

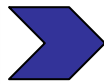
High Definition Surveillance Radar (HDSR)

Powered by RAYTHEON

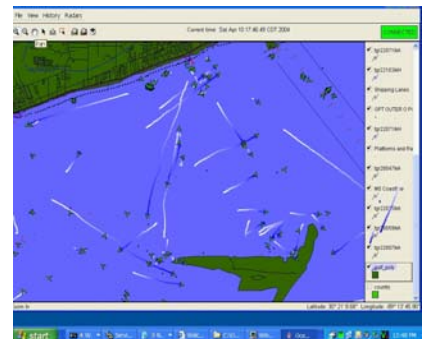
INTRODUCTION

Ocean Technologies introduces High Definition Surveillance Radar (HDSR). This highly developed surveillance and tracking radar uses a conventional vessel tracking system (VTS) radar. The HDSR applies advanced Raytheon developed correlation and multiple hypotheses tracking techniques to separate real targets from false targets even in high seas, thus enhancing the performance of standard tracking radars by several magnitudes. The system differs from normal commercial off-the-shelf (COTS) VTS or surveillance systems in hardware and tracking algorithms. Conventional marine and vessel tracking system radars have sufficient transmitter power, receiver sensitivity, and resolution in range and azimuth to detect extremely small targets when the targets are not obscured by waves. Thousands of small clutter and noise features, however, are also detected and tracked as false alarms, without proper computerized processing. HDSR automatically qualifies and initiates tracks on the smallest awash targets, such as Zodiacs and RHIBs as well as large vessels. These small targets are so frequently obscured behind waves and buried in clutter that even experienced operators are powerless to discern and track them. The HDSR is easy to use because the operator need only set a few operationally intuitive controls and therefore requires no specialized training. The HDSR automatically configures itself to deliver good performance depending on the radar pulse length set by the operator, the broad operational requirements for the tracking mission (maximum target speed, size, maneuverability and desired false track density) and the approximate sea conditions (sea state, swell).

High Seas lightweight radar, 25 kW or better.



The HDSR uses dedicated radar signal processing and tracking computers that are connected



Tracks and status data are displayed on the PC or web based Operator Console.

System Characteristics

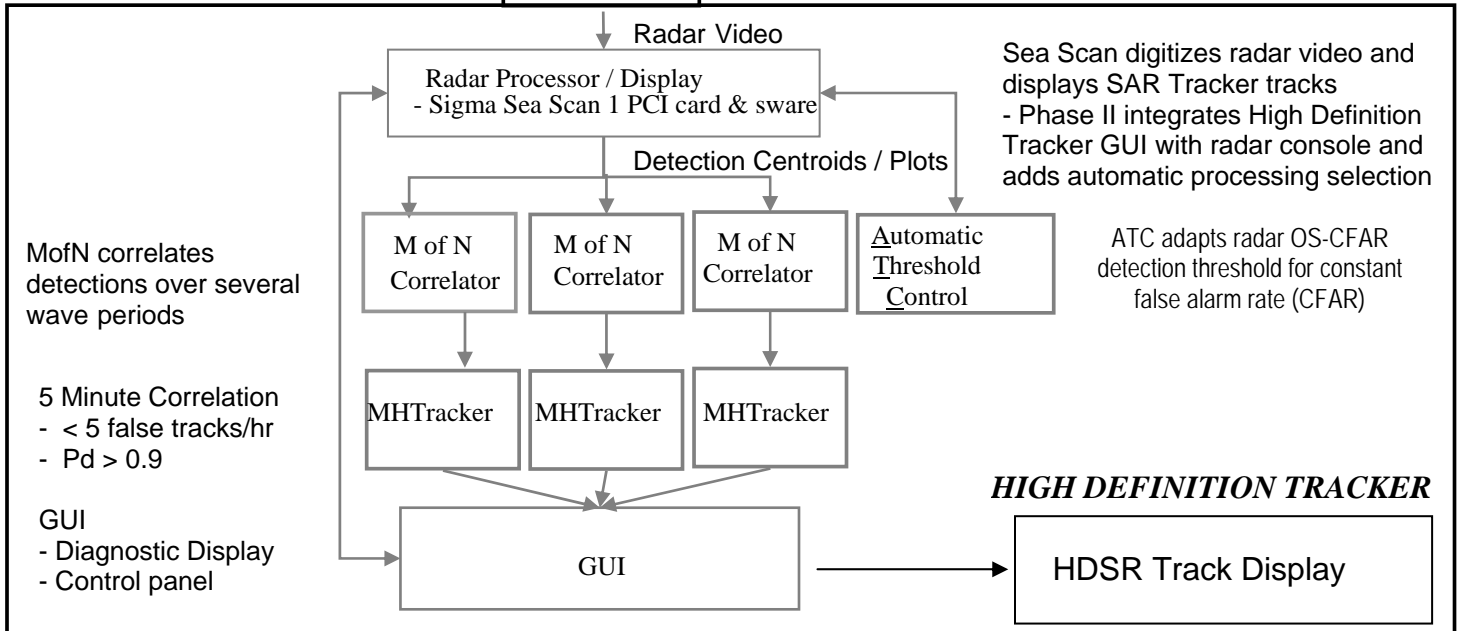
- Radar Transmitter COTS/VTS (Existing or New)
- Digitization Process Hardware
- 10 Zeon Processors and 10Gb of Ram
- 4 Multiple Hypothesis Trackers
- AIS Receiver
- Integrated Display (data may be forwarded to existing display)

HDSR TRACKER PROFILE



COTS Radar Sensor

Any VTS qualified radar up to 60 rpm



HOW DOES IT KEEP FROM REPORTING CLUTTER?

Through the presence of three specialized processing blocks:

1) ADAPTIVE CFAR DETECTOR

The HDSR computes an adaptive Constant False Alarm Rate (CFAR) threshold that maintains a constant probability of false alarm throughout the field of view. Extensive trials have demonstrated that true local CFAR is maintained irrespective of the local clutter intensity and statistical characteristics. The radar image is divided into 120 bins and optimized independent of each other. This allows the adaptive threshold to adjust out rain clouds and remain sensitive to small targets in other areas.

2) M OF N CORRELATOR

The M of N Correlator qualifies a return by setting the number of detections, or "hits", for a given number of radar scans to allow a target to show up as a return. It implements three nested correlations to combat bursts of plots from short-lived but strong sea spikes, like breaking waves, that would otherwise appear target-like. The M of N Correlator uses balanced tree techniques to build and prune a large dynamic database. In some cases, the M of N Correlator has run successfully with over 60,000 plots in its database. The software is written in object-oriented multi-threaded code and runs on a normal PC.

3) MULTIPLE HYPOTHESIS TRACKER (MHT)

The MHT is a statistical approach, incorporating false targets, new tracks, missed detections and finite track lifetimes. On conventional radars, the possibility of incorrect target association creates great problems associated with tracking multiple targets, based on large numbers of radar detections. The basic premise of the MHT is that through the application of Bayes' rule, the probability of any track/detection combination over a given number of radar updates is solely dependent on the probability of the combination from the previous scan, and the probability of the current track-detection updated association. The algorithm thus does not make any "hard" assignments at each step, it instead keeps all possible track/detection associations, ranking them by their probabilities (i.e., how

likely a given association actually is). Such hypotheses may be efficiently updated at each step merely by calculating the current probabilities for association. Thus, a combination of tracks and detections that looks very likely at one stage, may be at a later time revealed to be less feasible as its updated probability decreases. The correct (or more likely) association hypotheses will then predominate, allowing incorrect decisions to be prevented.

The MHT processing assumes that each new M of N plot is either an extension of an existing track, a new target or a false alarm (these last two options are combined). The combination and extension of tracks and hypotheses implies that there is exponential growth as new hypotheses are formed at each update. Efficiency is further maintained by clustering the data, whereby the multiple hypotheses are considered only for groups of tracks and detections that are close to each other. In this way, clusters may be processed independently and in parallel, preventing unconstrained growth of the hypothesis tree. The best track/detection hypotheses are determined as solutions to a linear assignment problem where the elements or "costs" are determined (probabilistically) by the closeness of targets and detections. In the HDSR, the auction algorithm is used (repeatedly) to solve these problems. Once under track, the target trajectories are propagated using a Kalman filter. The HDSR automatically initiates high confidence tracks on all targets meeting the user-defined criteria for track initiation. The track initiation process is extremely resistant to false alarms yet is very rapid when there is clear evidence of a track. All tracks are confirmed through two lower-confidence intermediate stages:

1. Potential Tracks result when plots on two consecutive updates (i.e., of M of N Detections) are close enough that they can be associated
2. Tentative Tracks are the extension of Potential Tracks through successive updates.

Because of their much greater confidence than the Tentative and Potential Tracks, only Confirmed Tracks are shown to the operator.

The HDSR can be configured so that on average less than 1% of pre-existing tracks will have lost track at any time. Once confirmed, tracks will be coasted for a user-set number of M of N updates to bridge periods of poor detections, target overlap and other problems. Confirmed tracks are always coasted further than tentative tracks as benefits the greater confidence expressed in them. The HDSR is particularly tolerant of crossing targets because of the use of multiple hypotheses and rigorous Bayesian association logic. As long as successive scans eventually resolve the targets before the tracker has reached 50% of its coasting limit, then in 95% of all cases the tracks will be unambiguously associated again. False tracks receiving updates are also rare and short-lived because of:

1. The limited number of false detections passing the M of N Correlator, and
2. The Bayesian association logic which is rigorously tied to the radar error ellipses and the estimated Kalman filter error.

THEORY OF OPERATION

The basis of HDSR design is that the Pathfinder II, and other High Seas Radars of 25 kW and 9-degree beam width or better (such as Furuno and TERMA which have been tested with this system), has sufficient transmitter power, receiver sensitivity, range resolution and azimuth resolution to (on average) raise small targets above the clutter. The resulting average probability of detection over many scans for a 1 square meter RHIB in heavy clutter will be low, typically 0.3 to 0.5, while the probability of false alarm will be high at 0.01 to 0.001 but this is precisely where the HDSR excels. The HDSR works by first minimizing the effects of sea clutter and then measuring the spatial and temporal correlation of each detection with those from previous scans. Next, the system correlates the sparse target detections amidst the more numerous clutter detections, over many scans, to accumulate a statistical basis for declaring a high confidence target track.

There are five user-configurable Data Extraction and Scan Averaging processing stages:



1. **Pulse Filtering**—integrates across the beamwidth to maximize the signal to noise ratio and remove impulsive noise
2. **Scan Averaging**—integrates over several scans to further improve signal to noise ratio and smooth out sea spikes
3. **Ordered Statistic CFAR**—reliably detects small features in clutter and is less affected by clutter statistics than simpler cell averaging CFAR
4. **Adaptive CFAR Threshold**—maintains constant probability of false alarm irrespective of the local clutter strength and statistics
5. **Centroid Plot Extractor**—locates the center of mass for contiguous detections, produces a “plot” and excludes those plots that are too large or small to be the target of interest

Plots are then processed by up to four, HDSR Trackers, each operating on networked dual Xeon computers and each consisting of :

- a) **M of N Correlator**—correlates over several scans to identify clusters of plots that are sufficiently grouped to be called a single target. Slower targets can be correlated over longer intervals than fast ones.
- b) **Multiple Hypothesis Tracker**—correlates M of N Detections into tracks using rigorous Bayesian association logic and Kalman filtering. Multiple hypotheses enable the tracker to maintain several candidate tracks and thereby resist confusion from the numerous clutter detections and missed target detections.

Typically each Correlator-Tracker would be configured for a particular class of target. Most commonly, one is configured for long correlation to detect small, slow targets and the other for short correlation to detect slightly larger but faster targets.

The Pathfinder II, Tracker, CFAR Detector, and Plot Extractor are easily configured to output detections in selected areas. Two techniques are available to the user:

1. high-resolution clutter masks typically 1024 to 4096 range X 1024 azimuth resolution cells, that can be easily drawn by the operator using a stored digitized image as a template, and
2. up to 32 sectors, each defined by the start and extent in azimuth and range.

PERFORMANCE

SEA STATE 3

HDSR is unique because it was explicitly designed to operate under these conditions and worse, being originally developed for North Atlantic shipboard search and rescue of targets as small as 0.03 square meters of Radar Cross Section (rcs), and in seas above 3 m. Such targets are awash and usually masked from masthead detection, being only detectable when they are at a wave crest. As the ship rolls, the radar frequently describes a 5 – 10 meter arc, which adds range error. In addition, the clutter varies in both strength and statistical properties between up, down and crosswind and is modulated by the prevailing ocean swell.

Analysis therefore predicts that a small 1 square meter rcs RHIB in sea state 3 is indeed detectable by the Pathfinder II from 3 to 15 km with a Probability of Detection equal to 0.5 and Probability of False Alarm equaling 0.01.

The reason most trackers cannot handle such targets in clutter is, that they are swamped by the excessive clutter detections that come with any reasonable probability of detection under these conditions.

SEA STATE 2

Using the standard Modern Radar System Analysis software tool, the Pathfinder II is estimated to detect the RHIB in Sea State 2 between 3 and 10 km with a Probability of Detection equal to 90% or 80% depending on whether the Probability of False Alarm is set to 0.01 or 0.001, respectively.

SEA STATE 1

Clutter is typically so low that the radar should be operated in the 200 nanosecond pulse mode rather than the 80 nanosecond pulse mode. The detection performance against targets in noise at long range is thereby significantly improved by the increased pulse energy.

EQUIPMENT AND MAINTENANCE

The HDSR is implemented on five dual-CPU PCs and integrated into the Pathfinder II (Raytheon) by Ethernet. Noteworthy is that the HDSR has also been tested with the Furuno and Terma radars. Maintenance and upgrades are facilitated by the use of standard PC hardware and software. All software is in object-oriented code. This facilitates system maintenance and enables Ocean Technologies to address customer-driven improvements at a reasonable cost. New features can be added with much less effort than would be normal, with lower level languages such as C.

Although the operator controls the HDSR with a few intuitive controls, the underlying parameterization is very detailed. These parameters are set-up on installation. A diagnostic display is provided to facilitate tuning the system to the particular site, mission and sensor characteristics.

CONCLUSION

HDSR reliably detects and tracks small targets with very few false tracks because:

- Data Extraction—Scan Averaging maximizes target detectability on each scan
- M of N Correlator dramatically reduces the number of false detections entering the Multiple Hypothesis Tracker
- Advanced MHT association techniques follow strict Bayesian logic, that minimizes the chances of spurious associations
- For a track to be confirmed, two consecutive M of N updates must be associated into a potential track, which must have several (typically 3 – 5) updates to be confirmed. If several updates pass with no association then the tentative track is deleted and never confirmed. The odds of sea clutter passing these criteria and being confirmed is extremely low under normal operating conditions.



HDSR will provide the most superior cost effective close-in and long-range, maritime surveillance while providing highly effective small target tracking for standard microwave radars. The HDSR product can be offered as a “stand-alone” or fully integrated “turn-key” system.

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