Active and Passive RF Sensing for Maritime Security

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Outline

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Background - UCL Radar Research Group

• Wide range of radar systems activities – civil, defence and security fields. Modelling, simulation, RF hardware design and build, experimentation and field trials.

• Extensive collaboration with other Universities, Industry and Government Agencies in UK and Overseas

• Funding from a number of sources including;
  • Engineering and Physical Sciences Research Council
  • Natural Environment Research Council
  • Industry
  • Government organisations and Agencies
  • European Union
Motivation

- Marine Security is of increasing importance as terrorist and piracy threats grow

- Many vessels carry radar systems but these may be of limited use against small close range threats especially in rough open waters

- Vessels which are moored or in harbour may not have active systems switched on.
Typical Applications

• Monitoring littoral waters from shore based sites to detect small marine vessels

• Monitoring harbour areas for suspicious movements

• Ship based detection of approaching small boats

• Monitoring shipping channels for non co-operating unidentified vessels
Collaborators

• Civil and military applications

• A range of national and international collaborators working with UCL in this area including:

  • Thales UK and Thales NL
  • Maritime and Coastguard Agency (MCA)
  • Port of London Authority (PLA)
  • US Office of Naval Research (ONR Global)
  • Council for Scientific and Industrial Research (CSIR) South Africa
Current Technology Problems

• Most vessel monitoring carried out by ship or shore based radar - very effective against large vessels at medium to long range but has a number of limitations:

• Detection problems in the case of
  – small targets
  – targets at short range
  – targets in rough seas

• Moored or berthed vessels are unlikely to have active radar systems switched on.
UCL RF sensor solutions

- UCL has been looking at two potential solutions:
  - Active Systems: Multiple networked radars able to form a better picture of the environment close to the sea surface
  - Passive Systems: Wireless based passive radar for monitoring harbours and littoral waters where no active systems are available or in use.
Active Systems
Networked radars – *Basic Principles*

- Two or more radars view the target from different perspectives
- The radars are connected and synchronised in time so that target data can be fused together coherently
- This can result in improved target detection and classification
Active Systems
Networked radars –*UCL Hardware and Experiments*

- UCL has developed a COTS based radar network
- Measurements of land targets have been carried out in the UK
- The radar power has been increased and trials of sea and maritime target returns are scheduled for Autumn 2009.
Active Systems
Networked radars – *UCL Hardware and Experiments*

- Land based radar network trial carried out at a UCL site.
- System field tested and results show enhanced detection

Trials site with radar nodes and antennas

Typical result showing enhanced target detection
Active Systems
Networked radars – *UCL Hardware and Experiments*

• Sea surface and marine target measurements now underway in UK

• GPS synchronisation of nodes and wireless data link being investigated in order to increase current cable length limited inter-node distance.

• Field trials campaign being planned for the Western Cape of South Africa for Autumn 2009 in conjunction with CSIR, University of Cape Town, Thales UK and ONRG

• Planned to demonstrate the advantages of networked radar in detecting small high speed vessels especially in higher sea states.
• Networked radar marine test sites in South Africa:

  Simon’s Town Naval Base

  Cape Point Area

  Western Cape
Passive Systems
Wireless based passive radar - *Overview*

- Wireless network transmitters are being widely rolled out and can be used as transmitters of opportunity for a passive detection system
- Only a passive receiver is needed making the system covert and lower cost
- The target return is correlated with a copy of the direct signal to extract target information
- UCL have already demonstrated personnel detection using *WiFi* in an indoor environment
- This work is being extended to the more powerful *WiMAX* system for outdoor surveillance
- A programme on vessel monitoring in conjunction with the Maritime and Coastguard agency is now underway
Passive Systems

WiFi based passive radar — typical airport/mall/office security scenario
Passive Systems

WiMAX based passive radar – Outdoor applications

- WiMAX can be deployed in a range of scenarios.
- In general this differs from WiFi in being longer range and in a primarily outdoor environment.
- This presents a different propagation environment and potentially reduces the problem with clutter, multipath and attenuation present in indoor situations.

- Intruders/Security Monitoring
- Personnel Location
- Vehicle tracking
- Vessel Monitoring

Link to central command and control centre
Passive Systems

*WiFi based passive radar – indoor detection results*

- Doppler/range plot for running person in corridor showing target detected at around 25 Hz Doppler using a 100 ms integration time.
Passive Systems

WiMAX based passive radar for vessel monitoring

Typical System Geometry
Passive Systems

*WiMAX* based passive radar for vessel monitoring

*Results and Analysis*

- A project sponsored by the Maritime and Coastguard Agency (MCA) has analysed potential WiMAX passive radar performance in two busy shipping areas:
  - Dover Strait
  - Port of London/Thames River and Estuary

- Signal strength maps have been plotted for typical targets marine targets.
Simulated WiMAX Radar SNR performance based on a 10 km baseline (green contour lines). The transmission power of the WiMAX basestation is 85 dBm EIRP and the target radar cross section has been set to 4000 m² (for the S-band WiMAX radar) to represent a large tanker. The red lines are the SNR = 10 dB contours for the existing active radars in the Dover Strait. The first simulation (a) uses an omnidirectional antenna and the simulation in (b) uses an 8 degree beamwidth directional antenna.
Simulated WiMAX Radar SNR performance based on a 32 km baseline (green contour lines). The transmission power of the WiMAX basestation is 85 dBm EIRP and the target radar cross section has been set to 4000 m² (for the S-band WiMAX radar) to represent a large tanker. The red lines are the SNR = 10 dB contours for the existing active radars in the Dover Strait. The first simulation (a) uses an omnidirectional antenna and the simulation in (b) uses an 8 degree beamwidth directional antenna.
WiMAX Radar SNR performance based on bistatic baselines of (a) 10 km, (b) 22 km, and (c) 32 km. All simulations use a radar cross section of 400 m² to model a medium sized coaster target. For clarity, SNR contours in the 10-20 dB range are shown.
Coverage contours for a WiMAX transmitter located on the Margate coast and the associated passive radar receiver located within the Kentish Flats windfarm. The SNR = 10 dB contour in (a) is generated from a target with an RCS of 40,000 m² (representing a carrier container vessel) and in (b) an RCS of 400 m² (representing medium sized coaster). The bistatic baseline in both simulations is 22 km.
Passive Systems
WiMAX based passive radar for vessel monitoring

**Potential system design**

- Since location of system and base station are known:
  - Would provide true range to target rather than “bistatic range”
  - Would also provide target bearing
- Output is therefore comparable with traditional radar
- Output would be suitable for use with existing processing
Passive Systems

WiMAX based passive radar for vessel monitoring

**Summary**

• These results show that medium size vessels could be detected out to 20 – 30 km depending on the design of the antenna.
• This would imply that small boats could be detected at ranges of several km.
• Calculations show that range resolution down to a few meters and Doppler resolution down to the equivalent of 0.6 knots can be obtained.
• Location accuracy can be further improved with triangulation and narrow beamwidth receive antennas.
Summary and Future Directions

• Two novel RF sensor solutions for maritime surveillance are being investigated at UCL

• Both active and passive methods have potential for security and defence applications

• A series of further simulations and experiments are planned to test the feasibility of these methods in real situations

• Potential users from civil and defence fields are actively engaged in these activities