EMSIG Meeting on Radar and EW

Adaptive Active-Passive Radar Control for LPI Operation

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Radar Sensing Group

The Science Inside

)utline

Introduction to Active-Passive Radar.

Active and/or Passive?

Adaptive Low Probability of Intercept Mode.

Active Passive Data Fusion – Experimental Result

Modelled Low Probability of Intercept Scenario.

Summary.

ctive Passive Radar

Hybrid radar combines active and passive radar sensing.

Passive radar uses a noncooperative transmitters available in the environment. e.g. FM Radio, DAB, DVB-T.

Looks to exploit the benefits of both active and passive sensing.

Benefits of hybrid radar:

- Enhanced detection performance.
- Resilience to Electronic Countermeasures.
- Low Probability of Intercept (LPI).

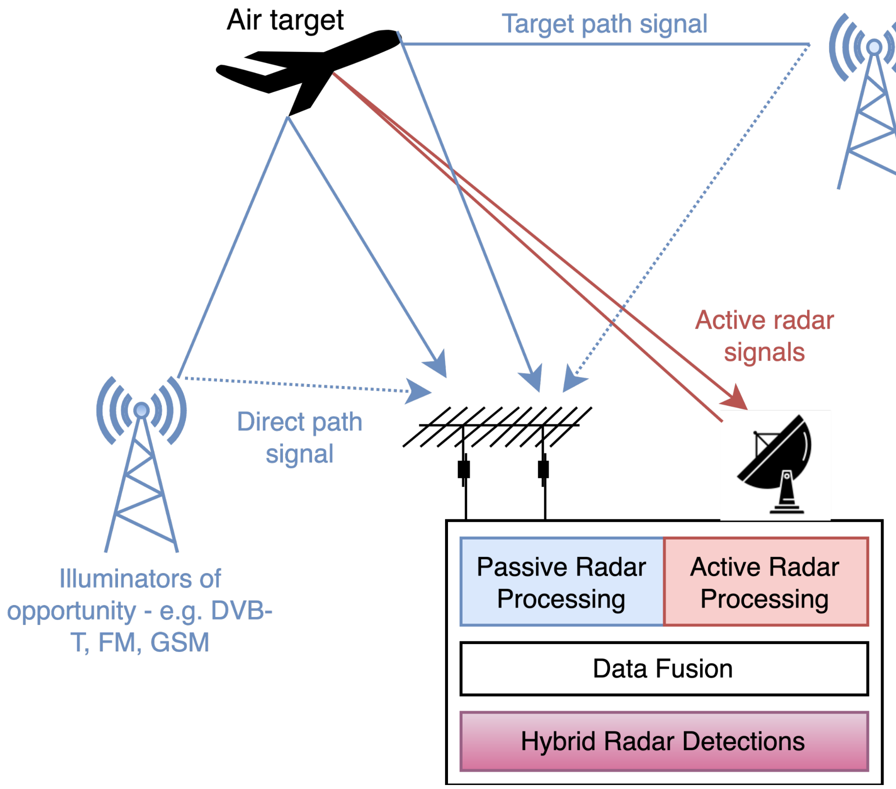

Fig.1 – Example of hybrid radar scenari

Active and/or Passive

Benefits of Hybrid Radar

Exploit the Benefits of Active and Passive Radar.

Low-Probability of Intercept (LPI). →

Enhanced Detection Probability.

Resilience to Electronic Counter Measures.

Characteristics of an LPI radar

- Low sidelobe antennas.
- High duty cycle / spread spectrum transmission.
- Accurate power control.
- Carrier frequency.
- High sensitivity.
- High processing gain.
- Coherent detection.
- Monostatic / Bistatic configuration.

Adaptive LPI Mode

bjective

- Minimize the probability of the active radar being detected by non-cooperative radar detection equipment or Electronic Support Measures.
- Whilst, sustaining a minimum level of detection performance for some predefined surveillance region and hypothetical target.

ethod

- When possible, only use passive radar sensing.
- If the passive radar's performance doesn't suffice, use the active radar to gap fill the passive radar.
- Minimize number of active radar emissions and their respective power.

Example Scenario

Active Radar

- Active AESA ±60° scan angle ← defines the surveillance region.
- Ability to dynamically illuminate regions of coverage.

DVB-T Passive Radar

- Passive Array ±60° scan angle.
- Able to resolve target location with single IoO.

DVB-T IoOs

- Crystal Palace - 200 kW
- Sandy Heath - 170 kW

Detection performance required

- $P{\downarrow}H{\uparrow}d=80\ \%$
- $\sigma=5\ m{\uparrow}2$
- $\rho=Swerling\ 1$
- $R=50\ km$ (1 km range granularity)

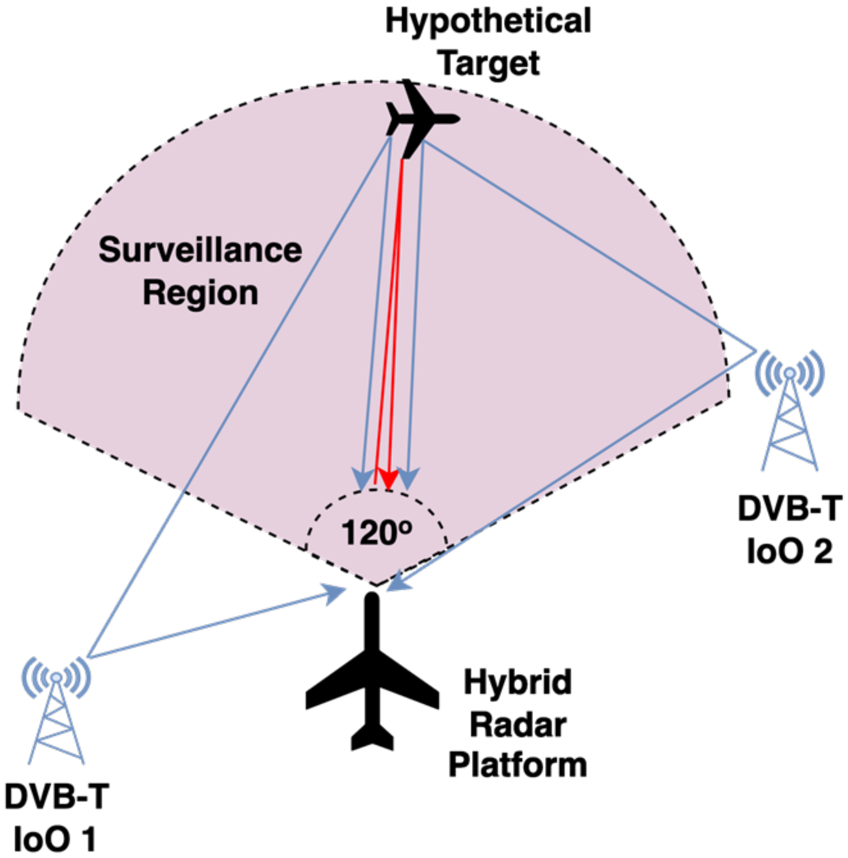

Fig.2 – Modelled Example Scenario.

Hybrid Radar Data Fusion

Centralised Approach

All signals, noises, and interferences are jointly processed.

Raw data combined at fusion centre - before thresholding.

De-centralised Approach

Higher level of abstraction

Local thresholding and detections.

Plots or Tracks combined at a fusion centre.

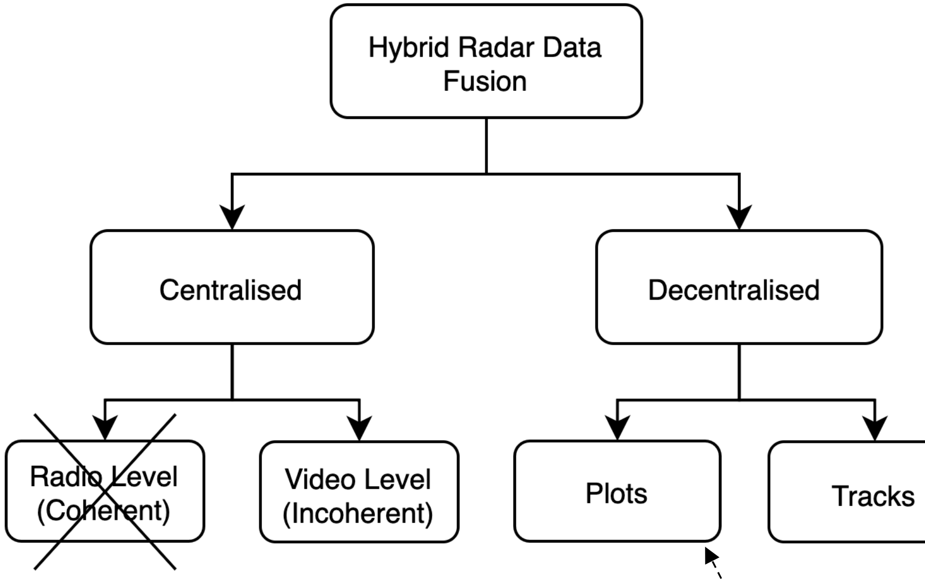

Fig.2 – Multistatic radar fusion categories.

“Multi-Band hybrid active-passive radar sensor fusion”, IEEE Radar Conf, 2023, In Press

lybrid Radar Data Fusion

ladeRAD Radar

- Low-cost multi-functional radar.
- Combination of Software Defined Radios (SDRs).
- Simultaneous active and passive measurements.
- Multistatic operation possible with GPS Disciplined Oscillator based synchronisation system.

Fig.3 – Photograph of bladeRAD node

Active Radar

- FMCW
- RF: 2.44 GHz
- BW: 30 MHz

Passive Radar

- DVB-T (64-QAM/OFDM)
- RF: 690 MHz
- BW: 7.61 MHz

“**bladerad: Development of an active and passive, multistatic enabled, radar system,**” *18th Eur. Radar Conf.*, 2022, pp. 98–101.

"**Multistatic radar synchronisation using COTS GPS disciplined oscillators**" *Int, Conf. on Radar Sys.*, 2022, pp. 429-434.

Hybrid Radar Data Fusion

Active-Passive Sensor Resolution Comparison

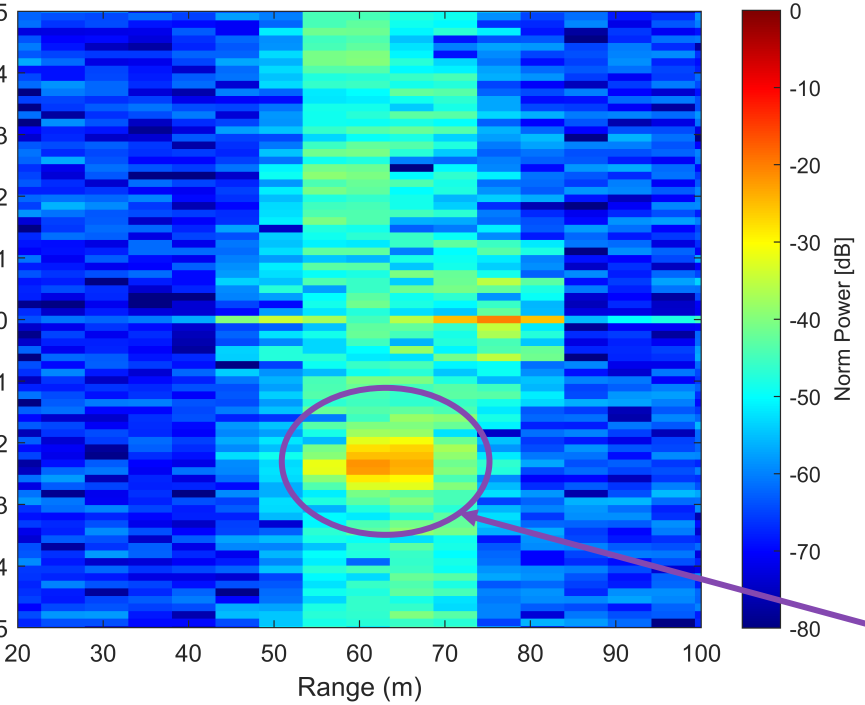

Fig.6 – *Example active radar range-Doppler surface.*

Range Resolution

Active: 5 m

Passive: 20 m

Doppler Resolution

Active: 0.123 m/s

Passive: 0.435 m/s

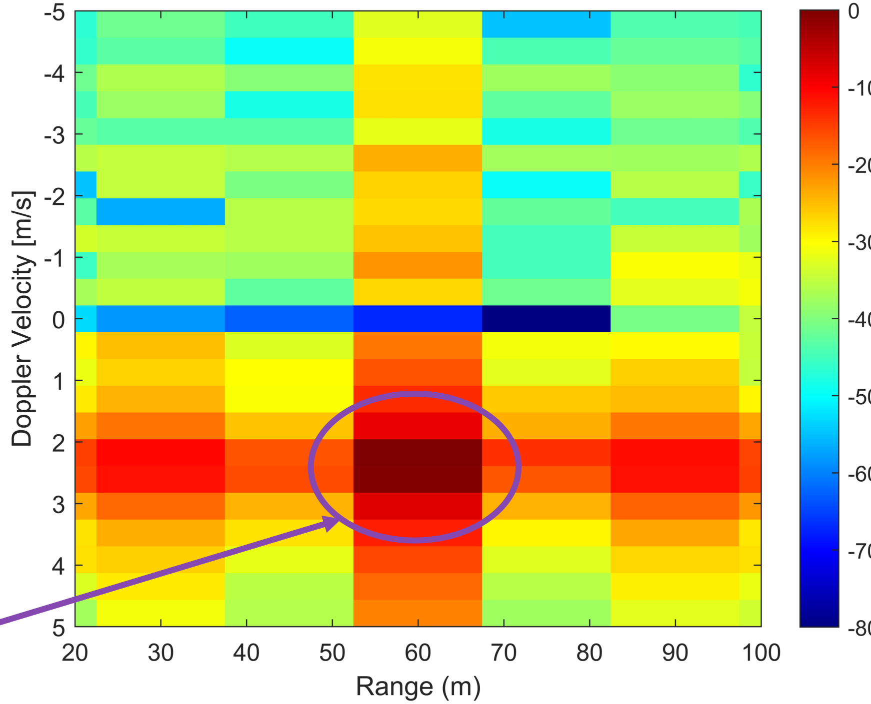

Fig.7 – Example passive radar range-Doppler surface.

LPI Algorithm

lgorithm 1: Adaptive LPI Algorithm

```
initialisation ($\sigma, \rho, P_H^d, R_t, \bar{\theta}, \overline{L_P}$)
    repeat for each new radar location $L_R$
        for each range from radar, $R \in R_t$
            for each scan angle, $\omega \in \theta$
                Evaluate $P_P^d(R,\omega)$ = U($R, \omega, \sigma, \rho, \overline{L_P}, L_R$)  ← Evaluate passive radar performance.
                If $P_P^d(R,\omega) \leq P_H^d$ then
                    $P_a^d(R,\omega) = J(P_H^d, P_P^d(R,\omega))$  ← Calc required active radar Pd.
                    $A_{SNR} = A(P_a^d(R,\omega), \rho)$  ← Calc required active radar SNR.
                    $P_a = Y(A_{SNR}, R, \sigma,)$  ← Calc required active radar transmit power.
                    If $P_a > P_A(\omega)$ then
                        $P_A(\omega) = P_a$  ← Update active radar AESA power weight vector.
                else
                    continue
        AESA power weighting ← $P_A(\omega)$
```

Parameters

σ = Target RCS

ρ = Target Swerling model

$P\downarrow H\uparrow d$ = Minimum detection performanc

$R\downarrow t$ = Surveillance ranges of interest from

θ = set of surveillance scan angles.

$L\downarrow P$ = set containing of coordinates of pas

$L\downarrow R$ = radar/platform position.

$P\downarrow A(\omega)$ = vector of AESA power weightin

Probability of Detection vs Scan Angle

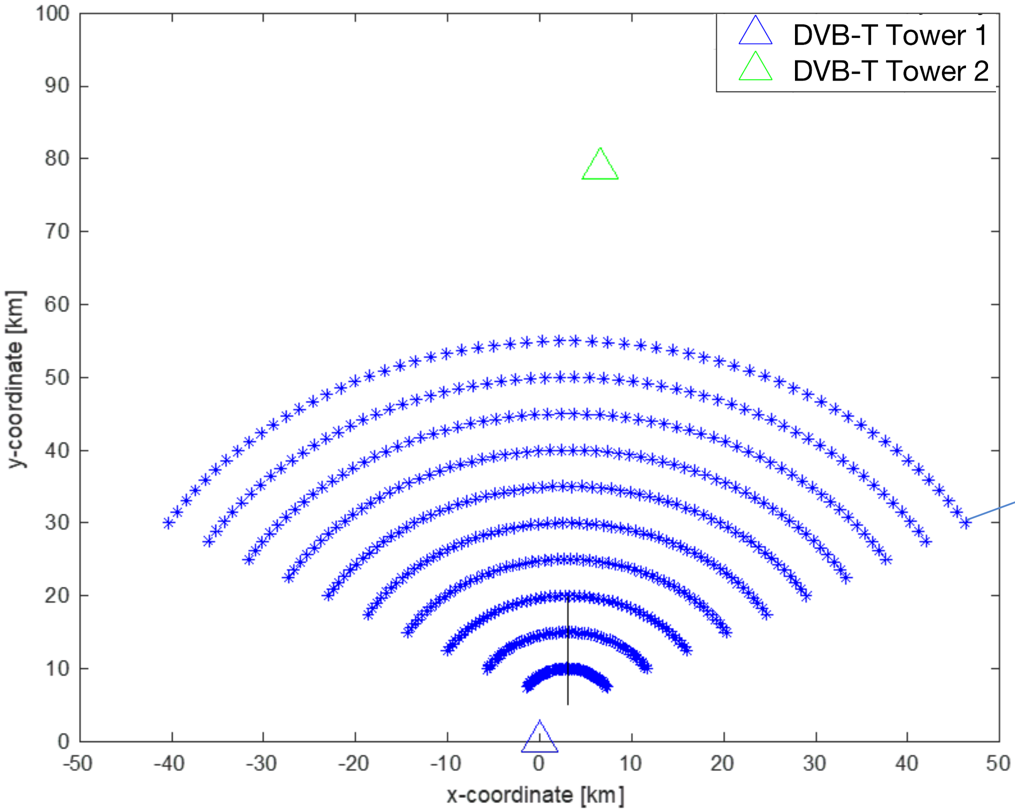

Fig.9 – Evaluation of surveillance area.

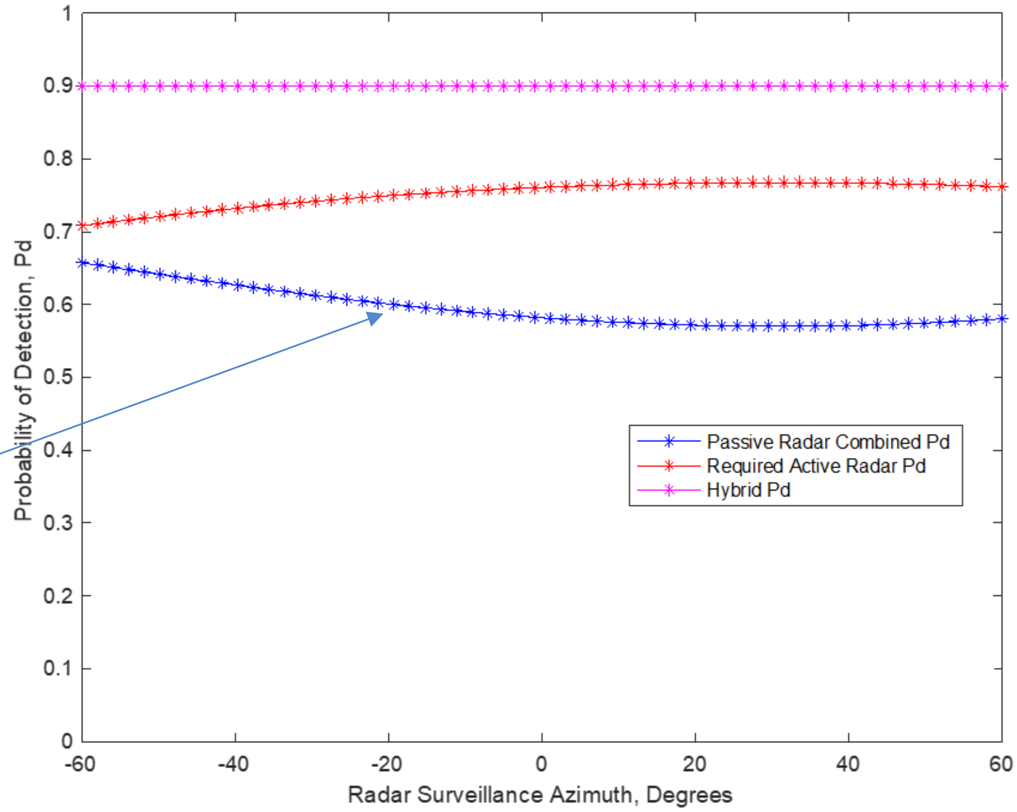

Fig.10 – Active, passive and hybrid radar Pd as a function of scan angle.

Required SNR as a function of Scan Angle

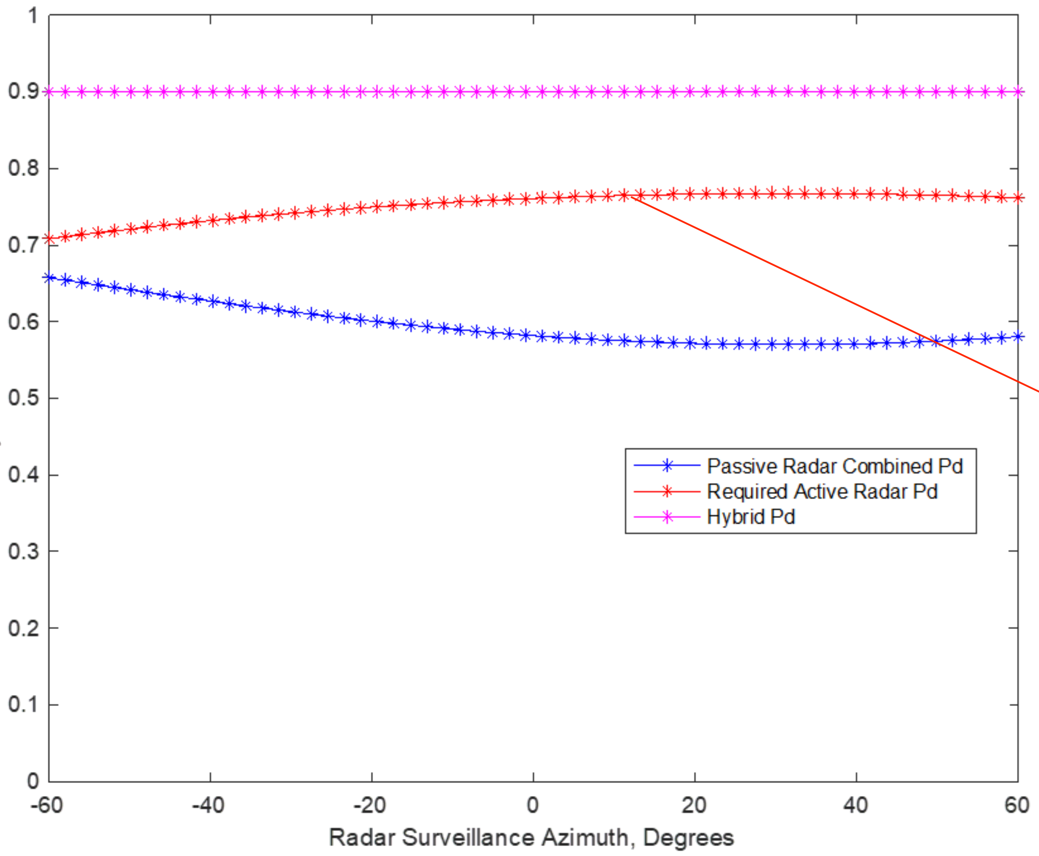

Fig.11 – Active, passive and hybrid radar Pd as a function of scan angle

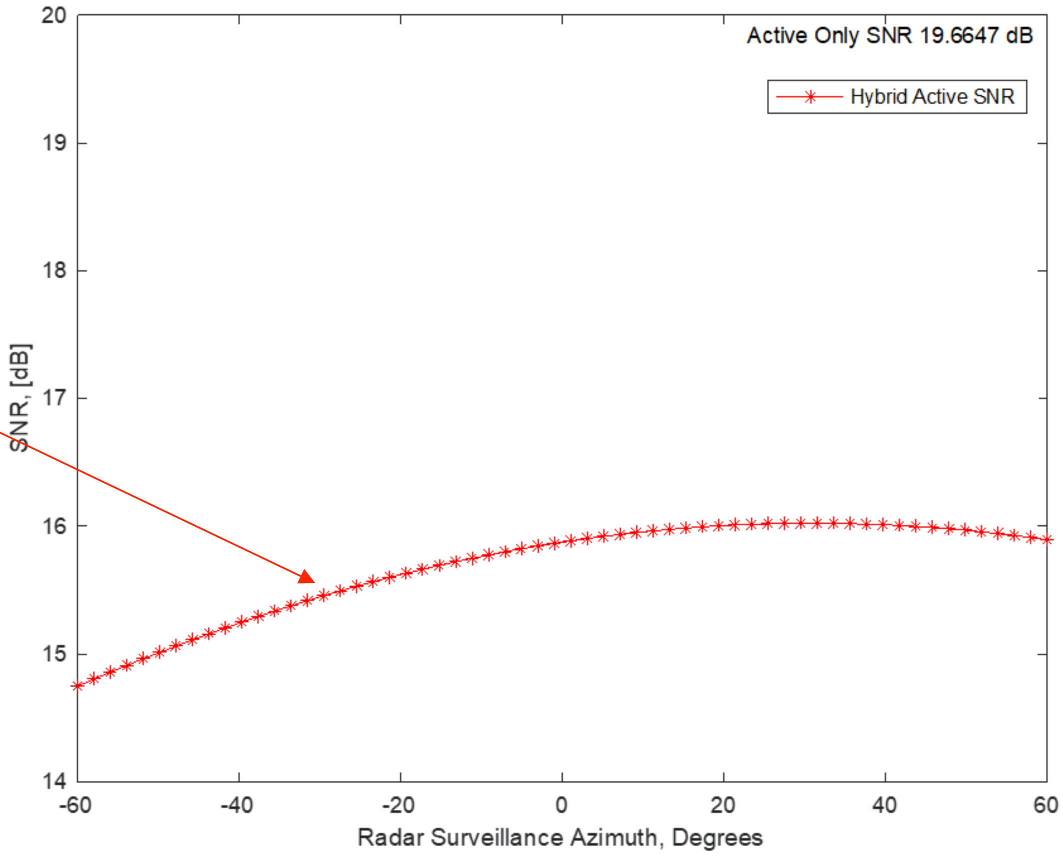

Fig.12 – Required active radar SNR as a function of scan angle.

Scenario Results

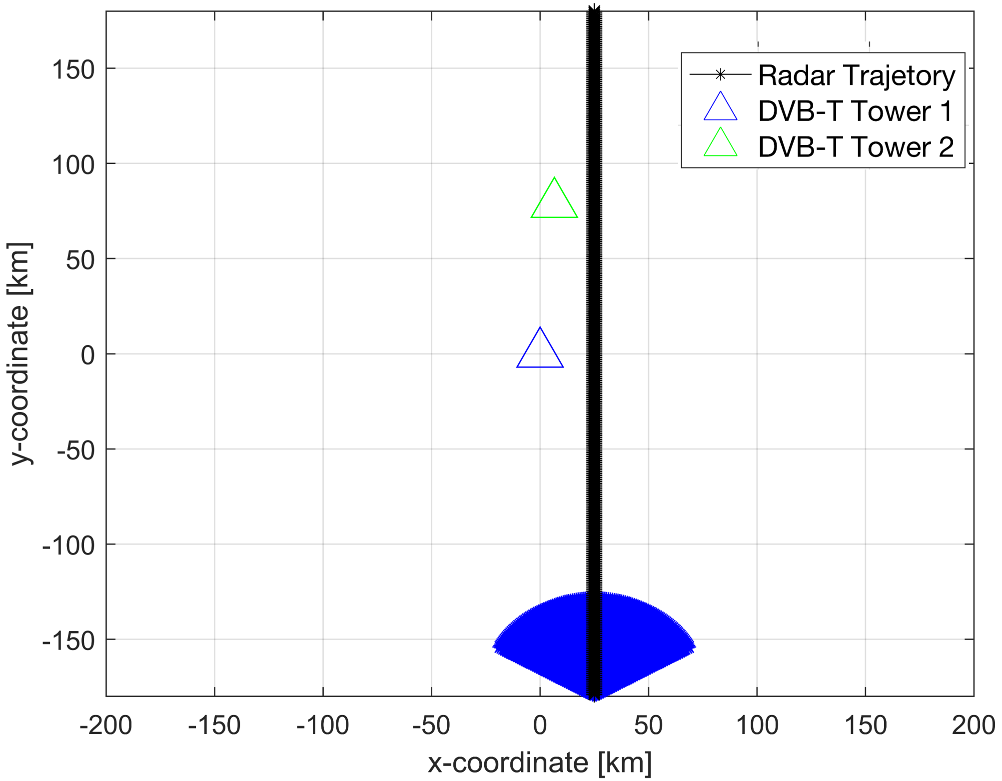

Fig.13 – Map of modelled scenario platform and IoO locations.

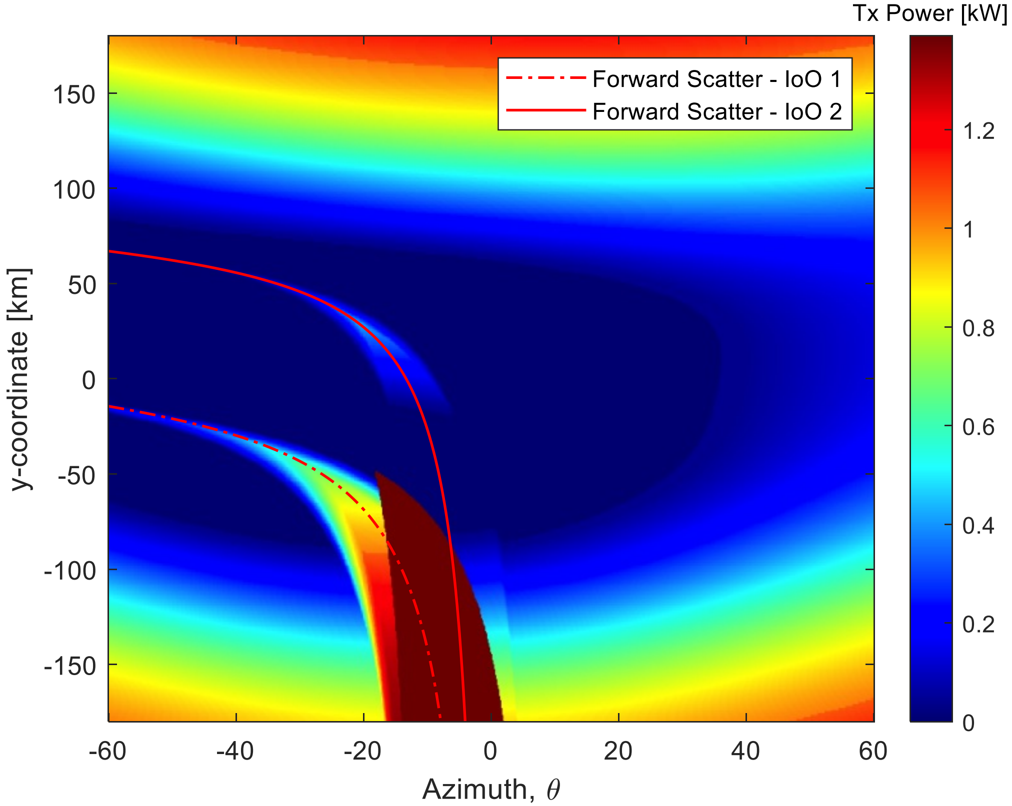

Fig.14 – Active radar transmit power as a function of scan angle and platform location.

Reduction In ESM Intercept Range

$$R = \mathrm{Pr}/N = P_t G_t G_r \lambda^2 /(4\pi)^2 R_t^2 kTF_n B_{ES} \; T L_R \qquad (1)$$

$$\mathit{max} = \sqrt{P_t G_t G_r \lambda^2 /(4\pi)^2 R_t^2 kTF_n B_{ES} L_T \; R\, SNR_{min}} \qquad (2)$$

$$2 /R_1 = \sqrt{P_{t2} /P_{t1}} \qquad (4)$$

$$n = \sqrt{P_m} \qquad (3)$$

$$SM\ Reduction = (1-\sqrt{P_m})*100 \qquad (5)$$

P_{t2} - new transmit Power

P_{t1} - original transmit power

R_2 - new ESM intercept range

R_1 - original ESM intercept range

P_m - radar power reduction multiplier

R_m - ESM intercept range reduction multiplier

Table 1. – Example ESM Intercept Reductions

Reduction in P_t, P_m (dB)	ESM Intercept Range, R_m	Reduction in ESM Intercept range
-3	0.708	29 %
-6	0.501	50 %
-10	0.316	68 %
-13	0.224	78 %
-16	0.158	84%
-20	0.100	90%
-30	0.010	97%

Scenario Results Analysis

Key Points

Considerable reduction in mean active radar power observed.

10 dB reduction is transmit power relates to a 68% reduction in ESM intercept range.

In the region of good passive radar coverage, in many scan angles no active radar illumination was required.

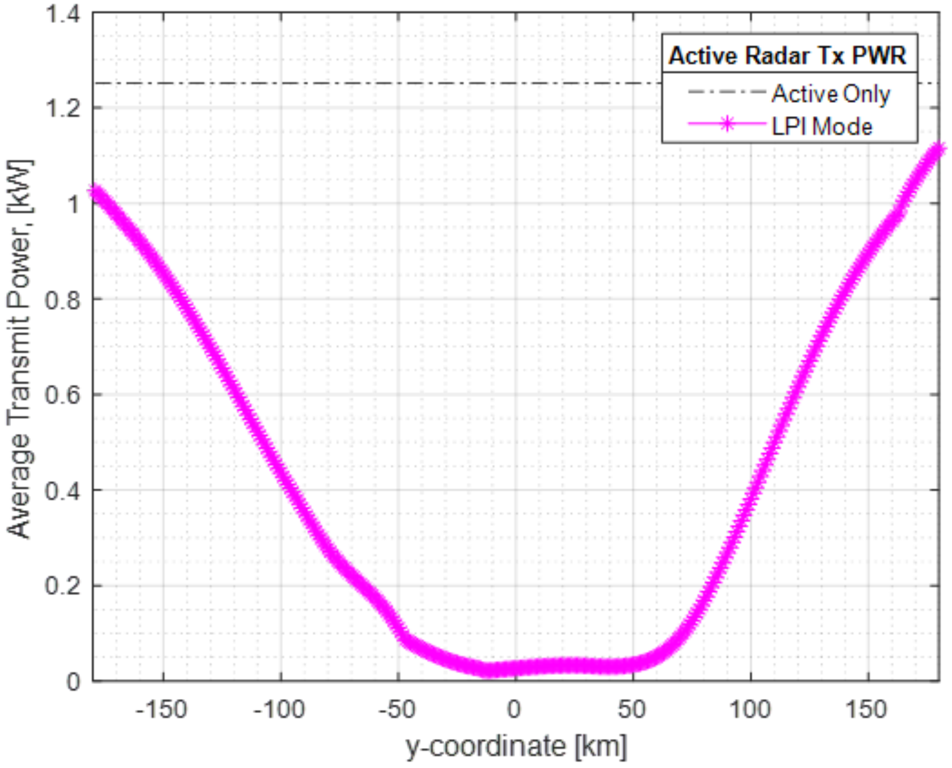

Fig.15 – Average active radar transmit power as a function of platform location.

Summary

Previous work has shown the detection performance enhancement by fusing active and passive detections.

Whereas, this modelling work has shown how through fusion of detections, considerable reductions in active radar emissions are possible.

The addition of a passive sensor on a platform would incur additional cost; though only a receiver is required.

A hybrid radar approach may allow future platforms to exploit passive radar sensing operationally.

Thank you for listening!

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