CHAPTER 1 RESEARCH FORMULATION

1.1 INTRODUCTION:

'*The key to air power is targeting and the key to targeting is intelligence'* - Col John Warden, 1990.

Today Remote Sensing and Image Interpretation carried out in the field of Security, Earth Observation & Surveillance, has shown large improvements by the use of software tools for Image analysis. However the requirement of the Image Interpreter / Analyst is indispensable for the system to operate efficiently. This is because the Image Analysis is both quantitative & qualitative in nature and also comparative & associative with the leading associated features against knowledge base. The value of information / Intelligence obtained is time-bound. Image Interpretation from huge remote sensing data by qualified Image Analysts is time consuming in the absence of reliable automatic analysis tools. Hence an objective approach to the fundamental Image analysis problem is rather an intelligent decision making process with a required degree / probability of success. Being an image interpreter, it is able appreciate the effort required especially when it comes to targets in vast oceans. India being a peninsular country has potential threats through seas which have been proven by 2008 Mumbai attacks and various breach of coastal security lines. With the Launch of RISAT-1 in Apr 2012 and further operationalisation, there has been potential availability of data which could be used for coastal monitoring. Also with RISAT-1 having the option of

Circular polarisation, Linear Receive capability which is available commercially, there is a vast opportunity for applications especially in the field of maritime reconnaissance.

1.2 REVIEW OF LITERATURE

Analysis of CP (Compact Polarimetry) image data has different approaches in general. First is based on using the parameters extracted from the CP Stokes vector (Charbonneau et al., 2010; Stacy and Campbell, 1993; Carter et al., 2011 & Raney, 2006; Raney 2007b) for the applications of planetary imaging. Second approach is based on the use of CP data to derive estimated components of quad-pol covariance matrix and use these to reconstruct quad-pol data called Pseudo-Quad (PQ) data in the existing quad-pol algorithms (Souyris et al., 2005 and Nord et al., 2009). Although these algorithms were designed for terrestrial imaging, it had excellent agreement with PQ covariance matrix and ground truth in maritime imaging (Collins et al., 2002).

The intial applications of CP to ship detection have been by Yin et al., (2011) in which the Souyris reconstruction algorithm for targets (like ships) by adding a helix scattering component to the covariance matrix model to change the volume scattering components and Shirvany et al., (2012) used the degree of polarization, a parameter derived from the Stokes vector, to detect ships qualitatively. Study on the use of compact polarimetry SAR for ship detection by G.E Atteia and M.J. Collins, 2013 also indicated performance of PQ HV data is the strongest of all the detectors followed by HV and CTLR data and

was as good as quad-pol data. The potential of compact linear polarisatioin SAR (CL-pol SAR) based on RADARSAT-2 using the relative phase helped in automation of static target detection of wind farms over large areas of oceans even at higher sea states (H. Li et al, 2013). A similar attempt by Yin et al (2015), based on Extended Bragg model, assuming backscatter reflection symmetry proposed a method for circular polarised transmission CP mode which provided comparable results as of full polarimetric data for ocean target detection proving the potential in ship observation. Based on the literature review, it is found that no actual CP data was used and also the quad pole reconstruction has been criticized for lack of consistent assumptions for terrestrial imaging while for a limited region of ocean the quad-pol data offered greater information (Cloude, 2009). Similar qualitative evaluation of CP data for ship detection and wetland by Touzi (2009) found that the CP data could not replicate his limited quad-pol based analyses.

All the studies have revealed that CP or hybrid pol data is not a substitute for the quad-pol data but in the case of ocean or maritime surveillance applications, CP data offers better swath width and easy adaptability to the scan-SAR imaging mode with better swath width. Hence it is derived that CP or Hybrid pol data is best suited for maritime applications and target detection. Since no true CP data was analysed till date, there is an opportunity to use the RISAT-1 CP data and ascertain its ability to improvise the ship detection algorithms and find factors other than system & environmental factors will affect the performance of the algorithms. The approach aims to establish the analysis techniques that can be applied to the

satellites with systematic coverage and compact polarimetric data switching on the go to detect targets of interest. The research also proposes the system switch over to establish the next stage of identification using the CP techniques and proposes the techniques for future to be applied in cases where no prior knowledge of the environment or the target like the cases of the surveillance scenario or Extra-planetary exploration.

1.3 RESEARCH PROBLEM

1.3.1 PROBLEM STATEMENT:

To evolve, improve and design the ship detection algorithms and proposed techniques for image analysis for ship detection using Space borne Microwave SAR systematic coverage and compact polarimetry mode namely Circular Transmit, Linear Receive (CTLR) of RISAT-1 SAR data to detect the potential ship pixels for acceptable False Alarm (FA).

1.3.2 MOTIVATION / NEED FOR THE RESEARCH:

Having known the background and the present threat scenario of the Indian sub-continent, it is indispensible to carry out a research in the future applications of the compact polarimetry modes of the operational RISAT-1 Mission and further missions like RISAT-1 repeat and NISAR. Also being the end-user of the target detection, it is imperative that the algorithm be designed so that it can undertake the task of maritime reconnaissance at ease taking into account the practical problems into consideration. The potential of spaceborne compact polarimetry like RISAT-1 which is first of its kinds is yet to be exploited for ship detection applications. The opportunity and the need go hand in hand with the RISAT-1 data being available for analysis and for development of various data products in the near future. The only available operational space mission with CP data is RISAT-1. Conventionally many applications have been developed to cater for the main mission objective of crop monitoring but the potential of this data for ocean target detection is yet to be fully explored. This research attempts to establish a clear methodology of using systematic coverage of PolSAR data to switch over to the CP data for

validation of the target. This will ensure that the data otherwise remains getting dumped is being utilised for surveillance environment analysis to get the maximum benefit & utility of the mission. The best part is that the techniques that are being explored are prudent in cases where the other factors need not the available and the only available single scene image is enough to extract the best possible target information. The existing methods are capable of extracting target information by using the image characteristics only while this research aims at using the polarimetric information to get the maximum benefit & suitability for ship detection. Using the proposed method, the various new missions can be utilised and in future the CP data missions can also be programmed to suit the specific target interests & requirements. This will come handy even in cases of the planetary exploration due to the hardware design advantage and to supplement this the proposed analyses tools will help in the software side also. The development of algorithms and analyses tools will enhance the usability of the data and further improvements in the applications in the actual problem situations using future microwave remote sensing missions.

1.4 RESEARCH OBJECTIVES

1.4.1 MAIN OBJECTIVE:

The objective of the research is to study the usability of compact polarimetry mode CTLR and evaluate the potential in improving the detection accuracy of the ship detection algorithms covering wider swath with reasonable degree of False Alarm (FA).

1.4.2 SUB-OBJECTIVES:

(i) To retrieve the different scattering mechanisms from Hybrid PolSAR and Dual PolSAR medium resolution data.

(ii) To derive various techniques of image analysis for detection of ships using systematic coverage.

(iii) To develop a robust empirical model based classification technique for analysis of PolSAR image for ship detection.

(iv) To generate and compare various decomposition techniques and classification techniques for deriving the target signatures of ships using Hybrid polarimetry.

(v) To assess using Kappa statistics of classification accuracy to give confidence level of various classification and detection techniques.

(vi) To compare the semi-empirical model output with the validation data from Satellite/terrestrial AIS data for quantitative and qualitative accuracy of ship detection.

1.4.3 RESEARCH LIMITS:

The research limits study to use of RISAT-1 data CTLR (Circular Transmit, Linear Receive) mode and MRS(Medium Resolution ScanSAR) mode to compute the parameters for ship detection and towards this CFRS (Circular Fine Resolution Spot) data with 3.33m azimuth x 2.34m range resolution with swath 25 km and MRS data level 2 CEOS product with 18m resolution with swath 115 Km was used . The scope of the research limits to development of techniques of image analysis, algorithm and analysis for the use of CTLR mode for the detection of potential ship pixels for a given degree of False Alarm (FA) based on the quality of data. The detection performance to be evaluated with archival ship Automatic Identification System (AIS) data provided by database (Sea-web / VT Exlorer) and accuracy assessment of classification of images using image processing tools like ENVI or Erdas Image. The independent factors like wind and vital system factor that will be analysed is effect of incidence angle. Besides the environmental factors, the potential of the automated detection with manual detection will be compared to draw lessons for semi-automation.

1.4.4 RESEARCH QUESTIONS:

The following questions have been identified from the defined objectives considering the limitations of the proposed scope of work:

(i) what is the dominant scattering mechanisms or parameter associated with the scattering mechanism that uniquely

distinguishes the ship pixels from the background from Hybrid PolSAR and Dual PolSAR medium resolution data?

(ii) What are the techniques of image analysis for detection of ships using medium resolution products of systematic coverage of satellites?

(iii) What is the effect of the Orientation angle in Dual PolSAR Medium resolution data and how is the target of interest is identified using the orientation angle in a versatile environment like Sea or Ocean?

(iv) How to retrieve a robust empirical model based classification technique for analysis of PolSAR image for ship detection

(v) To what extent the various decomposition techniques and classification techniques for deriving the target signatures of ships using Hybrid polarimetry help in enhancement of ship detection?

(vi) How viable the Hybrid PolSAR and Dual band MRS techniques for detection of ships by the validation data from Satellite / terrestrial AIS data for quantitative and qualitative accuracy?

(vii) How can the dynamic switch over from dual band Medium resolution scan be made to compact PolSAR mode for further image analysis?