The Polarimetric Dynamical Estimator HRP Improving Success in the Detection Process

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ABSTRACT

In several circumstances targets at sea are difficult to detect. This difficulty is intrinsically related to the target's physical attributes and its environment (sea and weather conditions).

The possibility of detecting and scaling the ATR levels from detection up to characterization depends on such aforesaid difficulties. In any given situation, are there any physical attributes which might enhance and temporarily stabilize the target radar response and/or the background?

The existence of such attributes could be initially detected by adopting a series of suitable RF radar parameters.

This poster illustrates the results of a technique based on the use of suitable RF parameters, data acquisition and processing methodologies in order to improve the probability of success in the detection process.

An agile full polarimetric multi frequency and PWs radar is used to transmit and receive scattered echoes.

I and Q channels are acquired using four fast, wide BW A/D converters possessing high throughput to memory. This allows the acquisition of a complete set of scattered radar responses from portions of sea surfaces that probably contain a target. Radar responses (echoes) catalogued in a scattering data bank are then used to feed a recursive d & c algorithm employing the polarimetric estimator which indicates the likely presence of targets in the area.

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RADAR MMS 300

Fig. 1

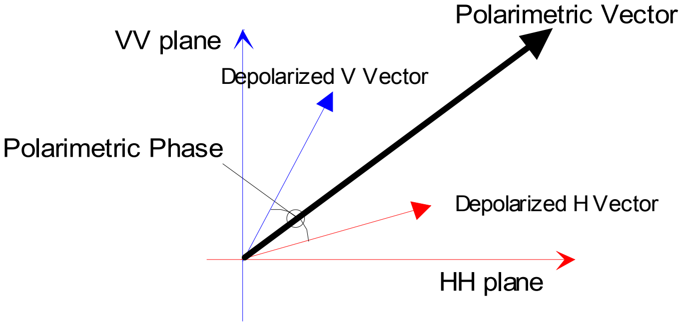
Fig. 2

Fig. 3

(Fig.1 and Fig.2)
MMS300 Radar;
2-18 GHz, polarization and frequency agile, multi PWs.

(Fig. 3)
4-channels A/D converter;
Wide analogic and digital bandwidths with high throughput to memory.

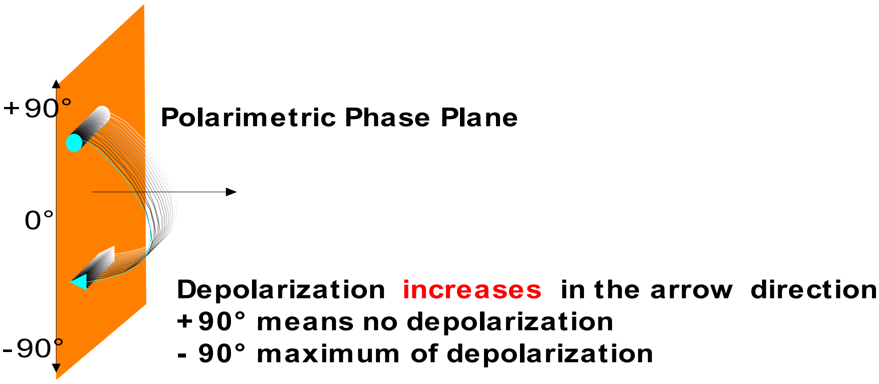
Polarimetric vector



Depolarization Plane

$$\vec{E}_H \bullet \vec{E}_V = \left\|\vec{E}_H\right\| \cdot \left\|\vec{E}_V\right\| \cdot COS\delta$$

The polarimetric vector allows the recovery of the scattered radar energy regardless of the depolarization it may have suffered.



INVARIANCE

With current technology large and small targets may represent the same threat level as well as having the same RCS.
This implies that all targets must be detected however small their RCS.
In a detection process, instead of using RCS, the use of different RF parameters might result in a stable radar response therefore increasing the probability of survival and the possibility of reaching higher ATR levels.
Doing this depends on the existence of certain physical target attributes – referred to as INVARIANT PHYSICAL PROPERTIES - whose radar response is stable.

> **INVARIANT RADAR QUANTITY**
> A quantity (tensor, vector or scalar) obtained by the analytic combination of some RF quantities giving a radar response which remains stable even if the interrogating frequency, PWs, and time of observation are altered.

The need

Detection of targets at sea.

The dynamic estimator

A procedure based on the use of the RADAR INVARIANT QUANTITY HRP: a scalar which is stable in time and space and obtained by the right combination of all the elements of the complete scattering matrix.
This scalar is not expected to be dependent on frequency and PWs but is very sensitive to changes in polarization.
Its efficacy is related to both the polarization coherence of the target and the polarization incoherence of the rough sea.

The procedure

A series of bursts are emitted at various frequencies, PWs and polarizations.
Received scattered pulses acquired in different range gates build up the complete scattering matrix.
A recursive algorithm based on a dynamic estimator permits the search for signals compatible with the presence of targets in the marked areas.
Subsequent specialized searches may be conducted in the identified areas by varying transmitted and received RF parameters (frequency, PWs).
Detected targets illuminated with specialized radar RF parameters are then studied in order to scale all levels of the "ATR chain" through the use of the dynamic estimator.
The procedure is not stochastic but deterministic.

Use: Target detection and characterization

Fig.4

Sea and Targets are synthesized

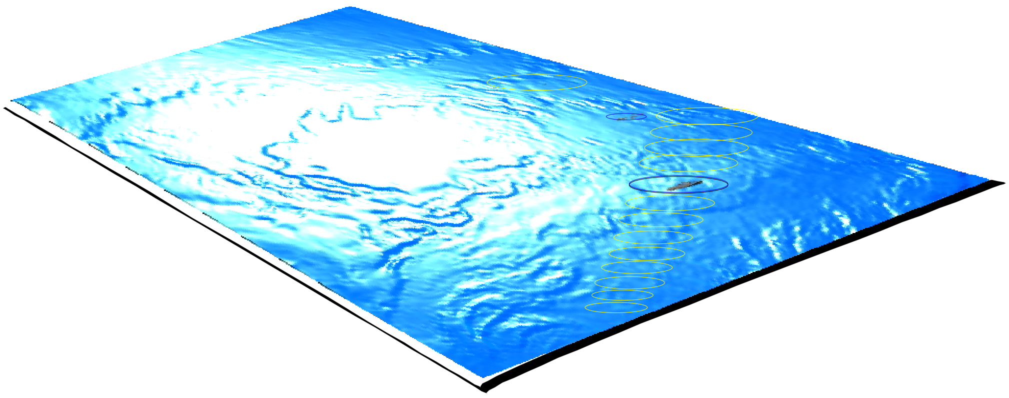


Fig. 5. Polarization area synthesis

A technique capable of calming a rough sea.
Targets are seen as in a calm sea

Fig. 6. Detail of photograph of the Fig.4

A 150-mt ship at anchor with tugboat on starboard side.
Graphs and ISAR radar images presented on right side of poster are referred to this ship.
The anchored ship avoided the necessity of doing range compensation on data.

Uses of dynamic estimator

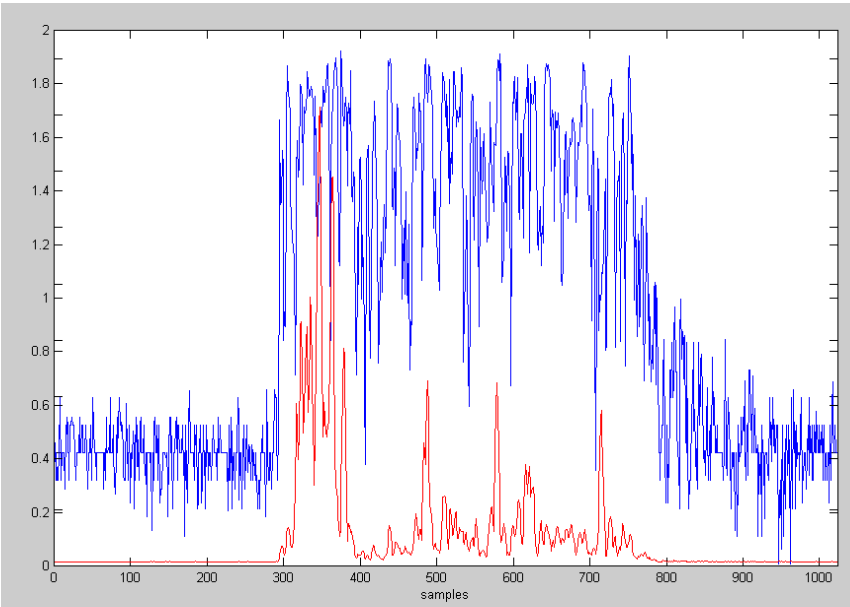


Fig. 7. Blue HRP vs down-range (d.r.) - Red Mag of Polarimetric vector vs d.r.

Trailing and leading edges correspond to interfaces sea-target-sea.

Some detail of the above Fig. 7.

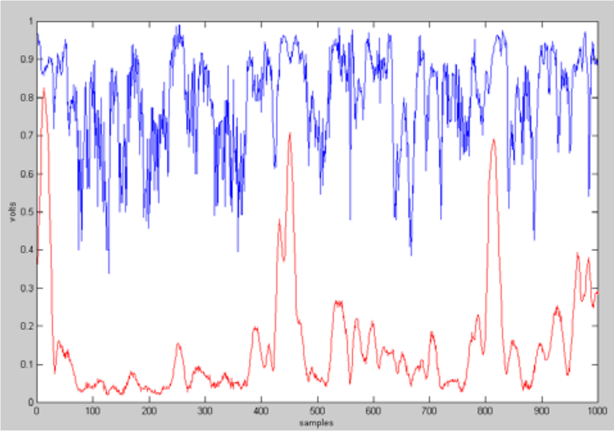


Fig. 8

Blue HRP vs d.r.
Red Mag of Polarimetric vector vs d.r.

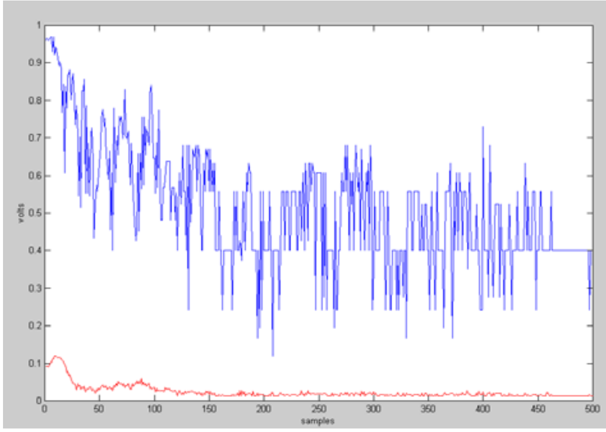


Fig. 9

Blue HRP vs (d.r.)
Red Mag of Polarimetric vector vs d.r.

- Targets are easily and automatically detected;
- The ATR chain can be scaled up to the desired level;
- Potential applications encompass any situation for which an ATR process has to be primed.

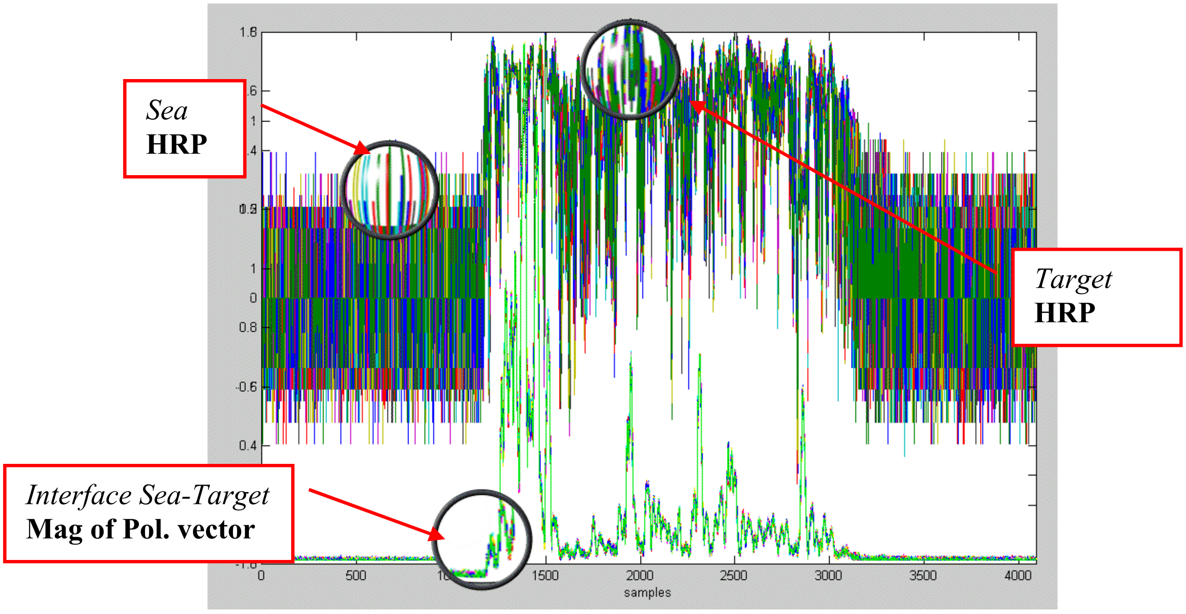


Fig. 10. Upper coloured graphs represent 100 different HRPs vs d.r.
Lower green graphs represent 100 different polarimetric vector MAGs vs d.r.

Each single graph was acquired in single shot. Point-to-point distance on each graph: 7.5 cm.
Graph-to-graph time distance is 1 msec; total observation time: 100 msec.
HRP is also sensitive to small MAG values of the target scatterers.

Below graphs are histograms of different detail part of the HRP signal of the above Fig. 10.

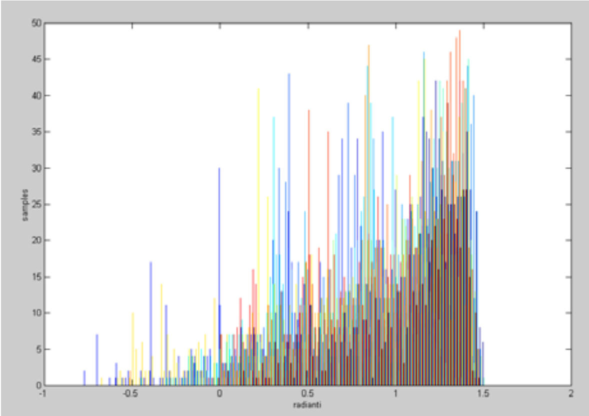


Fig. 11
HRP histogram performed only on entire target echo

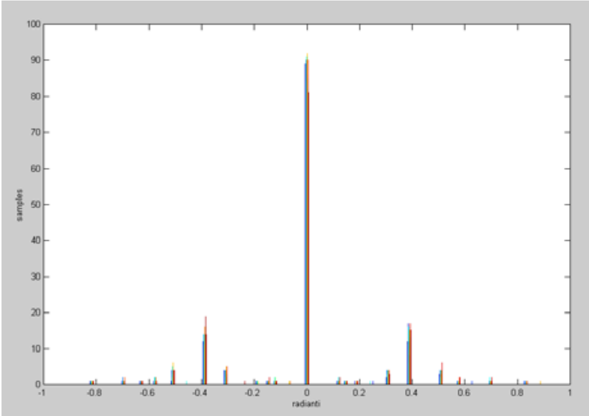


Fig. 12
HRP histogram performed only on sea radar signal

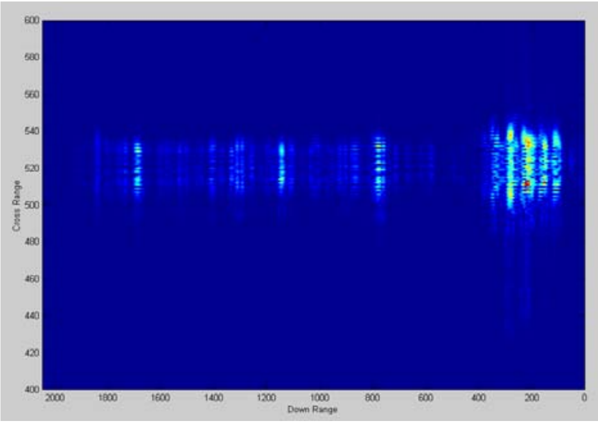


Fig. 13
2D ISAR radar image of circled ship in photograph of Fig.6.
X axis is d.r.; Y axis proportional to elevation angle.
The image is obtained using Magnitude of VV channel.
Down Range spatial resolution (Rayleigh criterium) is about 70 cm.
During observation time the roll angle variation was predominant and permitted a resolution in elevation range of about 4 mt.
Data was not focused nor compensated nor absolutely calibrated

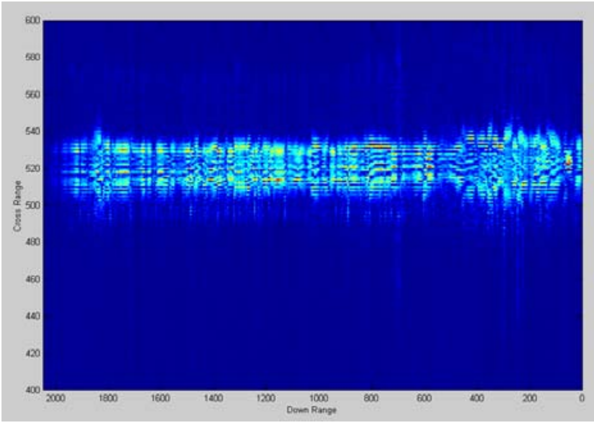


Fig. 14
2D ISAR radar image of the circled ship in the photograph of Fig.6, obtained using HRP.
Target textures, particulars and contours are made evident.

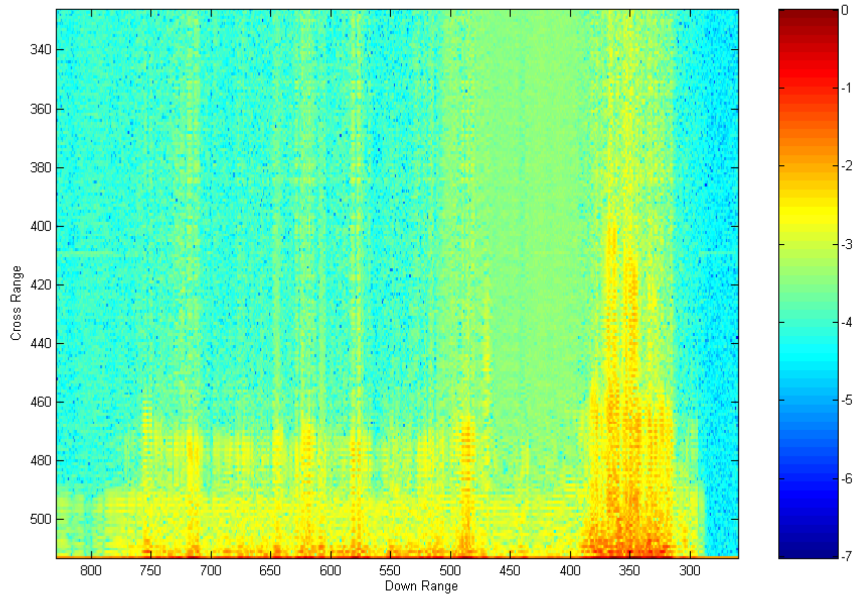


Fig. 15

2D ISAR radar image of circled ship in photograph of Fig.6.
X axis is d.r.; Y axis is proportional (not linearly) to the height of the scatterer in relation to the sea level. The radar image is obtained using the Mag of VV channel. Dedicated processing techniques permitted the extraction of the scatterers having different heights in relation to sea level.

Some verification

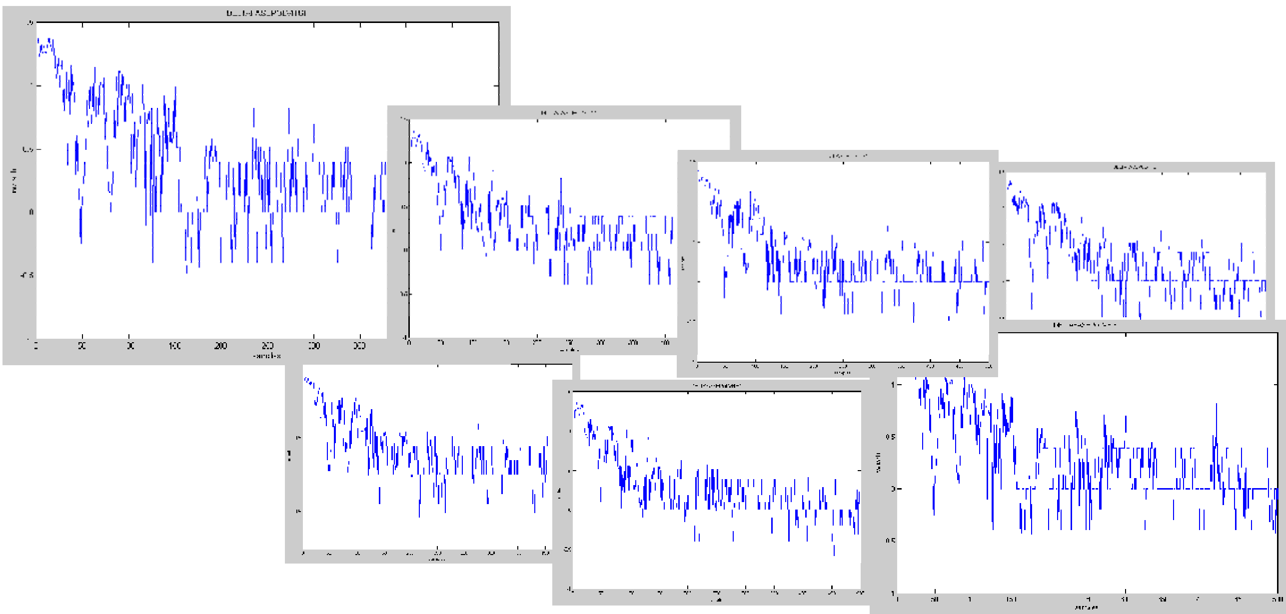


Fig. 16

Each Graph represents HRP vs time (down-range). Raw I & Q data were sampled in single shot. Elapsed time graph-to-graph is 140 msec. X axis is time (sample-to-sample about 500 psec).

Trailing edge of HRP of circled ship in the photograph of Fig.6. HRP is stable in space and with passing time.

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