Low Cost Embedded Passive Bistatic Radar Detection Testbed

by

Flynn Kelly
4741858
flynn.kelly@uqconnect.edu.au

School of Electrical Engineering and Computer Science,
University of Queensland

Submitted for the degree of Bachelor of Science (Honours)
in the division of Electrical Engineering

4 November 2024

Flynn Kelly
flynn.kelly@uqconnect.edu.au

August 16, 2024

Professor Michael Bruenig
Head of School
School of Electrical Engineering and Computer Science
The University of Queensland
St Lucia, Queensland 4072

Dear Professor Bruenig,

In accordance with the requirements of the degree of Bachelor of Science (Honours) in the School of Electrical Engineering and Computer Science, I present the following thesis entitled

'Low Cost Passive Bistatic Radar Detection Testbed'

This thesis was performed under the supervision of Professor Bialkowski(EECS). I declare that the work submitted in the thesis is my own, except as acknowledged in the text and footnotes, and that it has not previously been submitted for a degree at the University of Queensland or any other institution.

Yours sincerely,

Flynn Kelly

Acknowledgements

Acknowledgements: recognise those who have been instrumental in the completion of the project. Acknowledgements should include any professional editorial advice received including the name of the editor and a brief description of the service rendered.

SUPERVISOR, FRIENDS, ETC....

Abstract

Abstract: MINIMAL VIABLE PRODUCT OVERVIEW
broad need, specific need, response aim, response methods, key outcomes and implications.

ORIGINAL

This thesis presents the background, design and implementation of a low cost testbed for a passive radar based detection system. The relatively recent proliferation and cost reduction of software defined radio technology and the increase in single board computer processing capabilities has enabled passive radar detection systems to be implemented in a low cost, and even embedded manner. This project aims to investigate the feasibility of a low cost, embedded passive radar detection system utilising a digital broadcast signal as the illuminator of opportunity. The project will focus on streamlining the signal sampling and processing process through a singular embedded linux testbed setup, without the need for physical higher cost PC hardware at a given RX location. This will be achieved by using a combination of existing embedded IoT hardware, and through using existing DSP (digital signal processing) and radar filtering algorithms. A central feature of this thesis is its low cost nature, with potential for both scalebility but also cost/quality increases. The project will be evaluated based on the successful detection of aerial vehicles in a controlled environment, the latency of the detection system, and the overall cost of the design. The project will also be compared to existing work in the field of passive radar detection, and the potential for future work and scaleability will be explored.

RECAST

Affordable and effecient passive radar based detection, tracking and situational awareness technology is increasing in demand in a range of sectors and academia. As software-defined radio (SDR) technology becomes more widespread and single-board computers (SBCs) continue to gain processing power, the possibility of deploying passive radar systems in an embedded, cost-effective manner has emerged as a critical area of research and commercial development. The growing need for such systems is particularly evident in scenarios where traditional, expensive PC hardware setups at remote receiver (RX) locations are impractical or cost-prohibitive. This has created a specific need for streamlined, scalable systems that can function independently and effectively in various environments.

In response to these demands, this project aims to design and implement a low-cost, embedded passive radar detection testbed prototype system that leverages a digital broadcast signal as an illuminator of opportunity. The chosen approach involves utilizing existing embedded IoT hardware in combination with established digital signal processing (DSP) techniques and radar filtering algorithms. This integrated solution is intended to form a single embedded Linux testbed capable of handling both signal sampling and processing, along with sampling networking thereby eliminating the reliance on costly and complex physical hardware at each RX location.

Key outcomes of this research include the successful detection of aerial vehicles within

controlled environments, an analysis of the system's latency, and a comprehensive evaluation of the overall cost-effectiveness of the design. The implications of this work include offering valuable insights into the scalability and cost-quality balance that can be achieved in future passive radar system implementations. Moreover, the project aims to deliver a re-usable, scaleable testbed which can be used to further develop and test passive radar based detection and situational awareness systems.

Contents

List of Figures

List of Tables

Chapter 1

Introduction

Introduction: introduce the problem space and (at a high level) any relevant problem-space background. Summarise the contents of the remaining sections in the document (excluding appendices).
UPDATE FOR FINAL

This section will contain a clear definition of the thesis topic, goals, project scope, and relevance of the project.

1.1 Topic and Relevance

Passive radar detection technology is a class of radar detection whereby the radar system does not emit any radiation. Instead, it uses existing electromagnetic signals in the environment, such as television or radio broadcasts, to detect and track objects. Passive radar can be bistatic, whereby the transmitter and receiver are separate, or multistatic, where there are multiple receivers. The technology has been around since the early 20th century, but has only recently become feasible due to advances in digital signal processing and computing [6]. The technology has a number of advantages over traditional radar systems. It is covert, as it does not emit any radiation, and is therefore difficult to detect and directly jam, leading to a concentrated interest from defence cirlces [9]. It is also relatively cheap, as it does not require a dedicated transmitter and hence has less energy consumption. Conversely, it has a number of disadvantages, such as a lower signal-to-noise ratio, and a requirement for a relatively large amount of computational power to process the received signals [6].

Bistatic passive radar detection has a wide range of applications centered around situational awareness, including air traffic control, border security, and environmental monitoring. Embedding the passive radar technology is a relatively new field buoyed by recent and increasing developments in computational power on Internet of Things (IoT) devices [11]. Key components and processes of a passive radar RX system include the antenna, the receiver hardware (software defined radio), signal sampling hardware and memory, along with the compute to complete the digital signal processing [7]. Advantages of implementing some or even all of these components in a low cost manner include increased scaleability, portability, and lower reliance on external high cost hardware such as a PC.

1.2 Aims and Objectives

To explore the feasibility of a low cost embedded passive bistatic radar detection, and provide a scaleable proof of concept, this thesis aims to provide a user friendly testbed for digital signal based passive radar detection. The work conducted in this thesis and the eventual prototype hopes to decrease the barriers to entry for passive radar detection technology, and provide a platform for further research and development in the field. At a high level, the primary objectives of this thesis project are;

- Develop an understanding and proof of concept of passive radar detection algorithms on low cost single board computers (SBC) connected to software defined radio (SDR) hardware,
- Design and implement a small sized modular passive radar detection system on single board computer hardware with an emphasis on user friendliness and scaleability, and to
- Verify the functionality of the low cost embedded passive radar detection system in a controlled environment against higher power computing results, and investigate the potential for scaling up to a multistatic system through a network.

1.3 Scope

This thesis focuses on the development of a hardware testbed based on software defined radio (SDR) and single board computer (SBC) technology. The scope of this thesis project is limited to the following:

- The development of a passive radar detection system using existing digital broadcast signals as illuminators of opportunity,
- The design of a small scale, modular, low cost system using single board computer hardware, specically with simple user buttons to commence and cease data collection and processing, and
- The verification of the passive radar detection system performance and latency in a controlled environment agains higher cost PC hardware.
- Exploring the potential for scaling up the system to a multistatic, remote RX system through a network.

Given that passive radar based detection is a broad topic with much academic progress and commercial technological development, this thesis will not aim to cover the broad subject area. Consequently, the following topics are out of scope for this project:

- The development of a complete bistatic passive radar detection system optimized for low latency, and object classification,
- The development of a full multistatic passive radar detection system, whereby angle of approach and precise location of a target can be determined, and
- The development of a passive radar detection system using non-digital broadcast signals as illuminators of opportunity.
- The modification and development of digital signal processing / detection algorithms optimized for latency and customised hardware applications.

Chapter 2

Background

Background: this should include all (appropriately cited) information (concepts and prior literature) for a layperson to understand your project/experiment.
- NEED TO RESEARCH AND DISCUSS THE EFFECTS OF NOISE AND TYPICAL ATTNENUATION

This chapter collates the necessary background information for the project, including the fundamentals of passive radar, the use of illuminators of opportunity, range doppler mapping, radio hardware, digital signal processing, IoT architecture, and networking with embedded hardware.

2.1 Passive Radar Fundamentals

The key and unique feature of passive radar is its utilisation of existing illuminators of opportunity, such as television or radio broadcasts, to detect and track objects. The technology has been around since the early 20th century, with modern interest accelerated due to the use of passive radar systems on UHF TV signals and VHF FM radio tranmission systems in the 1980's [7]. Equivalent terms used to describe passive radar include passive coherent location (PCL), and passive covert radar (PCR), parasitic radar, piggyback radar. Specifically, *bistatic* radar refers to the distributed design of the transmitter and receiver, as opposed to classic *monostatic* radar. As reflectd by Figure 2.1 below, the turning parabolic of monostatic radar is able to receive both range and bearing of the signal echo, whereas passive bistatic radar measures time delay of the echos from the target, allowing doppler shift from the relative speed of the target to be measured.

The geometry of passive bistatic radar can be further explored and equations can be mapped accordingly, with the distance between the transmitter and receiver R being determined by known quantities such as the baseline as reflected below in Figure 2.2.

The bistatic range R_R is given by:

$$R_R = \frac{(R_T + R_R)^2 - L^2}{2(R_T + R_R + L\sin\theta_R)} \tag{2.1}$$

The Doppler shift f_D is given by the rate of change of the bistatic range sum:

$$f_D = \frac{1}{\lambda}\frac{d}{dt}(R_T + R_R) \rightarrow f_D = \frac{2v}{\lambda}\cos\delta\cos(\frac{\beta}{2}) \tag{2.2}$$

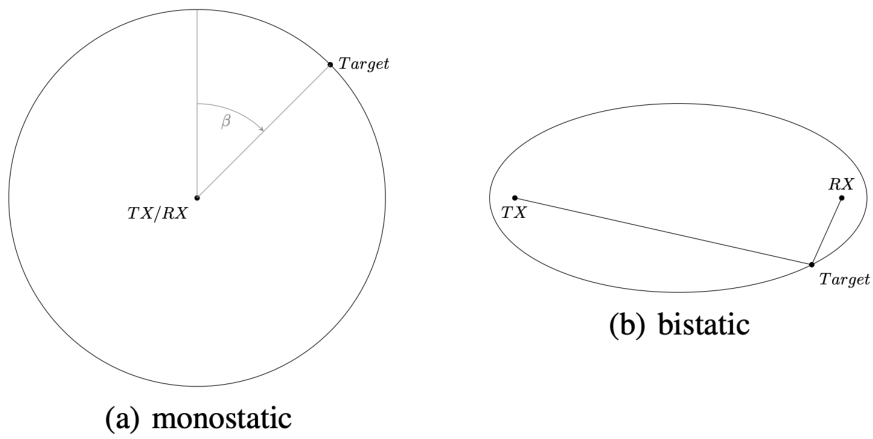

Figure 2.1: Monostatic (a) and bistatic (b) radar topologies [11]

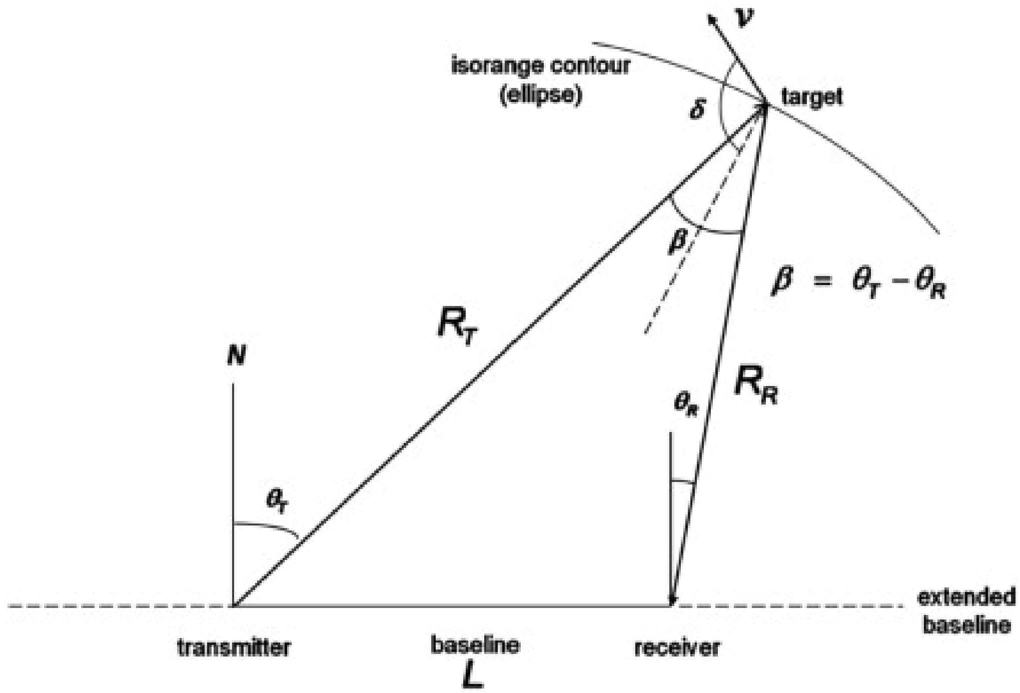

Figure 2.2: Bistatic radar geometry [7]

In the case of this project, both the TX (illuminator of opportunity) and the RX (embedded passive detection system) will be static, and the target will be moving, simplifying the mathematical calculations as much as possible, resulting in the cos version of equation 2 above.

The Doppler shift will be used to determine the speed of the target as well as its relative directional motion, and the range will be used to determine the distance of the target from the receiver. Another important feature of bistatic passive radar systems is its performance which can be equated through the bistatic radar equation, which is equivalently derived as the monostatic radar equation [7].

$$\frac{P_r}{P_n} = \frac{P_t G_t}{4\pi R_T^2} \cdot \sigma_B \cdot \frac{1}{4\pi R_R^2} \cdot \frac{G_r \lambda^2}{4\pi} \cdot \frac{1}{k T_0 B F} \tag{2.3}$$

Where:

- P_r is the received target echo power.
- P_n is the receiver noise power.
- P_t is the transmit power.
- G_t is the transmit antenna gain.
- R_T is the transmitter-to-target range.
- σ_B is the target bistatic radar cross section.
- R_R is the target-to-receiver range.
- G_r is the receive antenna gain.
- λ is the signal wavelength.
- k is Boltzmann's constant (1.38×10^{-23} JK^{-1}).
- T_0 is the noise reference temperature.
- B is the receiver effective bandwidth.
- F is the receiver effective noise figure.

The denominator of the bistatic radar equation includes the term $\frac{1}{R_T^2 R_R^2}$.This term implies that with omnidirectional antenna patterns, the contours of constant signal-to-noise ratio (SNR) are described by the equation $R_T R_R$ = constant, which represents Ovals of Cassini. These ovals represent the locations in a given PBR co-ordinate sytem where the distances from the target to the transmitter and receiver remain the same. In the case of directional antennas, these contours are altered. Moreover, the signal-to-noise ratio is minimized when the target is equidistant from the transmitter and receiver ($R_T = R_R$), and maximized when the target is closer to either the transmitter or receiver [7].

NEED TO MENTION / RESEARCH THE EFFECT OF NOISE AND DECIBELS EXPECTED HERE.

2.2 Illuminators of Opportunity

The illuminator of opportunity is the signal that is used to illuminate the target, and is the primary source of the signal that is received by the passive radar system. The illuminator of opportunity can be any signal that is transmitted through the air, such as television or radio broadcasts, and can be tailored to the specific requirements of the passive radar system. Griffiths and Baker outline the three key paramaters when selecting an illuminator [6]:

1. The **Power Density** at the target: It refers to the strength of the signal (in Watts per square meter) that reaches the target area from the illuminator. Higher power density can improve detection performance due to a stronger return signal.

2. The **Nature of the Waveform**: This includes the waveform's properties, such as bandwidth and modulation, which can affect the radar's resolution and ability to distinguish between targets and clutter.

3. The **Coverage**: The spatial area over which the illuminator's signal is spread. Adequate coverage is essential to ensure the target is within the illuminator's effective range.

Illuminator signals are not limited to terrestrial signals, and can also include signals from satellites, and can be tailored to the specific requirements of the passive radar system. The illuminator of opportunity primarily explored for this project is the DAB+ signal, and the target signal will be aerial vehicles - most likely in the form of civillian passenger jets. The DAB+ signal is a good option due to its high power density, and its relatively high bandwidth, which can be used to improve the radar's resolution and ability to distinguish between targets and clutter. Moreover, the geographical proximity of a DAB+ transmitter at Mt Cootha to the University of Queensland, St Lucia campus, making it a potentially ideal choice for the project. Another prospective digital illuminator signal is DVB-T (digital video broadcast - terrestrial), which is similar in its digital modulation to DAB, but provides increased bandwidth and signal power [5]. Furthemore, as shown by Yin et. al [15], due to the relative complexity of DVB visual signals, more signal processing steps can be required, which could exceed prospective hardware limitations of this project.

A potential problem associated with the use of DAB as an illuminator is direct signal interference (DSI), with the effects being amplified in urban environments. Coleman et. al [4] explain that the sheer signal size of direct illuminator size relative to surveillance signal size results in a high level of DSI. They outline that the cross polarisation of the transmitted DAB signal can be utilised along with illuminator cancellation filtering to attain higher level suppression. The leakage of the illuminator signal into the target signal can be due to a range of factors including buildings, trees and other reflective items as highlighted by Palmer et. al [9].

Typical characteristics of Australian DAB+ signals include frequency of just over 200MHz, bandwidth of approximately 1.5MHz, and a minimal output power of 10kW effective radiated power (ERP), consequently covering a large area [4]. These digital signals employ a modulation scheme called COFDM (coded orthogonal frequency division multiplexing), which is a form of multi-carrier modulation that is robust against multipath interference [6]. COFDM works by dividing the signal into multiple, simultaneous streams which are orthogonal to each other, modulated at a different frequency, maximising robust signal propogation. This is particularly useful in the context of passive radar, as it allows for the target and reference signal to be received by the passive radar system even if it has been reflected off multiple surfaces, such as buildings or trees.

FM / other signals: why / why not?

All of the above features result in DAB signals being condusive for ambiguity function performance (analyzed in further detail below). This can mainly be attributed to the relatively wide bandwidth of DAB enabling good resolution, constant DAB envelope stemming from COFDM protocol, and the multipath resistance [8].

2.3 Range Doppler Mapping

Range doppler mapping is a technique used to determine the distance and relative velocity of targets by analyzing the frequency shift (Doppler shift) and time delay of the received signals after they are reflected off the targets. The signal response of a target at a particular range and velocity can be predicted by the ambiguity function seen in equation 2.4 [6].

$$\chi(\tau, f) = \int s_{\text{reference}}(t) s^*_{\text{received}}(t - \tau) e^{j2\pi ft} \, dt \tag{2.4}$$

Where:

- $\chi(\tau, f)$ is the ambiguity function.
- τ is the time delay.
- f is the Doppler frequency.
- $s_1(t)$ is the transmitted signal.
- $s_2(t)$ is the received signal.
- $s_2^*(t-\tau)$ is the complex conjugate of the received signal, time-shifted by τ.
- $e^{j2\pi ft}$ is the complex exponential representing the Doppler shift.
- The integral is taken over all time t.

The ambiguity function can be plotted, thereby visualising resolution, sidelobe patterns and any discrepancies in range and doppler. This is especially important for passive bistatic radar, whereby waveforms are not explicitly designed for radar and the geometry also has an impact [7]. Hughes visualises the geometry considerations and potential flaws of generic passive bistatic configuration below in Figure 2.3.

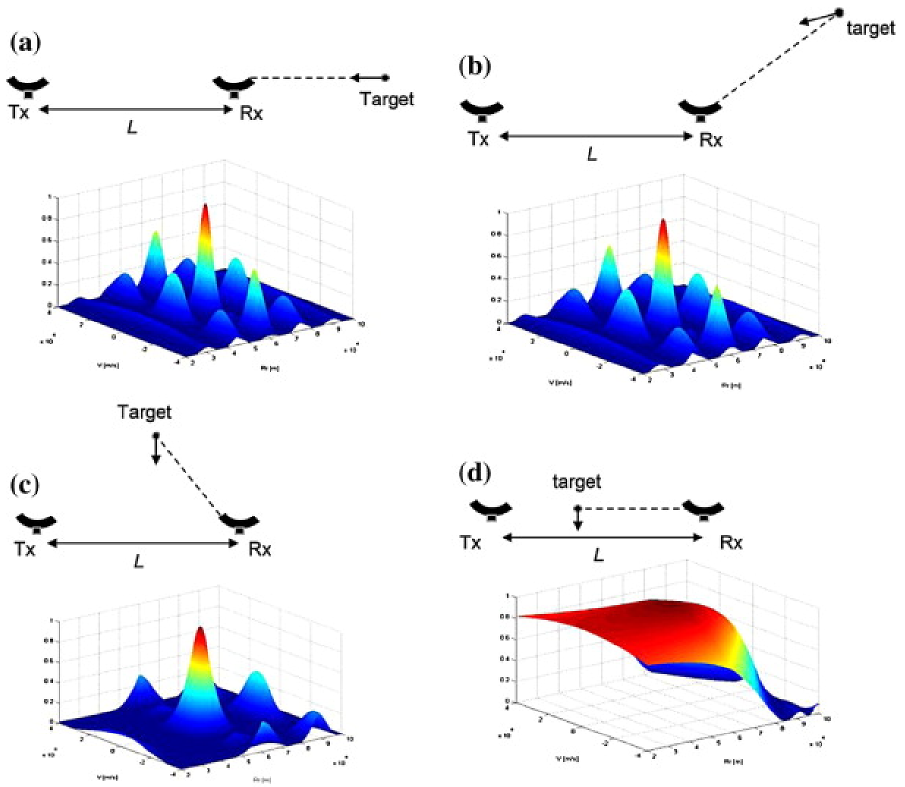

Figure 2.3: Geometry and ambiguity function [7]

Understanding the link between geometric configuration and theoretical signal properties, the practical manifestation of the ambiguity function is range doppler mapping. As shown in Figure 2.4, the map is a heat map and is derived with filters for noise minimsation, allowing for the visualisation of the target signal with minimal clutter.

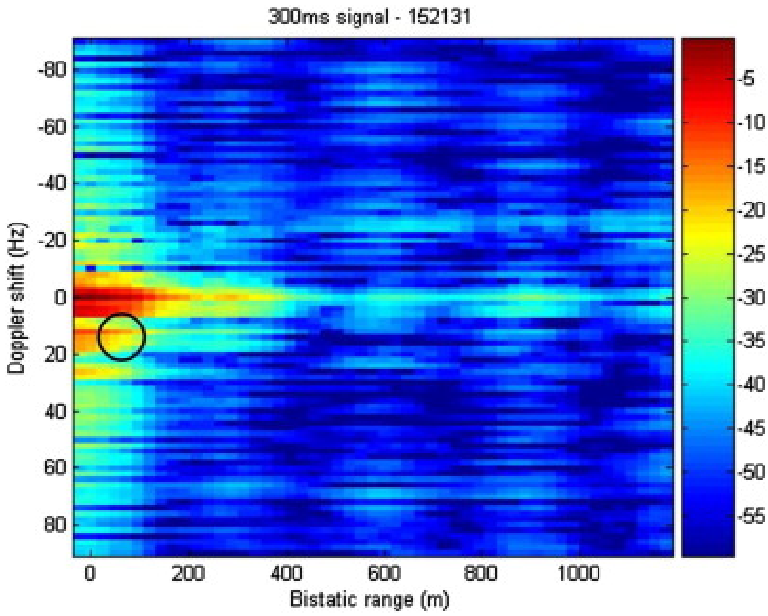

Figure 2.4: Example of range doppler map for WiFi PBR [7]

Should i use a better RDM??

In the case of this project, the time delay will be utilised to calculate the bistatic range (x axis) and the Doppler shift will be used to calculate the relative velocity of the target (y axis). In summary, ambiguity function and subequent range doppler mapping will be vital for mapping the DAB+ signal characteristics for given geometry and motion of the surveilled target.

MORE DETAIL

2.4 Radio Hardware

Given the low cost aims of this project, hardware cost and performance is a major consideration. Luckily, the proliferation of Software Defined Radio (SDR) has enabled low cost hardware modules enabling easy access to radio frequency (RF) signals [13].

More specifics about SDR

The most popular and lowest cost SDR module is the RTL-SDR, which is a USB dongle that can be used to receive and decode a wide range of RF signals. The RTL-SDR is based on the Realtek RTL2832U chipset, and has a frequency range of 24MHz to 1.7GHz, and a bandwidth of 3.2MHz. The RTL-SDR is also relatively cheap, with a price of around $40 AUD. Moreover, the RTL-SDR is compatible with a wide range of software, including MATLAB, and GNU radio [12]. Given the digital nature of the DAB+ signal, the direct reference signal and the target surveillance signal can in theory be sampled by a singular RTL2832U module as shown by Barrot et.al [1].

Block diagram of SDR transceiver?

There are also a range of other off the shelf SDR options such as BladeRF and LimeSDR, which provide marginally improved performance at a substantial increase in cost and hardware [3]. Regardless of sampling hardware architecture, based on previous studies and the nature of the DAB+ signal and modulation framework, a sampling rate of 2.048 MS/s is prudent [11]. This hardware can be scaled up, accordingly providing a reference antenna and a surveillance antenna, as seen in Yardleys 2007 DAB receiver project [14]. On the contrary, as a potential extension, the use of a single antenna can be attempted with additional reconstruction processing required (providing lower hardware cost), this has been achieved by Barott and Engle [1].

2.5 Digital Signal Processing

Broadly, the goal of the signal processing for general passive bistatic radar is to extract a range doppler map from a received signal. Obtaining a range doppler map involves a few steps, with specifics depending on the IOO chosen along with number of sampling channels. Furthermore, there is the option of autocorrelating these signals via correlation integrals which is the most time and compute intense, or through Batches algorithm in the frequency domain . Prior to the advent of of digital broadcasts, analague broadcast processing involved comprehensive filtering and synchronisation of at least two input channels[10]. However, more recently, given the nature of DAB / DVB-T and its COFDM modulation, filtering and synchronisation can be replaced with reconstruction of the surveillance signal [2], replacing the need for dual channel configuration. The use of a singular antenna is affirmed by Barott et. al [1] who utilised DAB passive radar to track micro-UAVs.

batches citation needed

2.6 IoT Architecture

2.7 Networking with Embedded Hardware

Chapter 3

Literature Review

There is a plethora of existing research and pilot projects which utilise a range of hardware and illuminator of opportunity signals, including existing commercial products.

3.1 Low Cost IoT Hardware

3.2 Illuminators of Opportunity

3.3 Signal Processing Architecture

3.4 Existing Commercial Technology

Chapter 4

Methodology and Design

Implementation: how was your experiment/project accomplished? Include enough details of your method and tooling that someone can easily replicate your results.

4.1 Hardware

4.1.1 Software Defined Radio

4.1.2 Embedded Computing Platform

4.1.3 NVME Based Storage

4.1.4 Antenna Configuration

4.2 Software

4.2.1 SDR Software

4.2.2 Networking Requirements

4.3 Digital Signal Processing Testing & Simulation

4.4 Pi Based Raw IQ Sample Testing

4.5 Testbed Design

Chapter 5

Results and Discussion

Results: latency comparison, design cost, sucessful detection

5.1 Detection Performance

5.2 Latency Comparison

5.3 Overall Design Cost

5.4 Comparison to Existing Work

Chapter 6

Conclusion

Conclusion: what conclusions can be drawn from the results of your research?

6.1 Summary & Conclusions

6.2 Limitations

6.3 Possible Future Work

Chapter 7

Bibliography

[1] William C. Barott and Justin Engle. Single-antenna atsc passive radar observations with remodulation and keystone formatting. In *2014 IEEE Radar Conference*, pages 0159–0163, 2014.

[2] Christian R. Berger, Bruno Demissie, JÖrg Heckenbach, Peter Willett, and Shengli Zhou. Signal processing for passive radar using ofdm waveforms. *IEEE Journal of Selected Topics in Signal Processing*, 4(1):226–238, 2010.

[3] Roberto Calvo-Palomino, Fabio Ricciato, Domenico Giustiniano, and Vincent Lenders. Ltess-track: A precise and fast frequency offset estimation for low-cost sdr platforms. pages 51–58, 10 2017.

[4] C.J. Coleman, R.A. Watson, and H. Yardley. A practical bistatic passive radar system for use with dab and drm illuminators. In *2008 IEEE Radar Conference*, pages 1–6, 2008.

[5] Michael Edrich, Alexander Schroeder, and Fabienne Meyer. Design and performance evaluation of a mature fm/dab/dvb-t multi-illuminator passive radar system. *IET Radar, Sonar & Navigation*, 8(2):114–122, 2014.

[6] H. Griffiths, Christopher J. Baker, and Ieee Xplore. *An introduction to passive radar*. Artech House radar series. Artech House IEEE Xplore, Boston Piscataqay, New Jersey, first edition edition, 2017.

[7] Hugh Griffiths. Chapter 16 - passive bistatic radar. In Nicholas D. Sidiropoulos, Fulvio Gini, Rama Chellappa, and Sergios Theodoridis, editors, *Academic Press Library in Signal Processing: Volume 2*, volume 2 of *Academic Press Library in Signal Processing*, pages 813–855. Elsevier, 2014.

[8] Abdulkadir Guner. Ambiguity function analysis and direct-path signal filtering of the digital audio broadcast (dab) waveform for passive coherent location (pcl). 2002.

[9] Tri-Tan Van Cao James Palmer, Simon Palumbo, , and Stephen Howard. A new illuminator of opportunity bistatic radar research project at dsto. Report, Defence Science and Technology Organisation, May 2009 2009.

[10] C. Moscardini, D. Petri, A. Capria, M. Conti, M. Martorella, and F. Berizzi. Batches algorithm for passive radar: a theoretical analysis. *IEEE Transactions on Aerospace and Electronic Systems*, 51(2):1475–1487, 2015.

[11] Daniel Moser, Giorgio Tresoldi, Christof Schüpbach, and Vincent Lenders. Design and evaluation of a low-cost passive radar receiver based on iot hardware. In *2019 IEEE Radar Conference (RadarConf)*, pages 1–6, April 2019.

[12] RTL-SDR.com. Buy rtl-sdr dongles (rtl2832u). `https://www.rtl-sdr.com/buy-rtl-sdr-dvb-t-dongles/`, 2024. Accessed: 2024-03-11.

[13] Mathew NO Sadiku and Cajetan M Akujuobi. Software-defined radio: a brief overview. *Ieee Potentials*, 23(4):14–15, 2004.

[14] Heath J. Yardley. Bistatic radar based on dab illuminators: The evolution of a practical system. In *2007 IEEE Radar Conference*, pages 688–692, 2007.

[15] Ying Yin, Shunsheng Zhang, Fuxia Wu, Zhulin Zong, and Wei Zhang. Passive radar detection with dvb-t signals. In *2016 CIE International Conference on Radar (RADAR)*, pages 1–5, 2016.

Appendices

Appendix A

Example Appendix Item

Appendix: Appendices are useful for supplying necessary details or explanations which do not seem to fit into the main text, perhaps because they are too long and would distract the reader from the central argument. Appendices are also used for program listings.

Quisque facilisis auctor sapien. Pellentesque gravida hendrerit lectus. Mauris rutrum sodales sapien. Fusce hendrerit sem vel lorem. Integer pellentesque massa vel augue. Integer elit tortor, feugiat quis, sagittis et, ornare non, lacus. Vestibulum posuere pellentesque eros. Quisque venenatis ipsum dictum nulla. Aliquam quis quam non metus eleifend interdum. Nam eget sapien ac mauris malesuada adipiscing. Etiam eleifend neque sed quam. Nulla facilisi. Proin a ligula. Sed id dui eu nibh egestas tincidunt. Suspendisse arcu.

Maecenas dui. Aliquam volutpat auctor lorem. Cras placerat est vitae lectus. Curabitur massa lectus, rutrum euismod, dignissim ut, dapibus a, odio. Ut eros erat, vulputate ut, interdum non, porta eu, erat. Cras fermentum, felis in porta congue, velit leo facilisis odio, vitae consectetuer lorem quam vitae orci. Sed ultrices, pede eu placerat auctor, ante ligula rutrum tellus, vel posuere nibh lacus nec nibh. Maecenas laoreet dolor at enim. Donec molestie dolor nec metus. Vestibulum libero. Sed quis erat. Sed tristique. Duis pede leo, fermentum quis, consectetuer eget, vulputate sit amet, erat.

Donec vitae velit. Suspendisse porta fermentum mauris. Ut vel nunc non mauris pharetra varius. Duis consequat libero quis urna. Maecenas at ante. Vivamus varius, wisi sed egestas tristique, odio wisi luctus nulla, lobortis dictum dolor ligula in lacus. Vivamus aliquam, urna sed interdum porttitor, metus orci interdum odio, sit amet euismod lectus felis et leo. Praesent ac wisi. Nam suscipit vestibulum sem. Praesent eu ipsum vitae pede cursus venenatis. Duis sed odio. Vestibulum eleifend. Nulla ut massa. Proin rutrum mattis sapien. Curabitur dictum gravida ante.