be two individual targets. MTI is also unable to distinguish more than one target when two or more targets are the same distance away, thus destroying an accurate count of targets and the rest of the properties.

An alternative method to detect moving targets for a pulse radar system is to use pulse-Doppler processing. This process applies the principle of the Doppler Effect to extract the relative velocity of the target to the radar. Doppler shift is the effect that occurs when a sinusoidal waveform reflects off a moving object and experiences a frequency shift proportional to the velocity of the object. The shift will be positive if moving towards the emitter, or negative if moving away from the emitter. The process of calculating the frequency of the Doppler shift of a pulse-Doppler system is similar to that of a CW radar with the exceptions of only containing one antenna, a duplexer and a coherent oscillator. These additions can be seen in a block diagram for a pulse-Doppler radar system in figure 2.
Determines the frequency and what is desired. I
\[
\sin(f_t) \times \sin(f_t + f_d) = \frac{1}{2} (\cos(f_d) - \cos(2f_t + f_d))
\] (1)

The output of equation 1 is a combination of two signals, a low frequency signal and a high frequency signal. The low frequency signal is the Doppler frequency and what is desired. In order to isolate this signal, a low-pass filter is applied, as seen in figure 2. The signal is then further processed using the Doppler frequency equation to determine the speed of the target. The advantages of this method are that it is able to measure the speed of a target as well as avoid having the issues with very low speeds. The disadvantages of pulse-Doppler are that the PRF determines the maximum unambiguous velocity, the number of pulses processed determines the velocity resolution, which in turn limits the accuracy of a targets speed, and processing is relatively complex.

When comparing MTI and pulse-Doppler, both share similarities of being able to determine target distance and overcome clutter by detecting moving objects. MTI radar is simpler and easier to process. Pulse-Doppler is more complex, but offers the ability to determine the objects speed and avoids the issues with slow speeds. Due to DSP, the added complexity of pulse-Doppler can be considered a much more feasible detection method because processing is run off a script. This means that both methods of pulse radar presence detection will require the same resources to operate.

The introduction of SDRadars and DSP has meant that previously impracticable detection methods are now able to be considered for use. Pulse-Doppler radar is able to provide additional information about the target including their distance as well as relative velocity. This is a great improvement compared to PIR or MTI radars.

Figure 2 shows a block diagram of a pulse-Doppler radar system. Of note is the coherent oscillator that provides a signal to the transmitter and receiver. This differs from conventional pulse radar where two individual oscillators can be used. This single oscillator serves to conserve the signal integrity, as when entered into the mixer, the original phase of the signal is maintained. If a local oscillator is used, it can have phase drift thus, inputting the wrong information and having a skewed output. Figure 2 is based on an analogue design of a pulse-Doppler system. The digital process is very similar and follows the same course of action, but is completed digitally. The received signal will first go through the RF amplifier and then through the mixer. It is mixed with the signal from the coherent oscillator. Equation 1 shows the output of the mixer.

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V. Methodology

In this project, a pulse-Doppler radar detection system will be constructed to prove the viability of this detection method and its superior informational output when compared to more established methods such as PIR and MTI radars.

A radar used for a presence detection system needs to be available without any need for licences for its use. Therefore these radars must not be very powerful and are able to be used unlicensed all around the world. They are required to have a small range resolution of a few centimetres due to their use in small urban environments. In order to be as efficient as possible in detection, the radars would ideally have a maximum range of approximately 10m as most urban spaces are equal to or smaller than this. To observe such an area an operating angle of greater than 50 degrees would be required as this allows the system to avoid having to rotate the antenna. For this project, the SOC radar used is a Xethru X4M03, which meets the previous conditions [12]. This is a micro power impulse radar which means it is a low power ultra-wide band (UWB) radar which is designed for short-range detection. Due to the high bandwidth offered, this means that the pulse width can be very small, which results in an increased range resolution. The range resolution for this radar is approximately 9.9cm, which was calculated from the 1.5GHz bandwidth of the radar [12]. Due to their very good range
resolution, most SOC UWB radar systems are designed for respiration monitoring [5]. The maximum range is 9.4m, which provides enough to distance to be used in large rooms or outdoor environments. Patch antennas are flat rectangular pieces of metal that are mounted over a larger piece of metal called the ground plate. The need for this ground plate is to create a half wavelength transmission line. The antennas used by this radar are directional patch antennas. There are two antennas used in the radar with one for transmission and the other reception. The antennas have been optimised for operating at frequencies between 6 and 8.5 GHz with an operating angle of 65 degrees in azimuth and elevation from the bore sight [13]. The center frequency for the radar is 7.29GHz [14]. This operating angle is very wide due to the antennas used. This is a characteristic that makes the radar useful for general presence detection. This is an SDRadar so is able to be programmed.

The radar module completes basic signal processing on the chip before it interfaces with an external device, which for this project is a computer but for real world application would be a standalone DSP processor. The radar conducts signal processing on the chip generating the radio frequency (RF) data and is presented to the external device for further processing. The RF data given to the external device is not representative of every pulse the radar receives. The chip integrates multiple returned signals together to form a frame. This results in strong consistent results with minimal noise. The frame is then given to the computer for the user to handle. The consequence for sending these frames and not the pulses is that the frames available per second (FPS) must be considered the PRF for the purposes of processing, as the PRF is the number of new pulses received every second just like the FPS is the number of new frames available every second. The PRF, and therefore FPS, dictate the unambiguous velocity range. Thus, it is imperative that the FPS be high enough to measure a human’s running speed unambiguously. This has to be balanced with processing capabilities of the computer. The velocity chosen for the radar was approximately 32 km/h or 9 m/s, as this would account for average sprinters which translate to an FPS of 875. The initial FPS for the system was 20 FPS. An increase to 875 FPS requires an efficient algorithm.

Every 0.17 seconds the algorithm processes a matrix of 151 pulses that each contain 1431 sampling points, which is the coherent processing time. It is able to achieve this through the use of loops and efficient resource allocation. It would be impossible to reprocess the information and then draw the figure for every new frame that the radar provided. Therefore, once the last 151 frames have been processed are thrown away, the matrix is set back to 0, and then refilled with 151 new frames. Once the new 151 frames have been collected, processing commences. The RF data is converted into complex baseband (BB) data by multiplying the RF data by the cosine and sine of the transmitted waveforms frequency, producing the in-phase and quadrature of the BB data respectively, which is the equivalent of putting the returned signal and coherent oscillator signal through a mixer in an analogue circuit. A low pass filter is applied to the BB data eliminating the higher frequencies. A Fast Fourier Transform (FFT) is applied to the filtered results producing the frequency spectrum desired. The spectrum is shifted so the zero-frequency component is in the centre and plotted as distance vs speed with scaled colours. In parallel to drawing the image, the target distance and velocity of the target are captured.

In order to test the processing of the data, it was first constructed offline using pre-recorded RF data. The RF data had been obtained by using a demonstration code and saving the results. This offline program was used to debug issues with designing the process in the matlab environment. A successful test was one where the processing was able to detect a moving target which would then be displayed on a static image. It would also display the distance and relative velocity for that one target. Once the processing of the data had been finalised offline, it was integrated into the real time application for testing. The purpose of this testing was to meet the required FPS and alter the algorithm to meet this goal.

To provide a comparison for the pulse-Doppler radar, a separate MTI algorithm was integrated into the radar module. This used the BB data provided by the radar’s on chip processing. This BB data was not complex, thus could not be used for the pulse-Doppler processing. Similar to the pulse-Doppler, it was constructed and debugged offline before being integrated into real time processing. The integration of MTI to real time testing did not require any additional changes from the way it was constructed offline. The FPS of the system did not have an effect on the algorithm, as it only needs two frames to compare.

The testing for both algorithms was completed in the radar laboratory, which was a controlled environment. The target control table was used to test both the pulse-Doppler and MTI. The target control table enables a flat small metallic plate to be moved about on a 90cm by 90cm table with control over the speed and direction of the plate’s movement. This was used because it provides a known speed to compare the output of the algorithms against. Both detection methods were tested against a 6’5 male walking and running towards the radar, as this provided a more realistic environment for the radars to work in.
VI. Results and Discussion

The results and discussion will be broken down into the two major parts. The first will be comparing the two methods of presence detection for a controlled target and the second will present results from testing against human targets. A final section will contain general discussion points.

A. Comparison of MTI and Pulse-Doppler

MTI and Pulse-Doppler both share the ability to distinguish moving targets from stationary clutter. Thus, when collecting the data for each method, a predictable moving target was required. The radar laboratory’s target table provided a controlled method by which a target could be moved at a known velocity towards and away from the radar. In the following figures of 3a and 3b, the target was approximately 13cmx13cm in size to give a satisfactory return and was moved towards and away from the radar at approximately 30cm/s.

Figure 3a and 3b are the results of the test for the pulse-Doppler and MTI respectively. The output of the algorithm for the pulse-Doppler has the target at a distance of 2.17m and a speed of 0.23m/s, which corresponds with the distance seen in the figure, the known speed of the target and that measured by hand. The bright yellow spot on figure 3a is the target. Being off-centre and to the right reflects the positive velocity the target has towards the radar. Note that the 0 velocity clutter has been filtered out. The top graph in figure 3b is the 2 baseband signals, and the bottom graph is after they have been compared against each other and what is the MTI output. The target is at the same range for the MTI of 2.17m. In the top graph at approximately 2.17m, a difference can be seen between the two signals. This is then what is represented in the bottom MTI graph.

When comparing the two methods and the desirable spatiotemporal properties, the MTI is not as favourable as the pulse-Doppler radar. The MTI and pulse-Doppler are able to determine:

a. Presence detection – It responds to a moving target
b. Count – Can determine the number of targets present
c. Location – It can only find the distance of any targets present
d. Track – Can update the current location of the target.

MTI has no ability to determine any identifiable features of a target. Depending on the velocity of the target, the reported distance of the target will change as the difference found between the two peaks will result in the output peak being in the middle. The strength of this peak is also reliant on velocity, making identifying the target more difficult; reference annex A figure A1 and A2 for a comparison between two speeds. In order to distinguish two separate targets, they must be greater than 0.18m for this MTI radar. The pulse-Doppler is able to meet the same properties as the MTI listed above but to a much higher detail. It is able to resolve objects that are 0.09m apart making counting easier, can determine the distance of a target to 5.56mm, as well as determine the target speed to 0.12m/s. Unlike MTI, pulse-Doppler has the potential to determine identifiable characteristics of the target if further developed.

In terms of the challenges faced due to both methods using pulse radar, the performance of both methods for noise, environmental variations and similarity to background signal are the same. Pulse-Doppler will perform
better for similarity to other people, active deception, appearance variability and unpredictability due to the radar’s increased ability to resolve the environment. This ability is particularly poignant for active deception, as moving slower than the minimum speed is a common way to defeat detection. When tested against a very slow-moving target of 3 cm/s, the tracking of distance and velocity stopped working because the return was so weak. However, on the scope, the target could still be distinguished.

The difference between the two methods is accuracy and versatility. The MTI is able to do most of what the pulse-Doppler radar is able to do, but it is at a lesser quality. MTI sacrifices accuracy for a simpler process and is unable to determine the relative velocity of the target. Pulse-Doppler radar is therefore superior, as it has more capability for the exact same tangible devices used.

Both methods operate off the same module with the only difference being the algorithm that the computer operates. If any part of the processing for either pulse-Doppler or MTI needed to be changed, it could be altered through the programming. For example, if the maximum unambiguous speed needed to be increased, the velocity resolution could be decreased to increase the FPS, thus proving the flexibility and utility of SDRadars.

B. Pulse-Doppler Testing

Testing the radar against human targets presents difficulties when compared to a metallic object on a target table. As described in the challenges, human targets are made up of many moving parts from clothing to their limbs. When tested, it will not result in a clean highlight as in figure 3a. Instead, it will be mixture of different frequency shifts resulting in a smeared return, as seen in figure 4a and 4b.

![Figure 4a: Pulse-Doppler response to a running human](image)

![Figure 4b: Pulse-Doppler response to a walking human](image)

The result shown in figure 4a and 4b demonstrate the spectrum of Doppler frequencies present when a human is running and walking respectively. In figure 4a, the programming of the radar places the human at 4.14m and a velocity of 3.78 m/s, which is approximately directly in the centre of the smudged return. For a human walking, the algorithm placed the human at 3.02m and the velocity at 1.18 m/s. Between the two figures, the smearing effect is greater on figure 4a than 4b. This would be a result of the speed of the target. The faster the target is moving, the more erratic their arm movements would be, causing a larger bandwidth of frequency shifts to be returned. The other reason is that as the target is moving faster, the main return would be spread across more range bins, which when comparing the figures, 4a has a longer and weaker central return and 4b has a smaller and stronger central return.

In figure 4a, at approximately 4m and with a velocity of 2 m/s, a distinct return can be observed. This could potentially be the hand of the person running moving backwards with respect to the person. Relative to the speed the person is moving, the retreating hand would still maintain a positive velocity but just slower than the person’s movements, thus causing a smaller frequency shift. The same effect can be observed in figure 4b but is much harder to see. Figure 5 shows the return in figure 4b, but zoomed to see the return more clearly. There are two points of interest. One is at a distance of 3.08m and a velocity of 0.4m/s and the other is at 3.04m and a velocity of 2.1m/s. Each point is the highlighted part in the figure. As demonstrated previously, these are most likely the return from the movement of the human’s hands as they walk towards the radar. A comparison
C. Discussion

The results obtained through experimentation by comparing the pulse-Doppler method against MTI and a test against walking and running humans, proves the feasibility of pulse-Doppler as a detection method. The testing of MTI and pulse-Doppler detection methods on the same physical components proves the utility and potential of SDRadar and how they can be reformatted and changed to suit whatever is specified within reason by the user.

In all of the pulse-Doppler measurements for figures 3 and 4, evenly spaced and symmetrical returns appear to occur. They behave like a sinc function as the further out from the centre they go, the less intense they are. The cause of these is yet to be determined, but is most likely due to the sampling problems or the way the data is processed. Another issue seen in the measurements are the trails that follow the object. This is most likely a form of backscattering. Using the colour scale in each of the figures, the severity of the unwanted returns can be seen. While present, they are not very strong thus, are not debilitating in the system’s functionality.

VII. Conclusion

From the information shown in this report, it is clear that pulse-Doppler radar is a viable and preferable presence detection method in providing the distance and velocity of a target. It is able to achieve these outputs using the same components that would be required to carry out other methods of detection that yield lesser results. This has only been possible by the use of SDR, which enabled the complex programming to be done on a computer rather than by components. SDR demonstrated its versatility and usefulness by showing that two different methods of presence detection could occur on the same physical hardware.

VIII. Future Work

Should work continue on this project, there are aspects of its performance that can be improved upon. The unknown symmetrical returns and trails could be understood and fixed. This is to give the best possible output, but is not a necessity. If the radar had its beam width decreased and mounted on a servo, angular information could be given about the target’s location. This would give a more precise read out about where the target is. An alternative to this would be to have multiple radars and have all the information feedback to one computer to generate a multistatic radar system. For either of these improvements, the antenna gain would need to be increased making the physical size of the system larger but providing more utility.

Whether the system is able to determine identifiable aspects of the target is yet to be determined. This could be further investigated and researched. Due to SDRadar, this is possible through adding more processing to the system. The potential addition angular information could potentially enhance this ability.

References


Figure A1: MTI response to walking human target. Target is at approx 3.2m

Figure A2: MTI response to running human target. Target is at approx 2.5m
Figure A3: Pulse-Doppler response to a walking human with swinging arms

Figure A4: Pulse-Doppler response to a walking human with no swing in arms