Establish Technical Baseline
WP1320

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Contents

1 Document Outline

This document establishes the technical baseline for the passive radar system as part of the *"Aircraft Detection System for Optical Ground Stations"* project. A breakdown is provided in the five sections of this document:

2 Introduction to Passive Radar

Passive Coherent Location (PCL) is a radar technique that allows target detection and ranging without transmitting any radiation or signals. It relies on external sources of electromagnetic (EM) radiation, termed as Illuminators of Opportunity (IoO), to provide the illumination of targets so that their backscatter towards the passive radar can be measured and declared if detectable amongst the system noise. Long-range (10's of kilometers) order detection is possible with low frequency signals emitted by IoO, which are usually abundantly available in residential areas in the form of TV (DBV-T) or Digital Radio (DAB) signals.

Passive radar is advantageous in a few regards over active radar detection. As signal transmission (and therefore a high power transmitter head) is not required, the ease of implementation is much greater, and adjustments to the system after the initial implementation are much simpler. Passive radar if using Digital TV or Radio IoO's makes the required components for implementation (discussed in Sec. 2) largely Commercial Off-The-Shelf (CotS) components that are readily available. Additionally, PCL not transmitting means there are no concern of spectral congestion or permissions required for operation.

Passive radar in exchange for these benefits may face potential issues not present for active systems. A non-cooperative transmitter requires efforts to validate a deployment through a site measurement, especially when some details of the IoO are not publicly or privately available. For a given site location, the IoO signal strength and quality are dependent on the transmitter type, power and the local geography. In the ideal case and with external cooperation, a copy of the transmitter signal could be sent via cable to the PCL system – but generally, careful antenna placement and tuning is required to maximise the received (direct) signal strength to allow the extraction of target signals from the IoO backscatter. Thus, the theoretical maximum operating range could be shorted due to difficulties gathering clean signals from the IoO transmitter.

The following sections describe the hardware (Sec. 2), signal processing (Sec. 3) and details of the deployment site (Sec. 4) that will inform the anticipated operational capabilities with budget and time frame of this project.

3 Hardware Requirements

Four hardware requirements need to be met to produce build a passive radar system:

- Software Defined Radio (SDR) / Universal Software Radio Peripheral (USRP) device
- Band Pass Filter (BPF)
- Low-Noise Amplifier (LNA)
- Tx & Rx Antenna

The hardware arrangement and required signal processing are shown in Figure 1. This section will describe the requirements for the radar hardware (left). Later, Section 2 will detail the processing steps and enabling hardware requirements to perform target detection.

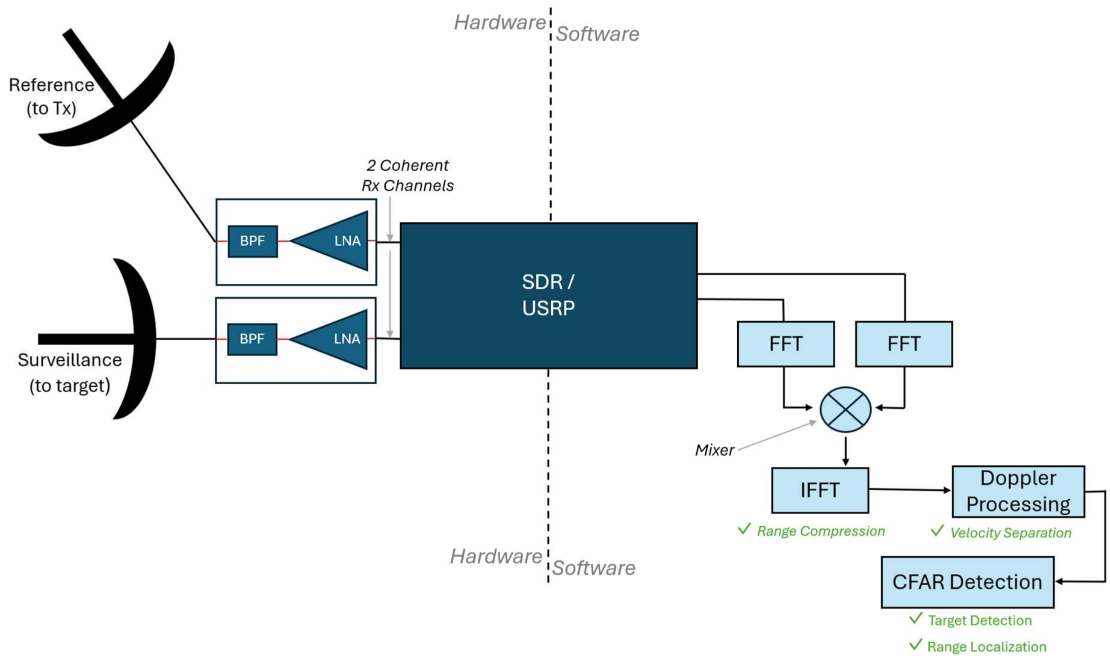

Figure 3.1 – Hardware Assembly and Signal Processing

3.1 USRP / SDR

A software defined radio is required to interrogate the passive signals for target detection. The features that are a requirement for passive radar is:

1. 2 Coherent Channels
2. Coherent Processing @ <700MHz
3. 16MHz Bandwidth
4. ADC 12-bits (minimum)

Some options of SDRs are shown in Table I below.

Table 3.1.1 – USRP Options

Device Name	Company	Price (£1000, Approx.)	Esti. Manu. Lead Time	Technical Specification							URL
				Freq. Range	Instant. Bandwidth	# Rx Chan.	Max Rx Gain (dB)	ADC depth	Noise Figure	Power Cons.	
USRP X410	Nat. Inst.	26.6	5wk	1M-7.2G	1.6G	4	~45	12	8dB	>190W	USRP X410 (Farnell)
USRP X440	Nat. Inst.	23.3	6wk	30M-4G	1.6G	8		12		>190W	USRP X440 (Farnell)
USRP-2955	Nat. Inst.	21.2	+8wk	10M-6G	80M	4	95dB	14	<5dB	~41W	USRP-2955 (Farnell)
USRP-2945	Nat. Inst.	19.0	11 wk	10M-6G	80M	4	95dB	14	<5dB	~41W	USRP-2945 (Digi-Key)
USRP-2954R	**Nat. Inst.**	**15.7**	**9 wk***	**10M-6G**	**160M**	**2**	**37.5dB**	**14**	**~6dB**	**~42W**	USRP-2954R (Farnell)
USRP-2944R	Nat. Inst.	13.8	9 wk*	10M-6G	160M	2	37.5dB	16	~6dB	~42W	USRP-2944R (Farnell)
USRP-2922	Nat. Inst.	-	**NLM**	400M-4.4G	>~20M	2	31.5dB	14	7	<18W	USRP-2922 (Farnell)

The USRP-2954R was selected as a flexible and reasonably cost-effective solution. The manufacture specifications are to be found here at ni.com. The complete specifications are additionally shown in Table II below.

Table 3.1.2 – Key USRP2954(R) Specifications for PCL

Specification Parameter	Value	Comment
# Receiver Channels	2	2 is minimum required for PCL
Frequency Range	10 MHz - 6 GHz	For long range detection, <1GHz is most suitable.
Instantaneous Bandwidth	160MHz	DVB-T BW is 7MHz, DAB is 1.5MHz
Max. I/Q Sample Rate	200 MS/s	
ADC Resolution	14 bit	Higher resolution leads to less quantisation error, leading to phase errors and thus loss with coherent processing
Max. Receiver Input Power	-15 dBm	10^{-5} W = 0.01mW
# Transmit Channels	2	Not going to be used for a passive setup

3.2 Band Pass Filter (BPF)

The band pass filter is used for both channels of the system so to remove the out of band signal modulations in the receive chain. As signals outside of the IoO transmitter bandwidth will not contain target echos, their inclusion will only add to noise. Thus, band-pass-filtering of the received signals in the reference and surveillance channels removes I/Q contributions from external and uninteresting sources that will add to noise after processing. These signal, prior to amplification, need to have irrelevant noise contributions removed to maximise the signal processing gain, ultimately maximising the operational range.

Bandpass filters are readily available at common frequency bands, such as at DVB-T or DAB. To maximise the effectiveness of the filter used, it would be important to capture the signals received at the site, measure the bandwidth, and then purchase the most optimal filter based on this observation. Signals from unintended sources if allowed to propagate through the rest of the circuit can lead to intermodulation distortion.

For DVB-T that is the initial candidate IoO suggested for this deployment, Table III displays some candidate filters that could be suitable for the application. A selection of available filters can be found at vendors, such as Mini-Circuit's Filter List, Farnell's Filter List or DigiKey Filters (SMA & Bandpass).

Table 3.2 – BPF Options

Device Name	Company	Price	Lead Time	Technical Specification	URL
RBP-650A+ BPF	Mini-Circuits	17.34		652Mhz Centre Frequency (PB=624-680MHz), >25 dB out of band loss	RBP-650A+ (Mini-Circuits)

3.3 Low Noise Amplifier (LNA)

Both the target receiver signal strength requires amplification to maximise the output signal-to-noise of processing. The maximum input of the USRP2954R is stated as -15dBm = 0.01mW. A 100kW transmitter (80dBm) placed 10km from the the receiver will experience approximately 110dB of free-space losses at 700MHz (DVB-T). Thus, the power of the signal measured at the reference receiver channel will be -20dBm, assuming no other losses which there will be. For the surveillance channel there will be a longer propagation path, and a further reduction from the backscatter off targets of interest. Both of these channels can have their (filtered) signal amplified to maximise the dynamic range of captured returns, that will later improve the Signal-to-Noise Ratio (SNR) and thus operating range of the PCL device. It is however, absolutely essential not to overload the receiver with too strong a power to damage the device. An in-field measurement of the absolute power of received signals (with antenna gain, cable losses, other geographical factors etc.) will dictate the model of LNA required.

Again, these components are very common and fairly cheap at <1GHz, in particular at the target frequency bands of DVB-T, DAB, VHF or otherwise, see for example LNA List (Mini-Circuits), SMA-based LNA List (DigiKey)
Some candidate SMA-based LNAs suitable for a DVB-T system are shown in Table 3.3.

Table 3.3 – LNA Options

Device Name	Company	Price	Lead Time	Technical Specification	URL
ZRL-700+ LNA	Mini-Circuits	151.73		Signal Gain >27dB, with 2dB Noise Figure (250-700MHz)	ZRL-700 (Mini-Circuits)

3.4 Attenuators

To protect the equipment, attenuation of the

3.5 Antenna

Two antennas are required in the operation of a passive radar system. 1 channel & antenna directed towards the transmitting tower, and the other directed towards the region of desired target detection. Require only to connect SDR input to antenna via SMA, N-Type or other connector. It could be desirable to have a highly-directional reference antenna, and a less directional surveillance antenna in a scenario where the surveillance antenna has a fixed placement.

There exists the option to use a *Yagi-Uda* or *Patch* Antenna, with both shown in Figure 2. Yagi-Uda antennas in-particular are commonly designed to receive signals of DVB-T and can typically be purchased from any hardware store. At frequencies below DVB-T, ~700MHz or DAB, ~300MHz, the size of the antenna grows significantly with desired gain, to the point where they can be impractically large.

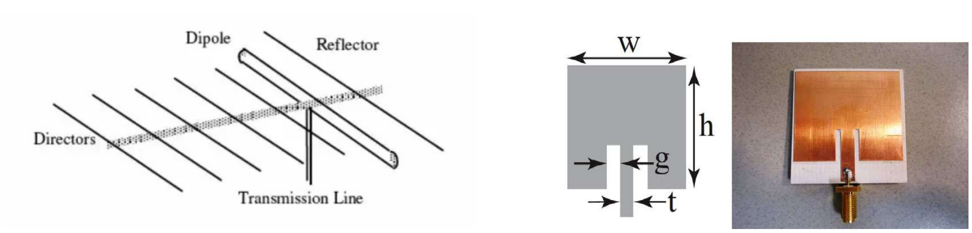

Figure 3.5 – Yagi-Uda (left) and Patch Antenna (right)

The choice of which of these antenna types can be largely considered a matter of convenience and operational setting. Table V (Yagi-Uda) and Table VI (Patch) list some antennas available from online retailers that would be suitable for the application. The specific model of choice will be dependant on the IoO frequency used, and within this is a choice of trade off with gain and directionality against coverage, which requires an assessment for optimal performance.

<table>
<tr><th colspan="2">Yagi-Uda</th></tr>
<tr><td>Pros
Large Gain
Strong Directionality / Directivity 9dBi
Fairly Flat Frequency Dependency (flexible)
Optimal for HF to UHF (3MHz-1GHz)</td><td>Cons
As highly directional, line of sight to target/ transmitting station is more important
Requires a proper, fixed mount point, robust to weather</td></tr>
</table>

Table 3.5.1 – Yagi Antenna Options

Device Name	Company	Price	Lead Time	Technical Specification	URL
BGYD890K	Amphenol PCTEL	84.01	14 weeks (if not in stock)	890-960MHz, Gain 10dBd, N-Type Female, Pole Mount	BGYD890K (DigiKey)
7175833	Amphenol Procom	339.03	5 Weeks	769MHz-896MHz, Gain 12.1dBi, N-type Female, Pole Mount	7175833 (DigiKey)

<table>
<tr><th colspan="2">Patch Antenna</th></tr>
<tr><td>Pros
Modest Gain
Good Directionality / Directivity 6dBi
As less directional, line of sight to target/ transmitting station can be more coarse
Less effort to fix flat antennas in mount, fixed mount point, robust to weather</td><td>Cons
Smaller Bandwidth, greater frequency dependency (less flexible)
Lower overall gain will reduce maximum detection range/size etc.</td></tr>
</table>

Table 3.5.1 – Patch Antenna Options

Device Name	Company	Price	Lead Time	Technical Specification	URL
ARRKP4065-S915A	Abracon LLC	11.39	25wks	902-928MHz, Gain 1.5dBi, Dielectric Ceramic	ARRKP4065-S915A (DigiKey)
FXP280.07.0100A	Taoglas Limited	12.36	6 wks	863MHz-870MHz, 1.5dBi, Flat Patch	931-1089-ND (DigiKey)
ANT-8/9-FPC-UFL-100	TE Connectivity Linx	3.67	6 wks	Dual Band, Flat Patch	ANT-8/9-FPC-UFL-100 (DigiKey)

4 Signal Processing Requirements

The signal processing utilised to enable PCL is described in this section. At first, Section 4.i describes in words the signal processing steps to perform detection from the measured signals at the reference and surveillance channels. Section 4.ii will mathematically define the essential operations taking place to enable PCL. Section 4.iii will reference literature describing advanced techniques to improve the quality of processed results that will be considered after the initial implementation

4.1 Signal Processing Description

The required signal processing to perform detection, range and velocity measurements is fairly simple. Many software platforms allow for the deployment of elementary signal processing steps.

1. (Digital) Fourier Transform of both the reference and amplified, filtered surveillance signal.
2. Mix (add) these together for each sample.
3. Perform the Inverse Fourier Transform on this result to compress the signal into range samples

(NB: This procedure 1 to 3 can be referred to as taking the *cross-correlation* of two signals)

4. This produces a range signal for a set operational timestep. The frequency of these samples occurs normally at the signal bandwidth.
5. Collecting and storing these (slow-time) samples, allows a final FFT in the time axis to convert a timeseries signal per range gate to a range-Doppler map
6. Detection via a suitable CFAR algorithm will produce detections at a fixed rate of false alarm.

4.2 Mathematical Overview

Sec. 4.2.1 details steps 1-3 above; how a target's range is determined in PCL.

Sec. 4.2.2 explains steps 4 and 5; how a target's velocity is extracted from a consecutive series of measurements.

Sec. 4.2.3 explains step 6: how and why the CFAR algorithm will enable robust detection of targets.

4.2.1 Range Compression

The mathematical formulation for this process is as follows.

The PCL system will receive two signals at the Reference, (R), and surveillance (S) channels. $R(t)$ and $S(t)$ are complex signals measured by the receiver.

The form of $R(t)$ received signals will be an intricate timeseries pattern that is transmitted by the IoO, along with any interference caused by multipath, diffraction and noise. For DVB-T, the waveform transmitted is well defined up to the contents of the programme \cite{Palmer}.

$S(t)$ contains $R(t)$ but with a delay (due to the greater propagation path length after reflection off the target) and weaker, (due to the small size of the target)[1]. This delay is not known, and will be found and subsequently used to declare target range.
As $S(t)$ contains a copy of $R(t)$, if we find a delay value, τ, for which $S(t)$ and $R(t)$ are the most similar ($S(t) \approx R(t-\tau)$), then we have determined the delay.

This could be achieved by finding the maximum value of the cross-correlation between two 1-D vectors. For two arbitrary 1-D vectors, $f(x)$ and $g(x)$, the cross correlation is defined as:

$$\text{Cross-Correlation}(\,f(x), g(x)\,) \;\equiv\; f(x) \star g(x) \equiv (f \star g)(\tau) \;=\; \int_{-\infty}^{\infty} f(\tau)^* g(x+\tau)\, dx \;\equiv\; \int_{-\infty}^{\infty} f(x-\tau)^* g(x)\, dx$$

Where * indicates the complex conjugate, and τ is a variable conceptually representing a time delay between the two signals. This outputs a new 1-D vector as a function of τ. The maximum value of $f \star g$ falls at a specific value of τ, which is the time delay of the signals.

For DVB-T based PCL, this could be performed for every *Frame* (10ms), *SubFrame* (1ms), *Slot* (0.5ms) *or Symbol* (5µs). It would be far too great of a computational burden to perform this integral at this update rate. A mathematical equivalent of this operation that is much more computationally efficient can be performed that relies on the Convolution Theorem, that the Fourier Transform (FT) of a convolution of two functions/signals is the pointwise product of their Fourier transform:

$$\text{Convolution}(\,f(x), g(x)\,) \equiv f(x) * g(x) \equiv (f * g)(u) = \int_{-\infty}^{\infty} f(x) g(u-x)\, dx$$

$$FT(f * g) = FT(f)FT(g)$$

This can be applied to the cross-correlation function such that only a mixing of two signals are required. The difference between Convolution ($*$) and Cross-Correlation ($\star$) is only the complex conjugation and time reversal of one of the input signals. Therefore,

$$(f \star g)(\tau) = FT^{-1}\left(\, FT(f(-x)^*) \cdot FT(g(x))\,\right),$$

where FT^{-1} is the inverse Fourier transform. Thanks to the computational efficiency of the *Fast Fourier Transform* (FFT), this algorithm can be performed in real time on even modest hardware.

Using the original PCL signals $S(t)$ and $R(t)$, a 1-D, complex vector is produced with a new axis of *delay*, τ:

$$A(\tau) = FT^{-1}\left(FT(S(-t)^*) \cdot FT\big(R(t)\big) \right)$$

where $A(\tau)$ is the range-compressed signal of the target matched against the reference.

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[1] $R(t)$ may feature the direct signal of S but without delay. This leads to interference, which reduces the resultant SNR, *and* will add additional ambiguities, so every effort to shield R from the direct IoO signal must be taken (for example, physical shielding, exploiting polarisation, using a highly directional antenna etc.)

This 1-D vector is a function of delay, τ. The strength of each discrete sample along τ indicates the presence of signal of increased received power at the delay value. If multiple targets are present at different delays, they will appear in the *range profile* at with their delay as matched to the reference signal.

4.2.2 Velocity Measurement

After producing $A(\tau)$ for a recorded sample of $S(t)$ and $R(t)$, velocity information can be garnered by considering a sequence of consecutive measurements, $A_0, A_1 \dots A_{N-1}$, where N is a power of 2.

For a target at $\tau = \tau$, its complex value will have a magnitude depending on the reflected strength from the target, and a phase that is dependent on the initial phase from the IoO transmitter, the propagation path length and EM frequency.

If the target, between A_n and A_{n+1}, moves towards/away from the surveillance channel, the path length will have decreased/increased, and so the phase of this sample will have changed due to both the target's location and the passing of time (the IoO position of the waveform existing at EM frequency ~700MHz will be different). For a series of collected samples of $A_0, A_1 \dots$, the constant frequency term of 700MHz can be removed via superheterodyne mixing with the known frequency. This process of *down-conversion* to *baseband,* means the resultant change in phase across consecutive samples is solely due to target motion.

A FFT across consecutive $A_0, A_1 \dots$ samples after conversion to baseband will yield peaks at frequencies corresponding to the Doppler shift of the radiation of the target. This is referred to as *coherent integration* of multiple pulses. This both increases the SNR of returns and allows velocity of measurement of targets that otherwise may be obscured by returns caused by static clutter, such as terrain or buildings.

The value N to an extent dictates the performance of the radar. A larger N means more samples are coherently integrated, which leads to a finer Doppler resolution (more and narrower velocity bins for the same velocity swath), and greater power of genuine signals provided it is not rapidly accelerating. A larger N means a greater SNR of target returns, thus a greater operational range, but also a larger time duration over which returns are integrated, so reducing the update rate. If a target is rapidly accelerating, then returns will not be integrated totally coherently so the resultant target peak will less than optimal, and will be spread over numerous Doppler bins. Thus, to allow the consistent detection of highly manoeuvrable targets, N must not be set excessively large.

4.2.3 Target Detection

The collection and coherent integration of a sequence of $A_0 \rightarrow A_{N-1}$ leads to the production of a *range-Doppler map* from which a target detection algorithm can be implemented.

A target detector sets a threshold of signal power across the range-Doppler map. The three possible outcomes of this approach are:

1. Correct Decision: A detection is declared for a target that exists
2. False Alarm: A detection is declared for a target that does not exist

3. Missed Detection: No detection is declared for target that exists

False alarms occur when a source of non-target source of noise or interference causes a resolution cell of a range-Doppler map to be greater than expected. A detection may be missed if the power of its signals are not sufficiently strong or coherent (accelerating too fast) to be integrated above the noise floor.

Naturally, the minimisation of false alarms and missed detections improves the operational standard of the PCL or radar in general. Raising the detection threshold means less chance of false alarms and increases the chance of missed detections.

In radar to combat this fundamental trade-off, the standard detection algorithm is Constant False Alarm Rate (CFAR) thresholding.[2] The working principle is to update the threshold such that the Probability of False Alarm (P_{FA}) is constant across time and space, allowing for the interference to change over time and space.

Figure 4.2.3 illustrates the CFAR principle via an expression of the probability distribution function of a target, and target + interference.

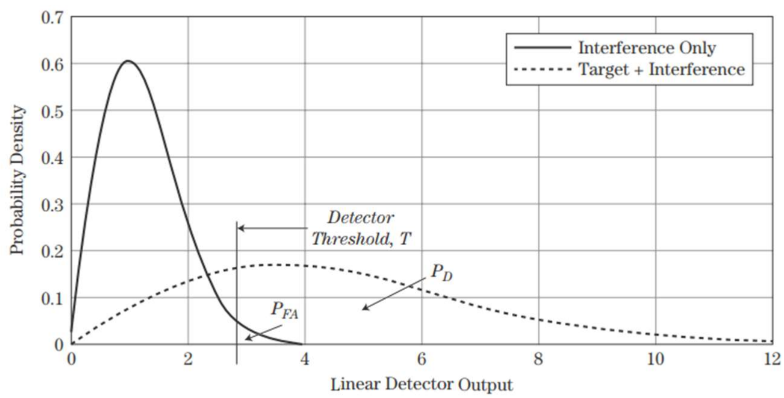

Figure 4.2.3 – CFAR Principle. 'Linear Detector Output' describes a range Doppler map that uses the (linear) magnitude of the complex vectors to represent power. From Chapter 16 of \cite{Richards2010}.

For the majority of the range-Doppler map, target presence will not exist, and the power in each range and Doppler bin will be dictated by present noise and interference. This distribution can be measured, and is shown in Fig. 4.2.3 as the solid black line.

Then on top of this, a target will introduce additional signal power to any existing thermal or interference noise. The dotted line of Fig. 4.2.3 represents a possible distribution of an arbitrary target.

The CFAR system sets the threshold such that the area under the curve due to the target-less power probability distribution *above the threshold* is constant. A value such as $P_{FA} = 10^{-4}$ may

[2] AKA Neyman-Pearson detector. Variations of CFAR exist, (Cell-Averaging, Order Statistics, Greatest-of, Least-of), and additionally, deep learning based detection is a modern research trend. CFAR however, is the work horse of radar detection in almost all scenarios.

be used, which is 1 false alarm per 10,000 observations. In real terms, a *False Alarm Rate (FAR)* for a system can be declared, mathematically expressed as:

$$FAR = \frac{P_{FA}M}{T_M} = N_D P_{FA}$$

where M is the total number of resolution cells for each coherently processed batch of returns, and T_M is the rate of returns processed i.e. how many range-Doppler maps are produced per second. Inspection of FAR allows operators to set the rate of false alarms they are happy to deal with for their system deployment. Later, Section 5.2 will provide an estimate of the FAR for the PCL system to be set up at Kryoneri Observatory.

With the P_{FA} set constant, the performance of the radar in terms of Probability of Detection (P_D) can be assessed and presented as a key performance metric of the system. Typically, this is shown as a Receiver Operating Characteristic (ROC) curve with P_{FA} on the x-axis and P_D on the y-axis \cite{Asif2021}. The area under this curve reflects the quality of detector performance. Different target SNR values can be assessed against a ROC curve, which can help an operator choose the value of P_{FA} that best suits their system and anticipated targets.

4.3 Advanced / Optimisation Techniques

The prior listed techniques will enable PCL of targets and allow feedback of detections for situational awareness. PCL however, as it is dependent on opportune transmitters and its effectiveness is subject to the geographical conditions of the deployment area, may benefit from further processing to improve deficiencies of a particular location.

The requirement for such methods will become apparent after observing the raw output of the PCL system. This project will do as necessary to enable robust detection of targets at the deployment site, and literature contains many techniques to improve the effectiveness of a deployment.

This section will list a few methods that may be required in this project:

1. Adaptive Clutter Removal \cite{Berger2010, Yoo2018}}
2. Extensive Cancellation Algorithm \cite{Colone2009,Colone2016}
3. Suppression of Pilot Signals \cite{Palmer2013}

5 Site Assessment

This section is divided into two subsections. The first, Section 5.1, shows an example power measurement of a DVB-T transmitter located 15km from the measurement site at the University of Birmingham (UoB). Then, Section 5.2 shows a remote assessment of the Kryoneri Site considering known IoO locations, and available information, that with some assumptions allows us to estimate the operational range of the proposed PCL system.

5.1 UoB Transmitter Measurement and Assessment

A DVB-T transmitter tower at 100kW based in [Sutton Coldfield](#) is located 17.44km from UoB.

Key differences between this scenario and the one at Kryoneri (see Sec. 5.2 following) are:

- Greece is an extremely Mountainous landscape, which will effect the signal propagation from the IoO. Contrastingly, Birmingham is fairly flat but much more urban, which will have a different but similarly detrimental effect.
- The Sutton Coldfield transmitting station was known to operate with 100kW of output power. The power of transmitters in Greece is not known.

Using a spectral analyser (Rhode & Schwarz FSH6) and a [CotS Yagi-Uda antenna](#) for DVB-T reception, the measured signals allows an assessment of the direct signal, which in turn allows a deeper assessment of the ability to perform PCL target measurements.

5.2 Kryoneri Site Transmitter Assessment

5.2.1 IoO Infrastructure

DAB+ is more recent in Greece https://www.worlddab.org/countries/greece#current_situation

DVB-T has been around for a much longer time \cite{Cheers Chris}

5.2.2 DVB-T Transmitter Locations

Using the Digea site's Coverage Checker, for TV reception it is recommended to tune into the transmitters at sites: *Ymittos, Osios Patapios,* or *Parnitha.* Figure 5.2.2.1 shows the simulated coverage as provided by Digea.

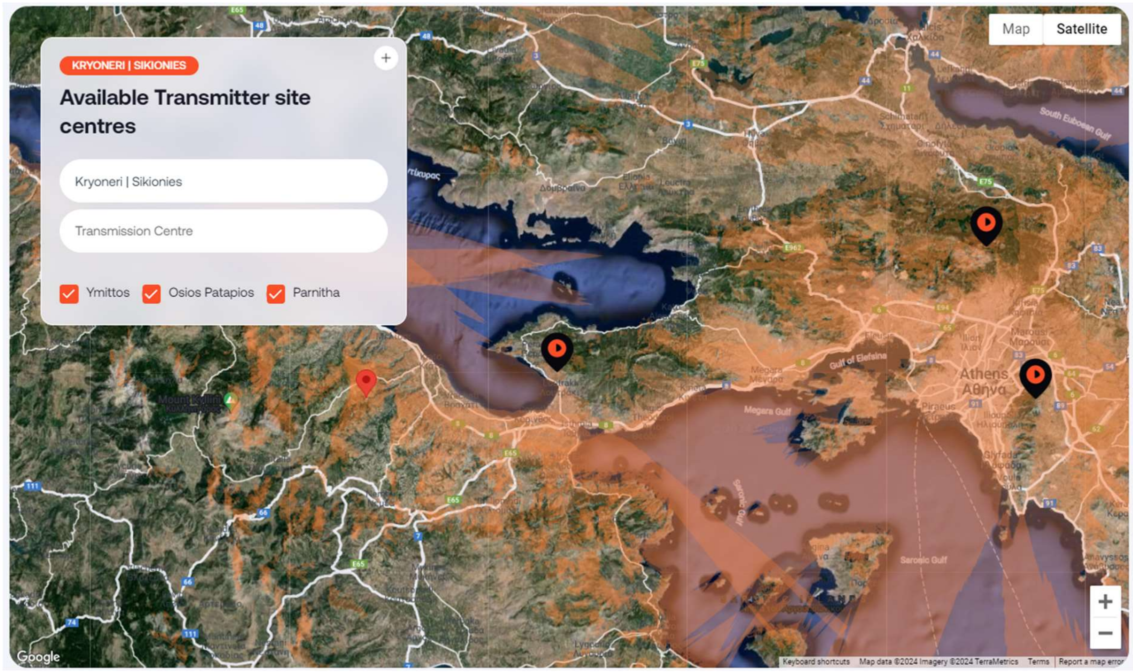

Figure 5.2.2.1 – Digea Coverage Recommendation for TV reception at Kryoneri Observatory Site.

At the centre of the figure, *Osios Patapios*, is 31.1 km from where the surveillance channel will be. The others, based near Athens, are ~ 100km away from the observatory, which is a very long distance and thus will experience a an extra 10dB of free space path loss, with further unknown complications arising from line of sight, diffraction and reflections.

Other IoO transmitters exist in the region, and are candidates for gathering the surveillance signal. Figure 5.2.2.2 shows the 14 closest Transmitters, and Fig 5.2.2.3 shows the three closest of these that will likely provide the best reference signal. *Xylokastro* and *Nemea* were not listed as options on the Digea site, but with a suitably tall mast their signals could conceivably be the best choices for PCL. In this scenario, direct signal suppression in the surveillance channel will be naturally reduced, giving better performance at the cost of effort in setup.

Of the three transmitters in Figure 5.2.2.3, each of them broadcast the same channels shown in Figure 5.2.2.4. This will

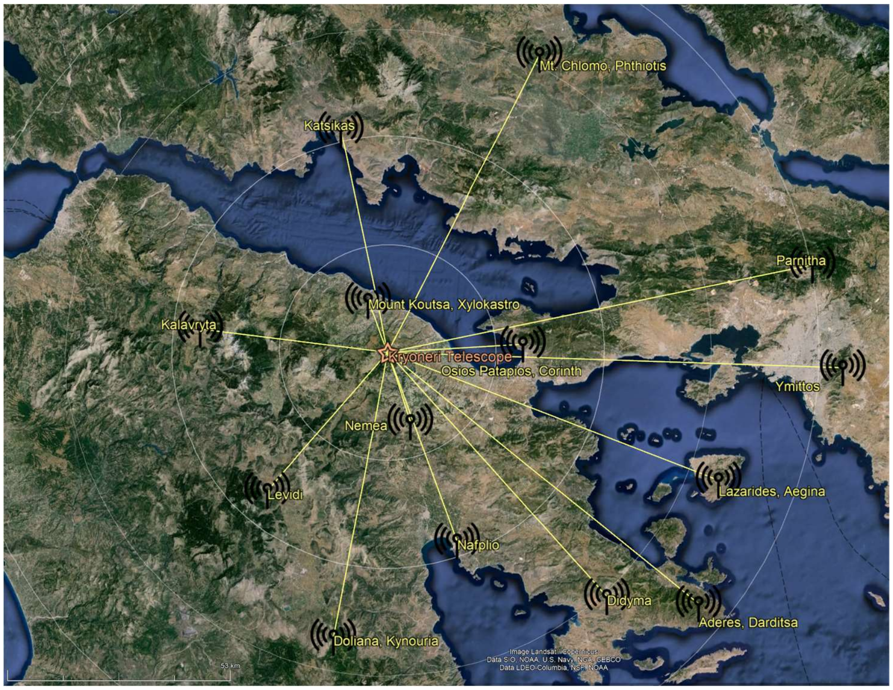

Figure 5.2.2.2 – Locations of possible IoOs listed by Digea.[3]

Figure 5.2.2.3 – Closest Candidates for IoO surveillance signal:
Xylokastro, Nemea and *Osios Patapios*

[3] White circles in these figures show the distance from Kryoneri Observatory in 25km range increments.

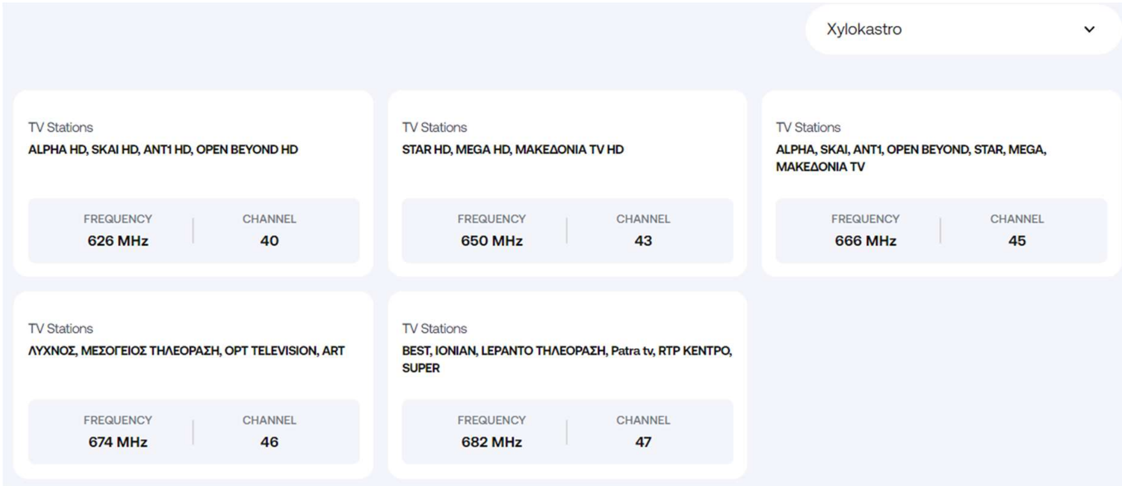

Figure 5.2.2.4 – Channels/Frequencies broadcasted by each of the three closest, candidate transmitters.

5.2.3 DVB-T PCL Range Assessment

The

Training - Do not need this section

Any new starts will need a sound understanding of fundamental passive radar concepts, experience with implementing hardware installations of radar systems, and the tools and skills to assess the physical and spectral environment of operation to perform site assessments.

To assess the situation of the passive radar system, with consideration of the opportune transmitter used, the use and implementation of the Radar Range Equation (RRE) is necessary for surveying the detection limits.

The suitability of a site requires an in situ measurement of the ambient spectra at the location. Intimate use with a **spectral analysers** to record and analyse the spectral power at the site of passive radar installation is required to ensure presence of signals required to implement the fundamentals for detection.

6 References

There are no sources in the current document.