PARTMENT OF ELECTRONIC & ELECTRICAL ENGINEERING

ultistatic Radar Data Fusion for Detection ith Reduced Transmit Power Consumption

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enda

- ackground context
- roblem addressed
- lultistatic radar communications methods
- nvestigation structure
- lethodology: simulation, CA-CFAR, data fusion
- esults
- onclusions

ckground & Motivation

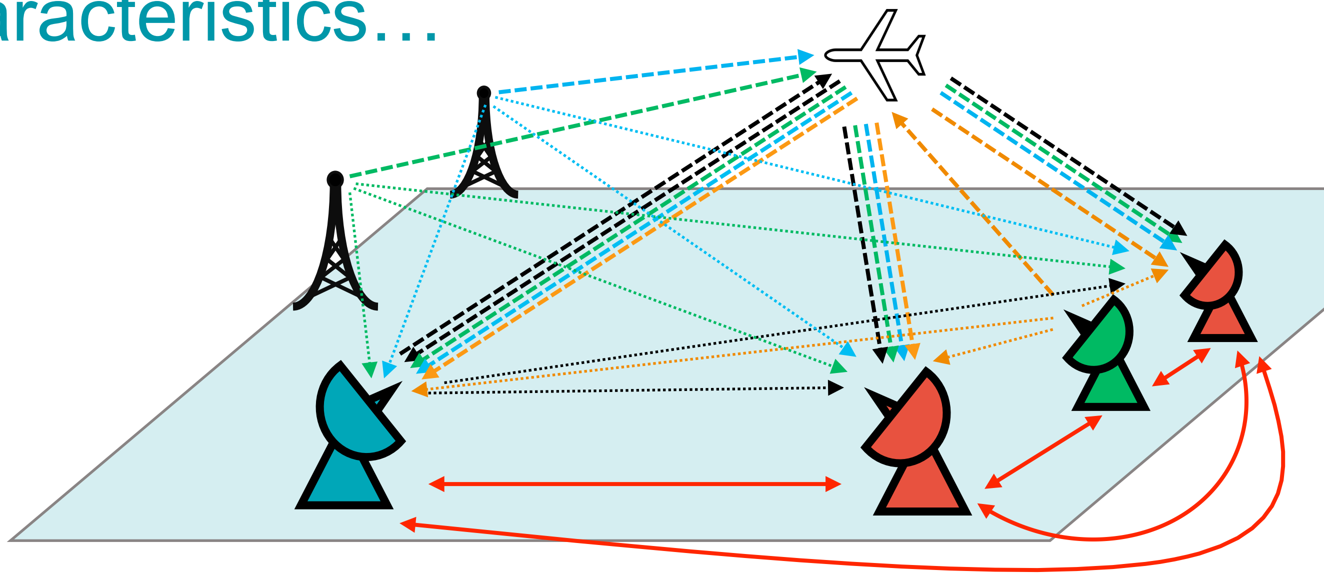
ultistatic radar = spatial separation + data fusion

arger choice in operating characteristics…

How to use optimally?

omething for nothing…

Quantify performance benefits?



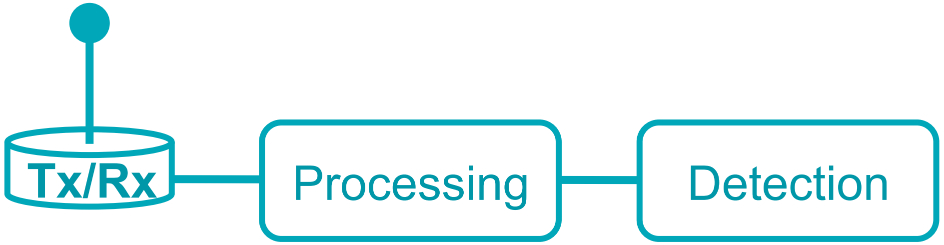
x power consumption is important:

Covertness 2) Operating Cost/Logistics

an the level of communications (i.e. data fusion) used by a multistatic
stem affect Tx power level for a given desired probability of detection
vel?

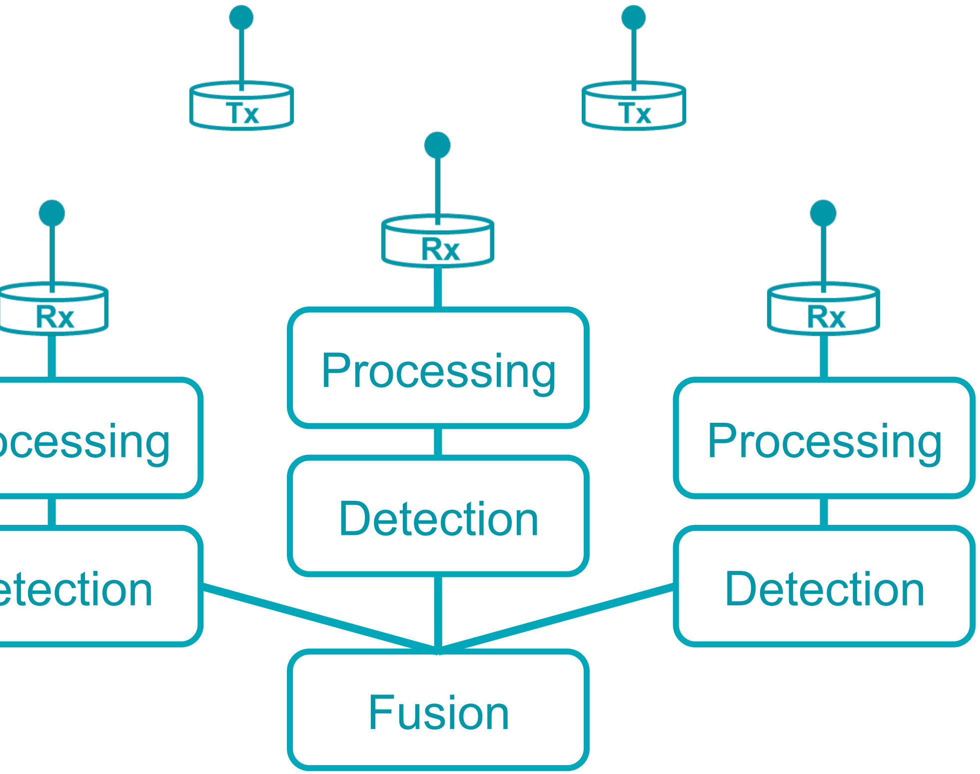
dar Systems

nostatic

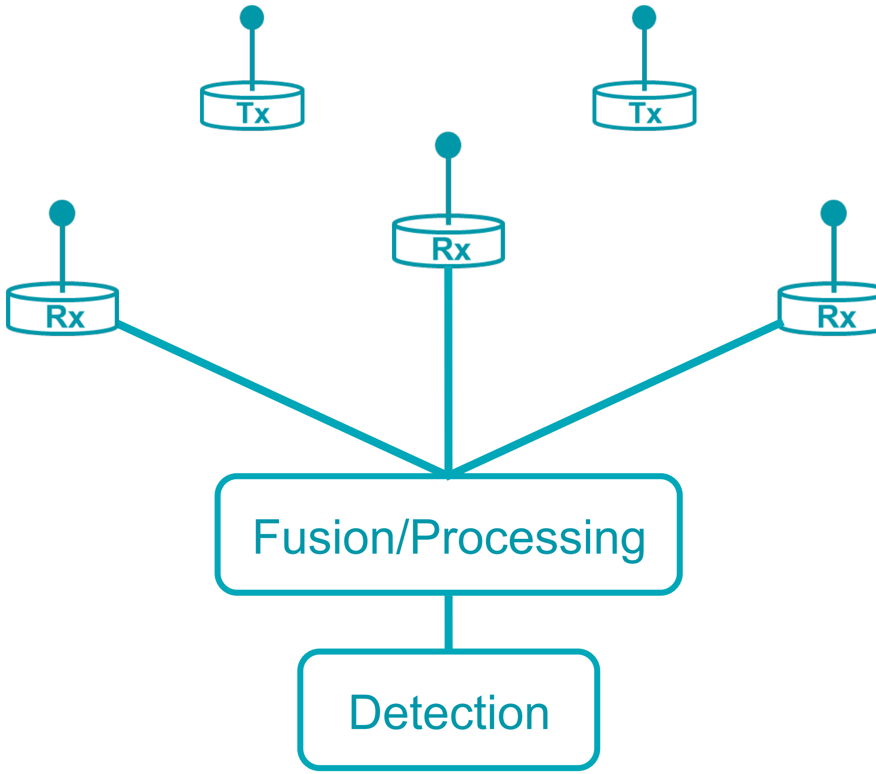


ultistatic

Limited Communications



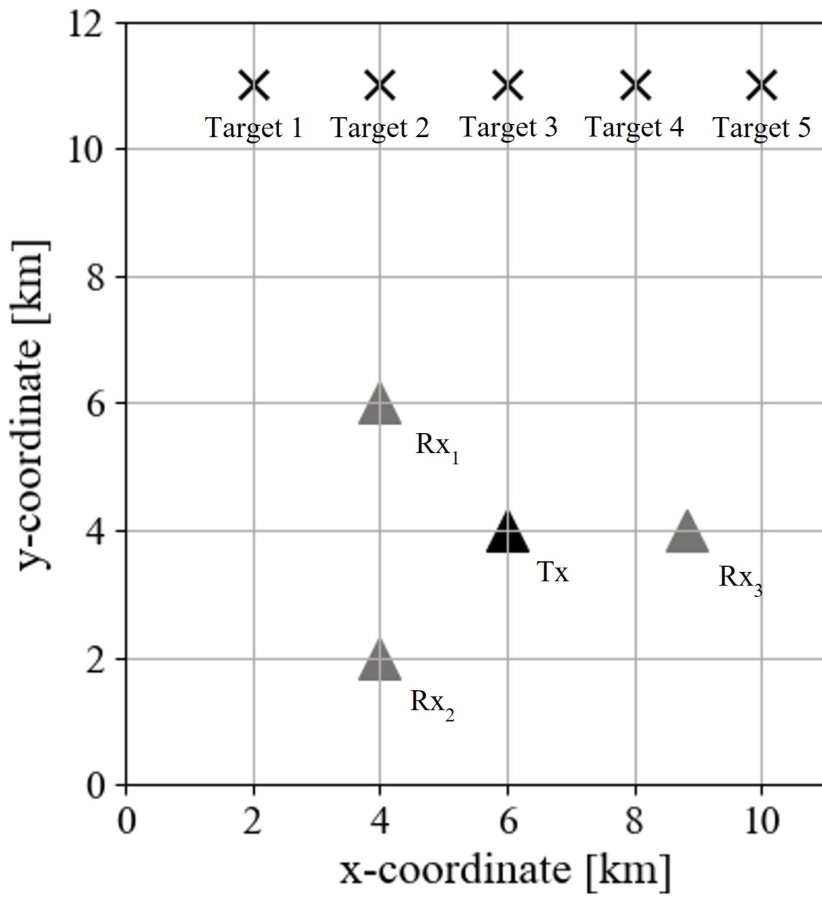
Unlimited Communications



vestigation

ermine power savings of each multistatic system over monostatic system hieve same detection performance

- ree architectures: monostatic, limited comms multistatic, unlimited comms multistatic
- aveform: Rectangular pulse with 1% duty cycle and 1 GHz carrier frequency
- onostatic Tx power: Fixed
- ultistatic Tx power: 60% - 120% of monostatic Tx power
- ve target positions tested
- 0,000 Monte-Carlo reps per position & architecture
- A-CFAR Pfa: $1\text{x}10^{-6}$
- A-CFAR test cells: 100
- A-CFAR guard cells: 2000
- A-CFAR threshold factor: square-law detector
- tal system characteristics maintained
- mnidirectionality assumed for all nodes



thodology: Multistatic Radar Simulator

lultistatic Radar Simulator

- enerates digitised baseband complex signal data
  mono/bi/multistatic systems
- tive and passive modes (Rectangular pulse, LFM,
  'B-T)
- stbed for data fusion, processing, and detection
  nd parameter estimation) techniques
- thon + UCL HPC Clusters

$$] = s[t - \hat{\tau}]\sqrt{PL\sigma}e^{j2\pi(f_D t + f_c \hat{\tau})} + n[t]$$

ved
al

Delayed transmitted signal

Amplitude modulation factor

Doppler shift

Phase shift

Noise

Target Model

- Simplified model to account for bistatic angle ar
  aspect angle

$$\sigma(\theta, \varphi, f_c) = A(\theta, f_c)\,B(\varphi, f_c)$$

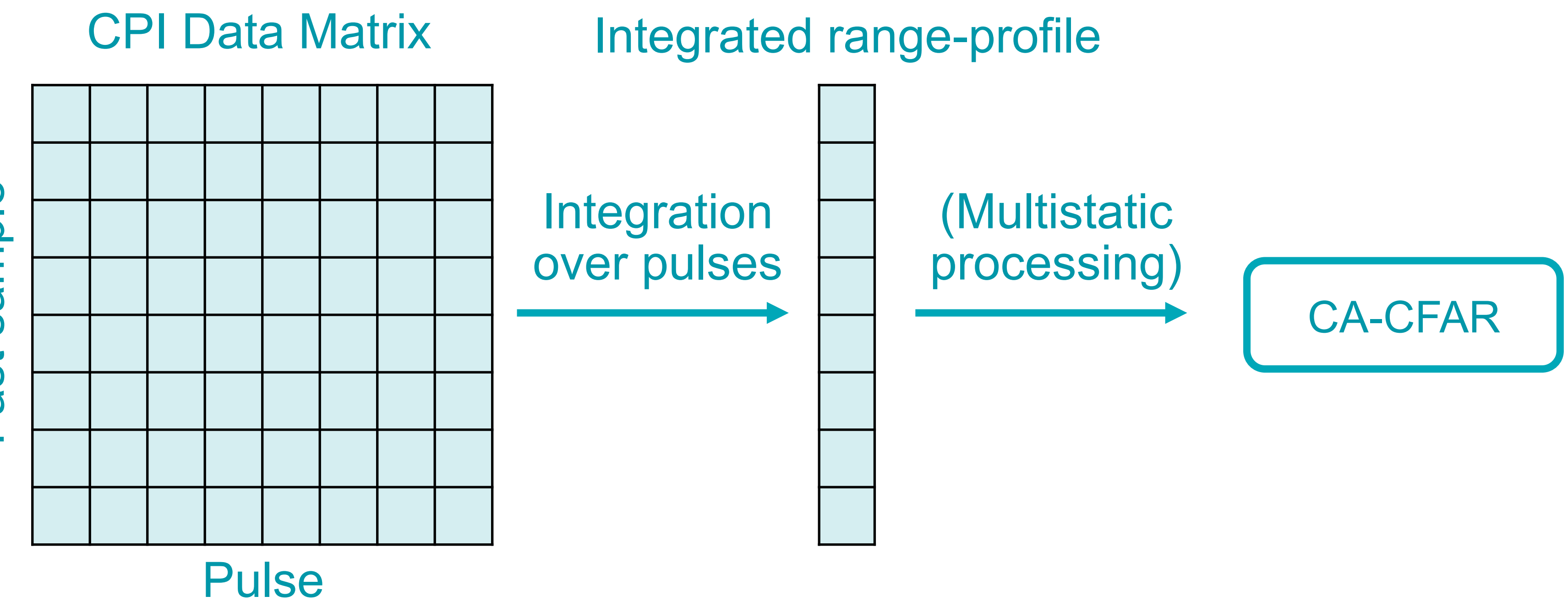
Final RCS

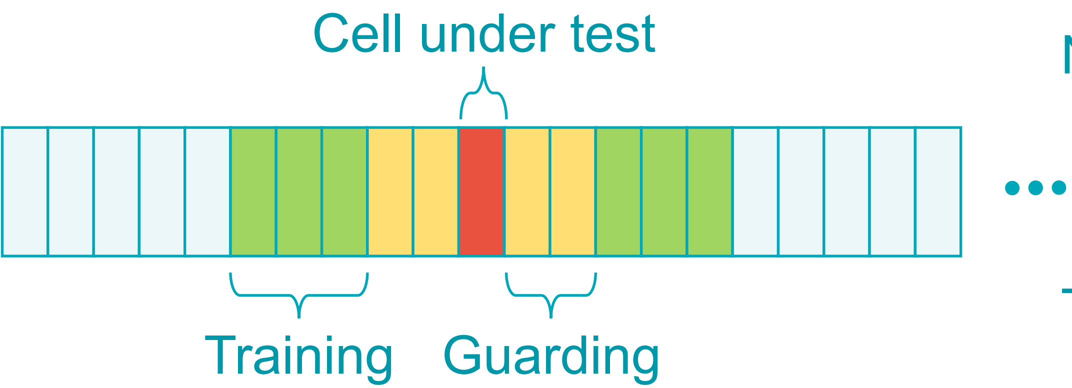
Bistatic RCS factor

Monostatic aspect angle RCS factor

- Bistatic angle contributions from PEC sphere
- Aspect angle contributions from monostatic RC
  measurements of target
- Assumed invariant polarisation
- Chose to use quadcopter style drone
- Slow decorrelation (Swerling Type I)
- Does not aim to include details which lead to tir
  varying characteristic phenomena (e.g. blade-
  flashes)

thodology: CA-CFAR





Cell under test threshold level:

$$V_{Thresh}[i] = \Phi[i] V_{Noise}[i]$$

Noise Estimate:

$$V_{Noise}[i] = \frac{\sum_{k=i-N_s}^{i-\frac{N_g}{2}} |r[k]| + \sum_{k=i+\frac{N_g}{2}}^{i+N_s} |r}{N_t}$$

Threshold Factor:

$$\Phi[i] = N_t(P_{fa}^{\frac{-1}{N_t}} - 1)$$

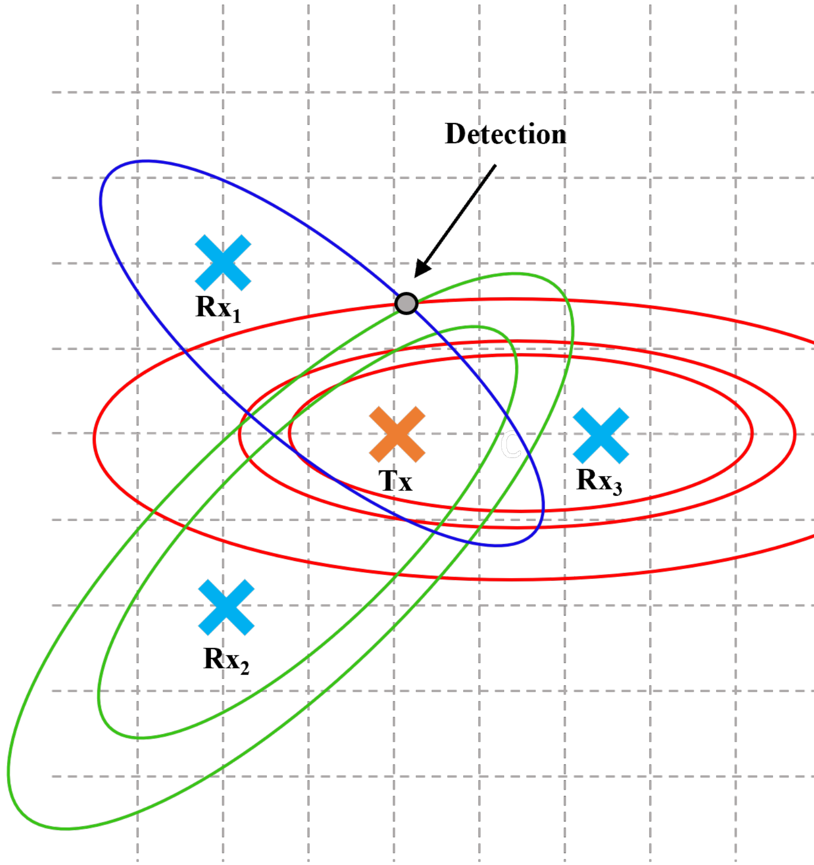
thodology: Fusion Methods

ited Communications

- ch Rx generates a range profile
- tector is used on each profile to determine bistatic ranges at which possible targets are believed to exist
- ts of possible target bistatic ranges shared from all Rx nodes
- ing known radar node locations, possible target bistatic ranges are cross-verified:
  - If an Rx has produced a possible detection which cannot be corroborated by corresponding possible detections from the other Rxs, it is ignored
  - If a combination of possible detections from the Rxs can be found to correspond to a particular point, a detection is declared

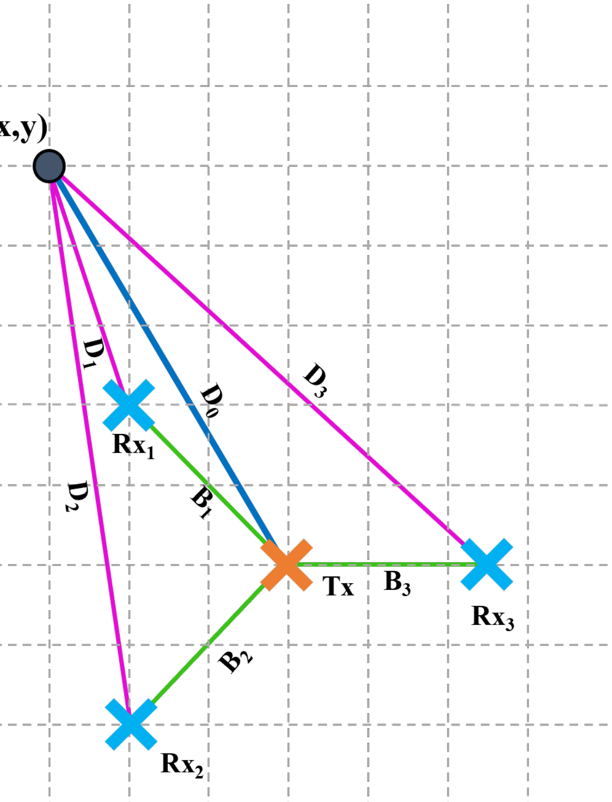
List of possible detection ranges:

Rx_1	Rx_2	Rx_3
br_1	br_2	br_4
-	br_3	br_5
-	-	br_6



thodology: Fusion Methods

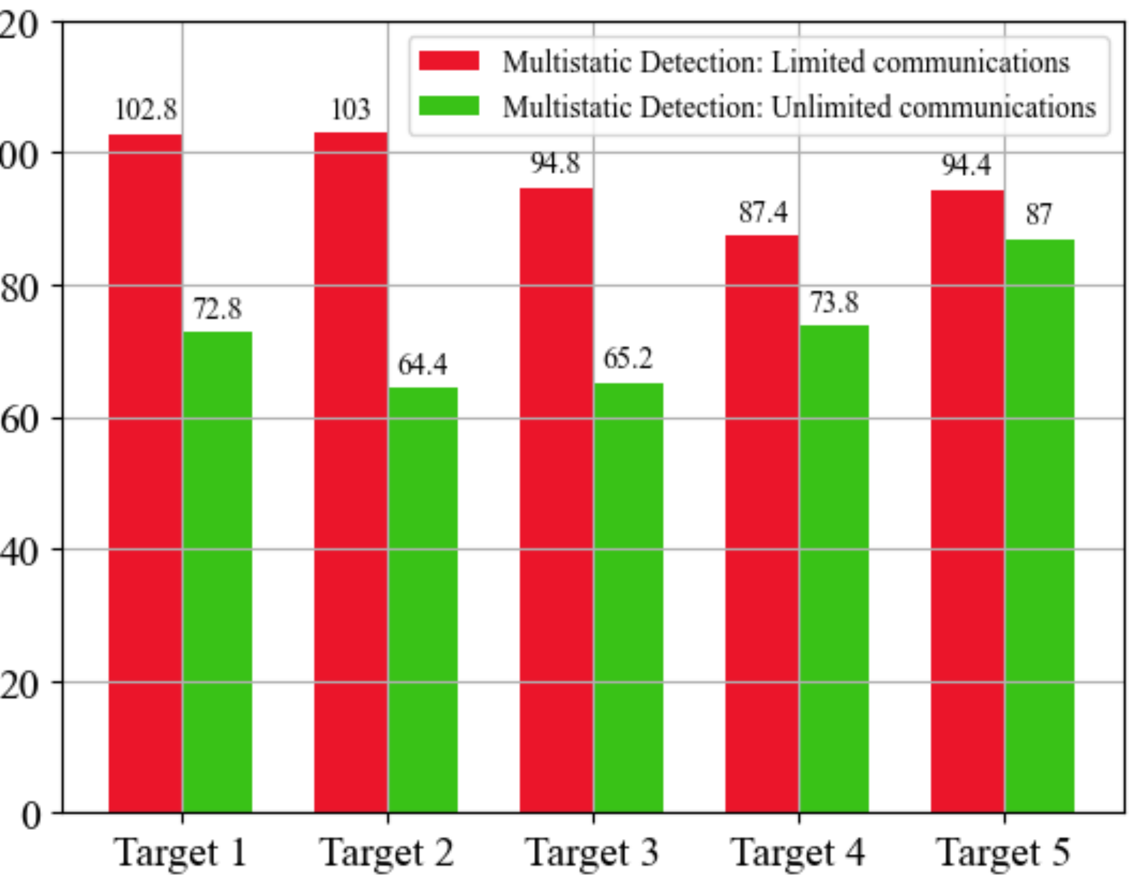
imited Communications



- For an arbitrary point in space, a, each Rx has a particular bistatic geome
- If an echo were to be produced from the point, a, the time of arrival for eac Rx would be different
- The relative differences in this arrival time may be calculated, and relative shifts which must be applied to hypothetical received signals at each Rx i order to temporally align them can be found
- These shifts are applied to the signals received at each Rx
- After shifting all range profiles, summation of the shifted profile from every Rx is possible
- This results in a single profile combining data from each Rx. The single point in the profile corresponding to point a can be inspected with a detect to determine if a target exists at that location
- Repeat for all possible locations in the physical space

sults

enerated by varying Tx power for each multistatic system and determining requir
el to achieve same P_d as monostatic (while maintain P_{fa})



- Unlimited communications (i.e. fusion level close to raw data) enables signi power savings for all target positions tested
- Limited communications multistatic systems offer less power savings but typically perform at least slightly bette than monostatic
- No guarantee that simply increasing t node number improves performance

nclusion

- stablished a comparison of detection performance for ‘edge case’ ultistatic systems relative to an equivalent monostatic system
- bserved empirically, via simulation, that data fusion at a level oser to raw radar data offers the greatest potential for power avings
- herefore… advantages in covertness (LPI operation) as well as se of logistically limited platforms for radar systems may be more ealisable through usage of highly communicative multistatic ystems
- he practical realisation of this presents many significant hallenges

Thank you for listening

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