1989

Operational use of ARPA structure and contents for a training course

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MALMÖ, SWEDEN

OPERATIONAL USE OF ARPA
STRUCTURE AND CONTENTS FOR A TRAINING COURSE

by

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India

A paper submitted to the Faculty of the World Maritime University in partial satisfaction of the requirements for the award of a

MASTER OF SCIENCE DEGREE

in

MARITIME EDUCATION AND TRAINING (NAUTICAL).

The contents of this paper reflect my personal views and are not necessarily endorsed by the UNIVERSITY.

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कर्मण्येवाधिकारस्ते मा फलेषु कदाचन

ACKNOWLEDGEMENTS

I have been very fortunate in receiving guidance and assistance from many persons in writing this paper.

I am grateful to the **Shipping Corporation of India** for enabling me to undertake this course.

I thank **Captain Stephen J. Cross** for his guidance while assessing this paper.

I am especially thankful to **Captain Samar J. Singh** who made valuable suggestions while co-assessing this paper.

I am greatly indebted to **Professor B. Berking** who found time to read through the paper. But for his incisive comments, this paper would not have been what it is now.

My **colleagues in SCI** have provided me not only with material for the paper but also with help in many other ways.

I have drawn upon the expertise and knowledge and also kindness of the **visiting and resident professors** of WMU.

My **friends in MET-N** have overwhelmed me with their affection and friendship throughout these two years in Malmo. I will cherish the pleasant memories.

Captain Wagner and **Mr. Poisson** have willingly given their time and help for which I am thankful to them.

Captain T.D. Hazari has as usual, been a source of inspiration in suggesting the subject for this paper.

I am grateful to **Professor Gunther Zade** for his encouragement during my studies.

My beloved wife **Nirupama** has given me tremendous support throughout these two long years. And I wonder if I could have completed this course without the constant reminder from our children, **Ajay and Gauri**, to " do your homework!"

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PREFACE

The paper presented by the Shipping Corporation of India at the seminar for senior personnel of the branches of the World Maritime University held at Malmo on 11 October 1988, stated, "We are striving to make the Maritime Training Institute a regional centre of excellence in the maritime sector and to keep abreast of technological developments. As a branch of the World Maritime University, we will not only be serving our nation but also the developing countries in the Asia and Pacific region."

The paper also indicated that new courses in compliance with STCW 78 will be developed.

Captain T.D.Hazari in his paper "Development of courses for the Maritime Training Institute of the Shipping Corporation of India", (submitted for M.Sc. in Maritime Education and Training (Nautical), 1985, recommended that the radar simulator training and ARPA course should be developed. He had also recommended that a radar navigation simulator be acquired for the Maritime Training Institute.

Keeping the above in view, I considered the "Operational Use of Automatic Radar Plotting Aids-Structure and Contents for a Training Course" to be an appropriate subject for my paper for M.Sc. in Maritime Education and Training (Nautical).

The writing of this paper has given me an opportunity to understand the working of Automatic Radar Plotting Aids (ARPA). I have been able to obtain guidance from excellent books and articles written by experts on the subject.

I have benefited from the proceedings and discussions of the International Radar and Navigation Simulator Lecturers' Conferences. I had also the privilege of learning ARPA from an acknowledged expert on the subject besides being an excellent teacher.

The subject matter is vast. I have often debated within myself on the material to be included, considering the limitations of time and space. I would have liked to treat certain topics comprehensively, e.g. predicted areas of danger, possible points of collision, different types of ARPA with possibly a comparision of their facilities and features. However, I am certain that the material I have been able to collect and read will also help the course instructors to conduct the course successfully.

The paper is divided into 8 chapters. Chapter 1 briefly describes why the development of ARPA course is necessary. Chapter 2 outlines the objectives and structure of the course including participants, equipment requirements, exercises and syllabus.

Chapter 3 deals with revision of radar theory, which may be necessary for officers who have obtained their Radar Observer's Certificate some years ago. This will refresh their theoretical knowledge to supplement their considerable practical experience.

Chapter 4 describes some aspects of digital technology in modern radars. Theory of Automatic Radar Plotting Aids has been explained in Chapter 5. Though inclusion of ARPA theory in detail in the course may not be necessary, it is felt that instructors and interested participants may be able to derive benefit from it. The material will also make useful reading material for the participants.

IMO performance standards for ARPA and ARPA features have been discussed in Chapter 6. Chapter 7 deals with errors and limitations of ARPA. Precautions to be observed while using ARPA have also been included. Chapter 8 contains conclusions and recommendations.

I consider the training of course instructors of vital importance. What is also essential is the updating of their knowledge by participation in forums like the International Radar and Navigation Simulator Lecturers' Conferences and International Maritime Lecturers' Association. Immense benefit can be derived from the deliberations at these conferences to conduct and improve the courses satisfactorily. One is able to judge the level of own course as compared to that being run by other institutes all over the World. The conferences also provide an opportunity to develop contacts which may fructify in close co-operation with other academies and colleges running similar courses. As a matter of fact, such co-operation already exists among various maritime colleges.

The necessity for the course instructors to keep abreast of latest practices and developments on board ships cannot be stressed enough. There is no better way to achieve this than by making regular short voyages on ships fitted with appropriate equipment.

If the course instructors at the Maritime Training Institute find this paper useful, I will feel satisfied that my efforts were worthwhile.

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INTRODUCTION

1 INTRODUCTION

1.1 THE MARITIME TRAINING INSTITUTE

1.1.1 The Shipping Corporation of India Ltd. (SCI), a public sector enterprise of the Government of India has set up its own Maritime Training Institute (MTI) to conduct specialised short courses for maritime personnel.

1.1.2 The MTI has been designated as a branch of the World Maritime University to conduct short specialised courses for the Asia-Pacific region.

1.1.3 The SCI owns, operates and manages a fleet of about 154 ships including break bulk, container, crude oil and product tankers, bulk carriers, passenger ships, off-shore supply vessels, research vessels etc.

1.2 NEED FOR DEVELOPING THE AUTOMATIC RADAR PLOTTING AIDS COURSE

1.2.1 As required by the International Conference for the Safety of Life at Sea, 1974 and its subsequent amendments (SOLAS), Automatic Radar Plotting Aids have been installed on twenty one tankers and twelve bulk carriers.

1.2.2 The International Convention on Standards of Training, Certification and Watchkeeping for Seafarers, 1978, and International Maritime Organisation Assembly Resolution A482 (XII) require that masters and navigation watchkeeping officers be trained in the use of ARPA.

1.2.3 Though the navigating officers in SCI have been trained in Radar Observation and Plotting as a mandatory requirement for Second Mate (Foreign Going) certificate of Competency, they have not received any formal training in the operational use of ARPA.

1.2.4 The tankers mainly ply on the India-West Asia Gulf trade where the traffic density can be substantially high. Proper use of ARPA is imperative for safe navigation of these tankers which carry major share of India's crude oil requirement from the West Asia Gulf.

1.2.5 The SCI alone employs over 1000 masters and navigating officers. The total number of officers in India is quite large. However, there is only one institution, the Lal Bahadur Shastri Nautical and Engineering College in Bombay which provides ARPA training. Considering the restricted number of officers who can be trained at the Lal Bahadur Shastri Nautical and Engineering College, it may be a long time before all officers are trained on the use of ARPA.

1.2.6 The SCI has planned for acquiring a radar simulator with ARPA to be installed at the Maritime Training Institute.

1.2.7 Being a branch of the World Maritime University, officers from the Asia-Pacific region are also expected to benefit from the facility of short specialised courses conducted at the MTI.

1.3 OBJECTIVE OF DEVELOPING THE ARPA COURSE

The objective of developing the course in the operational use of ARPA is to enable the MTI to conduct the course after the simulator has been installed for training of navigating officers from India as well as from other countries in the Asia-Pacific region.

CHAPTER 2

OBJECTIVE AND STRUCTURE
OF
THE ARPA COURSE

2 OBJECTIVE AND STRUCTURE OF THE ARPA COURSE

2.1 THE OBJECTIVE OF THE ARPA COURSE

2.1.1 International Convention on Standards of Training,Certification and Watchkeeping for Seafarers, 1978 (STCW78) requires that masters and navigating officers shall make most effective use of all navigational equipment at their disposal. They are also required to demonstrate their knowledge of the fundamentals of radar and ability in the operation and use of radar, and in the interpretation and analysis of information obtained from radar equipment.

2.1.2 Resolution 20 to the STCW 78 Convention recognises that it is essential that masters and officers in charge of navigational watches be properly trained in the use of collision avoidance aids and shall be fully aware of capabilities and limitations of such equipment.

2.1.3 Appendix to the Resolution A 482 (XII) adopted by the International Maritime Organisation (IMO) requires that, in addition to the above, masters, chief mates and officers in charge of navigational watch on ships carrying ARPA shall be trained in the fundamentals and operation of ARPA equipment and the interpretation and analysis of information obtained from this equipment.

2.1.4 Already a law court in the United States of America has denied limitation of liability to a shipowner for failure to properly train his crews in the use of ARPA.

The Court, finding that the master did not know how to use the ARPA, stated "The shipowners have the ability and responsibility to ensure that the master is sufficiently trained on the ships equipment, particularly those required by law. It undermines the law that required the equipment if shipowners fail to train their masters in its operation."

(Case involving collision in fog between the Seapride II and an electric power transmission line tower on the Delaware River, U.S.A.)

2.1.5 The development of Automatic Radar Plotting Aids (ARPA) has been a great leap forward in the radar technology. The synthesis of digital data processing techniques and radar technology has opened the door to an exciting new area with a promise of many applications.

2.1.6 Every new technology brings in its wake a host of new difficulties to be surmounted. ARPA is no exception. When radars were installed on board, they were hailed as the ultimate solution to collision avoidance at sea, untill the first "Radar assisted" collision between two passenger liners the "Andrea Doria" and the "Stockholm" occured on the 25th July 1956. Already an "ARPA assisted" collision between the bulk carrier "Buenos Aires" and a hydrofoil has taken place in the Dover Straits on 14th August 1981. However, it must also be realised that many collisions have been averted by the use of radars and ARPA.

2.1.7 This only highlights the philosophy of basic seamanship that radar and other equipment are just aids for the prudent mariner who makes use of them, understanding fully their pontential as well as limitations.

It is necessary to demystify the electronic gadgetry so that the resourceful navigator can confidently assimilate the information provided by the ARPA and utilise it as appropriate to the situation, duly tempered with the knowledge of its inherent limitations and errors.

2.1.8 ARPA provides information in large quantities more quickly. It is quite easy to be "drowned" in the vast amount of information. However it is important to sift the particulars and choose precisely what is required for the situation at hand. Different situations call for different information. Different locations create different situations.

2.1.9 Radar and ARPA should be allowed to create not a sense of safety and security but a sense of responsibility. Small passing distances calculated by ARPA should not make the watchkeeping officer complacent but should immediately flash a warning signal in his mind. Target contact on the radar should create the same cautious attitude in the watchkeeping officer as that of a man in a dark room who is told of an exposed electric contact.

2.1.10 No mariner standing watch on the bridge of a ship should forget the four basic tenets of seamanship:

Lead, Log, Latitude, Lookout.

2.1.11 It is necessary to remember that simple sailors and clever equipment will never be as safe as clever sailors and simple equipment.

2.1.12 It is this compliance with International Conventions and Regulations, adherence to law, creation of sense of responsibility and above all, making of clever sailors that is the objective of this ARPA course.

2.2 PARTICIPANTS

2.2.1 The participants for the course will be masters, chief officers, other navigating officers and marine superintendents of shipping companies. Short introductory courses will also be conducted for apprentices possibly during their mid-term courses or Radar Observer's Courses.

2.2.2 Though the requirements of the SCI's own officers will be catered for, other Indian as well as foreign participants will also be encouraged.

2.2.3 The course will be conducted as frequently as required to the needs of the Shipping Corporation of India and other participants.

2.2.4 The course will be conducted for participants of varying levels for

- Masters and Chief Officers,
- Other Navigational Officers,
- Marine Superintendents,
- Apprentices.

2.3 SCHEDULE FOR THE COURSE

2.3.1 Institutes having radar simulators have formulated course schedules which vary from one another in their contents. However, all of them emphasise that exercises on the simulator impart the most benefit to the participants. Some Institutes include topics which do not strictly form part of the " Operational Use of Automatic Radar Plotting Aids" course, e.g. navigation lines, use of V.H.F. radio telephone etc.

A suggested schedule for the ARPA training course to be conducted at the Maritime Training Institute is shown on page 8.

WEEKLY SCHEDULE FOR ARPA TRAINING COURSE

TIME	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY
0930 TO 1100	INTRODUCTION FAMILIARIZATION WITH SIMULATOR (S)	EXERCISES ON PLOTTING TECHNIQUES TRUE MOTION (S)	SETTING UP AND MAINTAINING DISPLAYS, TARGET ACQUISITION (S)	OBTAINING INFORMATION FROM ARPA (I) (L)(S)	EXERCISES IN TRAFFIC SEPARATION SCHEME (S)
1115 TO 1245	REVISION OF PLOTTING TECHNIQUES (L)	MODERN TECHNIQUES IN RADAR (L)	TRACKING CAPABILITIES AND LIMITATIONS (L)(S)	OBTAINING INFORMATION FROM ARPA (II) (L)(S)	PADS, PPCS PRINCIPAL TYPES OF ARPA (S)
1345 TO 1515	EXERCISES ON PLOTTING TECHNIQUES RELATIVE MOTION (S)	INTRODUCTION TO ARPA THEORY (L)	PROCESSING DELAYS (L)(S)	TRIAL MANOEUVRE (S)	EXERCISE IN AREA OF HIGH TRAFFIC DENSITY (S)
1530 TO 1700	EXERCISES ON REFLECTION PLOTTER (S)	IMO PERFORMANCE STANDARDS FOR ARPA (L)	DISPLAY OF TARGET DATA (S)	EXERCISES TO DEMONSTRATE RISKS OF OVER-RELIANCE ON ARPA (S)	COLREGS DEBRIEFING

(L) = LECTURE (S) = SIMULATOR

2.3.2 BRIEF DETAILS OF LEARNING OBJECTIVES

.1 INTRODUCTION

- objectives of the course,
- schedule for the course,
- introduction of instructors,
- introduction of participants,
- documentation.

.2 FAMILIARISATION WITH SIMULATOR

- explanation of equipment,
- layout of "own ship" cubicle,
- radar controls.

.3 REVISION OF PLOTTING TECHNIQUES

- relative and true motion plotting,
- determination of range, bearing, true course, speed, closest point of approach, time to CPA of targets using relative and true motion display observations,

.4 EXERCISES ON PLOTTING TECHNIQUES RELATIVE MOTION

- observation of targets,
- determination of their CPA, TCPA, true course, speed on relative motion presentation,

.5 EXERCISES ON REFLECTION PLOTTER

- observation of targets,
- determination of their CPA, TCPA, true course and speed,

.6 EXERCISES ON PLOTTING TECHNIQUES TRUE MOTION

- observation on targets,
- determination of their CPA, TCPA, true course and speed on true motion presentation,

.7 MODERN TECHNIQUES IN RADAR

- digital scan conversion,
- scan to scan and sweep to sweep correlation for reduction in clutter,
- day-light radars - echo brightening, echo stretching,
- rasterscan radars,

.8 INTRODUCTION TO ARPA THEORY

- quantisation in range,
- quantisation in azimuth,
- tracking,
- processing delays,

.9 IMO PERFORMANCE STANDARDS FOR ARPA

- IMO Resolution A 422 (XI),

.10 SETTING UP AND MAINTAINING DISPLAYS

- familiarisation with ARPA controls and their functions,
- choice of mode and presentation,
- proper use of gain, anti-sea clutter and differentiator controls,

.11 TARGET ACQUISITION

- procedure to acquire targets,
- exclusion areas,
- guard zones and alarms,
- target overflow and alarms,

.12 TRACKING CAPABILITIES AND LIMITATIONS

- IMO performance standards for tracking,
- target swop,
- target loss,

.13 PROCESSING DELAYS

- delays in the display of correct target data on acquisition, re-acquisition and when manoeuvring,

.14 DISPLAY OF TARGET DATA

- target bearing and range,
- target course, speed, CPA and TCPA,
- vectors,
- past positions,
- errors in displayed data,

.15 OBTAINING INFORMATION FROM ARPA (I)

- sensor errors and their effects,
- effect of incorrect input of speed and course,

.16 OBTAINING INFORMATION FROM ARPA (II)

- errors due to misinterpretation of display presentation mode and true and relative vectors,
- failure to detect or acquire targets,
- uncritical acceptance of presented data,

.17 TRIAL MANOEUVRE

- static manoeuvre,
- dynamic manoeuvre,
- own ship characteristics,
- COLREGS,

.18 EXERCISES TO DEMONSTRATE RISKS OF OVER-RELIANCE ON ARPA

- unreliable target data due to manoeuvre of target and/or own ship,
- undetected small targets,
- acceptance of small distances indicated on ARPA as safe distances,

.19 EXERCISES IN TRAFFIC SEPARATION SCHEMES

- COLREGS

.20 PADS, PPCS, PRINCIPAL ARPA SYSTEMS

- introduction to PAD and PPC theory,
- principal ARPA systems and their particular features using video films, technical literature, brochures, posters,

.21 EXERCISES IN AREAS OF HIGH TRAFFIC DENSITY
- COLREGS

.22 DEBRIEFING
- discussion on exercises and participants' performance,
- documentation,
- course evaluation,
- suggestions from participants.

2.4 INSTRUCTORS

"The most important requirement of the Maritime Training Institute of the Shipping Corporation of India would be a team of well qualified, well trained, dedicated and a highly motivated faculty. The success of the institute would depend to a great extent on the faculty."

(Hazari T.D.,"Development of courses for the Maritime Training Institute of the Shipping Corporation of India", paper submitted for MET-N course at WMU, 1985)

The instructors selected for conducting the ARPA courses will need to be trained on the simulator by the simulator manufacturer. The training will include use of the hardware and the software and their capabilities. When the instructors are confident of correctly operating the simulator, they will be able to design effective exercises.

The Maritime Training Institute has been conducting Radar Observer courses for many years. The instructors for these courses have good experience of preparing the syllabus, conducting the courses and evaluating participants.

The faculty at the MTI includes one graduate from the World Maritime University in Maritime Training and Education (Nautical) and another will graduate in 1989, also in the same stream.

These officers will form two teams which will conduct the courses.

2.4.1 SHIPBOARD EXPERIENCE

Continuous contact with shipboard practices is essential for the instructors in designing and altering the course to reflect the current trends. Regular periodic voyages on board for the instructors will be necessary and will prove to be useful.

2.4.2 PARTICIPATION IN INTERNATIONAL CONFERENCES

The International Radar and Navigation Simulator Lecturers' Conferences are held regularly. The participants to these conferences are internationally known and experienced radar simulator lecturers. Many important and useful aspects of radar simulator training are deliberated at these conferences. Participation by the instructors in the MTI in these conferences will prove to be very beneficial.

These conferences also afford an opportunity for developing contacts which can fructify in co-operation in designing and exchanging exercises.

2.5 THE ADVANTAGES OF SIMULATOR

It will be essential to have a radar- ARPA simulator for real time exercises. The simulators have many advantages, some of which are indicated below.

Simulators provide an opportunity to gain adequate and satisfactory experience and thus confidence in the use of ARPAs. The capabilities and limitations of the ARPA can be demonstrated by simulating encounters of ships in real life without of course, the hazards of real encounters at sea.

Situations can be repeated many times on the simulators to gain comprehensive experience without recourse to expensive real ship manoeuvres at sea.

Every mariner does not get an opportunity to experience various errors of the system and malfunctions of the sensors providing inputs to the system. Malfunctions and technical failures of the ARPA equipment and input sensors can be simulated.

Experience of ships of different types having different manoeuvring characteristics can be gained without actually having to serve on board so many ships.

Various types of encounters -crossing, end on or overtaking - can be exercised with different types of target ships.

Complexity of the situation can be varied to suit the level of participants. Two ship, multi-ship and rogue ship situations with varying proximity of navigational dangers can be created.

Potentially dangerous but rarely met situations can be successfully created which are the most fruitful sources of inspiration. (A.Bole, 4th IRN SLC, May, 1986)

Practice involving other vessels and shore based services can only be experienced on a simulator.

Awareness of importance and forms of bridge procedures and the need to achieve efficient utilisation of bridge manpower and equipment can be created on a simulator.

2.6 EQUIPMENT REQUIREMENT

2.6.1 The simulator equipment shall comply with the specifications approved by the Directorate General of Shipping in the Ministry of Surface Transport, Government of India.

2.6.2 The simulator should preferably have four "own ship" cubicles, each having a radar and ARPA. More number of "own ship" cubicles increases the number of participants per course and also the opportunities for interactions between "own ships".

Though different makes of radars and ARPA would give an opportunity to learn to operate different sets having diverse features, consideration needs to be given to the make of radar and ARPA fitted on SCI's own ships. Atleast one ARPA should have Rasterscan presentation where the officers can be shown the difference in presentations of normal PPI and Rasterscan.

2.6.3 Video tapes or films showing particulars of different types of ARPA from various manufacturers should be obtained for viewing. This will satisfy partially the need to demonstrate functions of different types of ARPA.

2.6.4 A plotter should be provided to record manoeuvres of "own ships" for subsequent discussions and also for analysis in future.

2.6.5 A printer should be provided to print parameters selected by the Instructor for on-line monitoring. These parameters include radar and ARPA data, display mode, course and speed from all "own ships".

2.7 EQUIPMENT IN "OWN SHIP" CUBICLES

Room

Each "own ship" cubicle should have the following equipment:

DISPLAYS:

- Radar,
- ARPA,
- Gyro Compass Repeater,
- Rudder Angle Indicator,
- Speed Log Indicator,
- Water Depth Indicator (Echo Sounder),
- Rate of Turn Indicator,
- Ship's Time Display,
- Engine Control Telegraph,
- Main Engine RPM Indicator,
- Wind Speed and Direction Indicator (Anemometer).

EQUIPMENT:

- Communication between "own ship" and the Instructor shall be provided by a telephone with multiple lines which can be used for simulating intra-ship communications,
- V.H.F. Radio Telephone for simulating inter-ship and ship-shore communications,
- Facility for Sounding Fog Signals,
- Reflection Plotter,
- Steering System with Auto-pilot,

- Chart Table with Lamp,
- Charts and Publications,
- Log Books for Bridge and Radar, Movement book,
- Parallel Rulers, Pencils, Eraseres, Dividers, Compass,
- Chinagraph Pencils, Rubber Tipped Dividers,
- Own ship manoeuvring characteristics as indicated in the sea trials,
- Tables of essential parameters of ship and engines, speed in knots against RPM,
- Examples of manual plotting methods for quick reference including true and relative motions,
- Table of passing distances against course alterations and time.

2.8 EXERCISES

A software library of different ship-models and various exercises should be available for practice. These exercises will be designed and prepared by the instructors.

The exercises will include areas of high traffic density and areas frequented by SCI ships including tankers and bulk carriers.

2.8.1 REQUIREMENTS FOR SIMULATOR EXERCISES

Effective simulator exercises can be described in following terms:

- an effective exercise is one where the aims and objectives are achieved,

- all aspects of an exercise occur by design and are under the conscious control of the instructor,
- exercises designed to run in a parallel mode should have a predictable outcome and are intended primarily for training on the basis of comparative discussion, result
- exercises run in an interactive mode have an indeterminate outcome and are therefore more appropriate for independant decision making and interpretive discussion,
- the message that the exercise is intended to carry should need as little explanation as possible,
- the seamanlike integrity of the exercise is essential,
- target vessels should play as little part in the final encounter as possible,
- during debriefing, the instructor should only have to play a minimum role,
- the ultimate objective with any exercise is that it should be both effective and successful. final

(A. Bole, at the 4th International Radar and Navigation Simulator Lecturers' Conference, held at Mariehamn, May 1986)

2.8.2 At the same Conference, J.A. Klerk and Samar Singh stated that an effective exercise should be designed to illustrate the need to analyse all available data by the observer. The exercises shall be so designed as to demonstrate to the observer the importance of considering the evolving situation in totality, not only from own ship's view point but also that of the target ships.

2.8.3 DESIGNING SIMULATOR EXERCISES

Simulator exercises can be designed based on

- analysis of past casualties and other sources of ideas,
- mistakes and misunderstandings which are repeatedly observed in the behaviour of trainees,
- the experience of practising mariners who find a certain situation particularly difficult to deal with.

2.8.4 OBJECTIVES OF ARPA EXERCISES

Well-designed exercises result in showing many ARPA particulars to the trainees. The exercises inculcate various mechanical skills like the use of ARPA controls to obtain vital information from ARPA display. They also demonstrate various ARPA functions and the limitations and errors of ARPA more effectively than by mere classroom lectures.

The exercises will be constructed to concentrate the attention of the trainees on a single problem. The objectives of the exercises will be to demonstrate the following:

- **SETTING UP PROCEDURE**
  - correct setting up of radar controls especially anti sea clutter and FTC controls and effects of improper use of these controls,

- **ACQUISITION**
  - change in the size of the tracking window (as far as this is symbolised on the PPI),

- acquisition of weak target, targets close to each other, targets at the same bearing, targets within an area of sea or rain clutter,
- acquisition time,
- use of guard zones, exclusion areas.

- TRACKING
  - target lost including the period of time until a warning is given (if any),
  - target swop,
  - target overflow.
- accuracy of information regarding CPA, TCPA, target ship's true and relative course and speed,
- effects of sensor malfunctions including incorrect speed and course input,
- effect of changes of own ship's course and speed,
- effect of changes in target ship's course and speed,
- differences between trial manoeuvre information and actual ship manoeuvre executed,
- advantages and disadvantages of true and relative vectors and of past positions,
- applicability of ARPA in different sea areas for collision avoidance in two-ship and multi-ship encounters,
- processing delays especially when there are too many targets on the same bearing.

2.8.5 MATHEMATICAL MODELS OF SHIPS FOR EXERCISES

The simulator shall have the following mathematical models of ships for exercises

- VLCC loaded and in ballast,
- 45000 DWT bulkcarrier,
- 16000 DWT general cargo ship,
- 67000 DWT tanker.

2.8.6 PLAYING AREAS FOR EXERCISES

The simulator shall have the following sea areas for exercises:

- Dover straits,
- Singapore straits,
- Straits of Hormuz,
- Straits of Gibralter,
- Straits of Malacca,
- Approaches to Bombay.

2.8.7 CHART DIGITISING EQUIPMENT

Chart digitising equipment enables creating new playing areas by digitising navigational charts. The equipment will be very useful when need is felt for additional areas for exercises. When the simulator is upgraded to a navigational simulator, new harbours and areas of high traffic density can be added to the library, Depending on the availability of funds, this equipment should be acquired as soon as possible.

2.9 EVALUATION

The methods for evaluation of participants of ARPA course vary among the institutes all over the world. The methods tend to follow the requirements of the national maritime safety administration. The number of institutes requiring written tests is however, small. Most of them evaluate the participants on a continuous basis i.e. the participants are observed throughout the course for their ability to operate the ARPA correctly and to understand the limitations and capabilities of ARPA.

Debriefing of the participants at the end of the exercises forms an important part of the courses and also assists in assessment of proficiency of the participants.

It is difficult to determine criteria for performance of the participants due to widely varying situations at sea. However, guidelines can be set and explained before the exercises so that the participants are aware of what is expected of them.

The participants, some of whom will be experienced masters, will also be able to provide valuable inputs in preparing the guidelines.

2.10 MAINTENANCE OF RECORDS

Detailed information regarding participants and their performance during simulator exercises will be necessary for statistical analysis. For this purpose, each participant should be required to fill up documentation including

- name, age, rank,
- date of Radar Observer's Certificate,
- years of service at sea,
- types of ships served on,
- experience on ARPA.

The instructors will maintain records of the performance of the participants including

bất thg [illegible]

- common, abnormal and novel manoeuvres,
- common and abnormal mistakes,
- types of encounters which participants find particularly difficult.

bắt gặp

2.11 MAINTENANCE OF EQUIPMENT

Availability of the simulator is a pre-requisite for a successful ARPA course. The course will be degraded by non-availability of simulator. Any down-time due to Break breakdown will disrupt the course schedule. Therefore, maintenance of the simulator and peripheral equipment is important. It will be necessary to have available a technician having adequate background in electronics and Knowledge specific training on computers and simulators. The simulator manufacturer will be required to train the technician in maintenance, fault finding and repairs. It is recognised that in modern electronic equipment, it is difficult to repair printed circuit boards at their component level. However, a trained and competemt ability enable technician can maintain a simulator in good condition and with experience, be able to maintain required spares in stock and thus ensure its continuous availability.

2.12 SYLLABUS FOR ARPA TRAINING COURSE

2.12.1 PLOTTING TECHNIQUES REVISION

.1 Manual plotting techniques, reflection plotters, plotting exercises, advantages and limitations of relative and true motion plotting.

.2 Identification of critical echoes

- Position fixing by radar from land targets and sea marks.
- Accuracy of position by ranges and by bearings.
- Importance of cross checking accuracy of radar against other navigational aids.

- The value of recording ranges and bearings at frequent intervals when using radar as an aid to collision avoidance.

.3 **Course and speed of other ships**

- Different methods by which course and speed of other ships can be obtained from recorded ranges and bearings:
- unstabilised relative plot,
- stabilised relative plot,.
- true plot,
- relationship between visual and radar observations;
- accuracy of estimates of course and speed of other ships. Detection of changes in movements of other ships.
- importance of making own ship movements substantial to be detected on other ship•s radar.

changes

.4 **Time and distance of closest approach of crossing, end-on or overtaking ships**

- Use of recorded data to obtain:
  measurement of closest approach distance and bearing,
  time to closest approach.
- The importance of frequent, regular observations.

.5 Detecting changes in course or speed or both of other ships

- Effects of changes of course or speed by other ships on their tracks across the display in relative and true motion presentation.
- Delay between change of course or speed and detection of that change.
- Hazards of small changes as compared with substantial changes of course or speed in relation to rate and accuracy of detection.

.6 Effects of changes in course or speed or both of own ship

- On a relative motion display
- Effects of own ship's movements, effects of other ship's movements, advantages of compass stabilisation of a relative motion display.
- On a true motion display
- Effects of inaccuracies of speed and course settings on a true motion display,
- Effects of compass stabilisation data driving a stabilised relative motion display.
- Effects of changes in course or speed by own ship on tracks of other ships on display.
- Relationship of speed to frequency of observations.

.7 Importance of evaluating evolving situation with attention to

- Navigational dangers and restrictions on manoeuvring space available.
- Own ship manoeuvring characteristics.

.8 Importance of considering the situation from the other vessel's position

.9 Application of the International Regulations for Preventing Collisions at Sea

- Relationship of the Regulations for Preventing Collisions at Sea to the use of radar.
- Action to avoid collision, dangers of assumption made on inadequate information and the hazards of small alterations of course or speed.
- The advantages of safe speed when using radar to avoid collision.
- The relationship of speed to closest point of approach and time to closest point of approach.
- Manoeuvring characteristics of various types of ships.
- The importance of radar observation reports being well defined, radar reporting procedure.
- Use of radar in clear weather, to obtain an appreciation of its capabilities and limitations, compare radar and visual observations and obtain an assessment of the relative accuracy of information.
- Importance and advantages of practising manual plotting and comparing results with ARPA.
- The need for early use of radar in clear weather at night and when there are indications that visibility may deteriorate;
- Comparision of features displayed by radar with charted features;
- Comparision of the effects of differences between range scales.

2.12.2 THEORY OF AUTOMATIC RADAR PLOTTING AIDS

.1 Digital Radar Data Processing

- Problem, aim, principle, precautions;
- Quantization, range, bearing, amplitude;
- Improvement of signal, correlation, echo stretch, echo brightening, retiming,recycling;
- Rasterscan.

.2 ARPA philosophy

- Introduction;
- ARPA procedure review;
- The acquisition and tracking windows;
- Target tracking;
- Filtering.

.3 ARPA features

- Acquisition;
- Vectors;
- Past positions;
- Alpha-numeric.data;
- Possible points of collision (PPC);
- Predicted areas of dangers (PAD);
- Sectors of danger (SOD);
- Sector of preference (SOP);
- Trial manoeuvres- static and dynamic;
- Operational warnings;
- Navigation lines;
- Speed and course measurement.

.4 Errors and limitations

- Introduction;
- Sensor errors:
  - IMO resolution A.422 (XI),Annex 3,
  - Radar errors in range and bearing,

- Speed input error,
- Course errors,
- Influence on vectors,
- Influence on PPC's.

- ARPA errors (tracking errors):
  - Sea clutter,
  - Target swop,
  - Fast manoeuvre,
  - Display delay,
  - Quantisation error in range and bearing,
  - Target glint,
  - Reasons for target loss.

.5 **Errors of interpretation**

- Misinterpretation concerning vectors,
- Misinterpretation due to ground or sea stabilised motion,
- Misinterpretation due to varying display symbols on different ARPAs,
- Dangers inherent in misinterpretation.

.6 **The possible risks of over-reliance on ARPA**

- Appreciation that ARPA is only a navigational aid and that its limitations including those of its sensors make over-reliance on ARPA dangerous, in particular for keeping lookout,
- Need to comply at all times with the basic principles and operational guidance for officers in charge of navigational watch,
- Need to recognise that small passing distances indicate possibly dangerous situation and NOT safe passage,

- Need to recognise that only failure of sensors will be indicated by alarms. Any incorrect input from the sensors will not be indicated.

.7 The principal types of ARPA systems and their display characteristics

- Knowledge of principal types of ARPA systems in use, their various display characteristics and an understanding of when to use ground or sea stabilised modes and north-up, course-up, or head-up presentations.

.8 IMO performance standards for ARPA

- An appreciation of the IMO performance standards for ARPA, in particular the standards relating to accuracy.

.9 Factors affecting system performance and accuracy

- Knowledge of ARPA sensor input performance parameters: radar, compass and speed inputs, effects of sensor malfunction on the accuracy of ARPA data,

- Effects of the limitations of radar range and bearing discrimination and accuracy,
- Effects of the limitations of compass and speed input accuracies on the accuracy of ARPA data,
- Knowledge of factors which influence vector accuracy.

.10 **Manual and automatic acquisition of targets and their respective limitations**

- Knowledge of the limits imposed on both types of acquisition in multi-target scenarios, effects on acquisition of target fading and target swop,

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- Exclusion areas for acquisition of targets by sectors and zones.
- Non-actuation of alarms by targets already in guard zone.

.11 **Tracking capabilities and limitations**

- Knowledge of the criteria for the selection of targets by automatic acquisition
- Factors leading to the correct choice of targets for manual acquisition,
- Effects of tracking of "lost" targets and target fading,
- Circumstances causing "target swop" and its effects on displayed data,
- Knowledge of criteria for automatic cancellation of target tracking.

.12 **Processing delays**

Trễ hiện sẵn có

- The dalays inherent in the display of processed ARPA information, particularly on acquisition and re/acquisition or when a tracked target manoeuvres or when there are too many targets on the same bearing.

.13 When and how to use the operational warnings, their benefits and limitations

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- Appreciation of the uses, benefits and limitations of ARPA operational warnings,
- Correct setting, where applicable, to avoid spurious interference.

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.14 System operational tests

- Methods of testing for malfunction of ARPA systems including functional self testing
- Precautions to be taken after a malfunction occurs.

.15 When and how to use true and relative vectors and typical graphic representation of target information and danger areas:

- Thorough knowledge of true and relative vectors; derivation of target's true course and speeds. → Thu tuỳ điều chỉnh
- Threat assessment; derivation of predicted closest point of approach and predicted time to closest point of approach from forward extrapolation of vectors, the use of graphic representation of danger areas,
- Effects of alteration of course and/or speed of own ship and/or targets on predicted closest point of approach and predicted time to closest point of approach and danger areas,
- Effects of incorrect vectors on danger areas,
- Benefits of switching between true and relative vectors.

.16 **When and how to use information on past position of targets being tracked**

- Knowledge of the derivation of past position of targets being tracked,
- Using historic data as a means of indicating recent manoeuvring of targets and to use the information as a method of checking the validity of the ARPA's tracking.

2.12.3 PRACTICE EXERCISES ON ARPA

.1 **Setting up and maintaining displays**

- The correct starting procedure to obtain the optimum display of ARPA information.
- Choice of display presentation;stabilised relative motion display and true motion displays.
- Correct adjustment of all variable radar display controls for optimum display of data.
- Selection and monitoring as appropriate, of required speed input to ARPA.
- Selection of ARPA plotting controls, manual / automatic acquisition, vector / graphic display of data.
- Selection of time scale of vectors / graphics.
- Use of exclusion areas when automatic acquisition is employed by ARPA.
- Performance checks of radar, compass and speed input sensors and ARPA.

.2 System operational tests

- System checks including self diagnostics, determining data accuracy of ARPA including the trial manoeuvre facility by checking against basic radar plot.

.3 When and how to obtain information from ARPA display

- Demonstrate of ability to obtain information in both relative and true motion displays, including:

- identification of critical echoes;
- speed and direction of target's relative movement;
- time to and predicted range at, target's closest point of approach;
- courses,speeds and aspects of targets; detecting course and speed changes of targets and the limitations of such information;
- effects of changes in own ship's course or speed or both;
- operation of the trial manoeuvre.

.4 Application of the International Regulations for Preventing Collisions at Sea

- Analysis of potential collision situations from displayed information, determination, execution and subsequent monitoring of action to avoid close quarters situations in accordance with International Regulations for Preventing Collisions at Sea.

3 REVISION OF RADAR THEORY

3.1 CHARACTERISTICS OF ELECTROMAGNETIC WAVES

Propagation velocity	299792.5 km/sec
	161,875 nm/sec
	$2.99*10^5$ km/sec
	$2.99*10^8$ mtr/sec
	299.7925 mtr/µ sec

> Time required for radar pulse to travel 1 nautical mile (1852 mtrs) = 6.18 µ sec

1 Micro second = 1 µ sec = One millionth of a second

1 Millisecond = 1 m sec = One thousandth of a second

One second = 1000,000 µ sec = 10^6 µ sec

= 1000 m sec = 10^3 m sec

> Time required for radar pulse to return from a target at a distance of one nautical mile = 12.36 µ sec

3.2 PULSE LENGTH AND PULSE REPETITION FREQUENCY

3.2.1 PULSE LENGTH

The radar transmitter produces pulses, the duration of which is known as the pulse length, expressed in microseconds (μ sec). It can also be given in metres.

A pulse of 1 μ second is 299.7925 mtrs. long.

3.2.2 PULSE REPETITION FREQUENCY

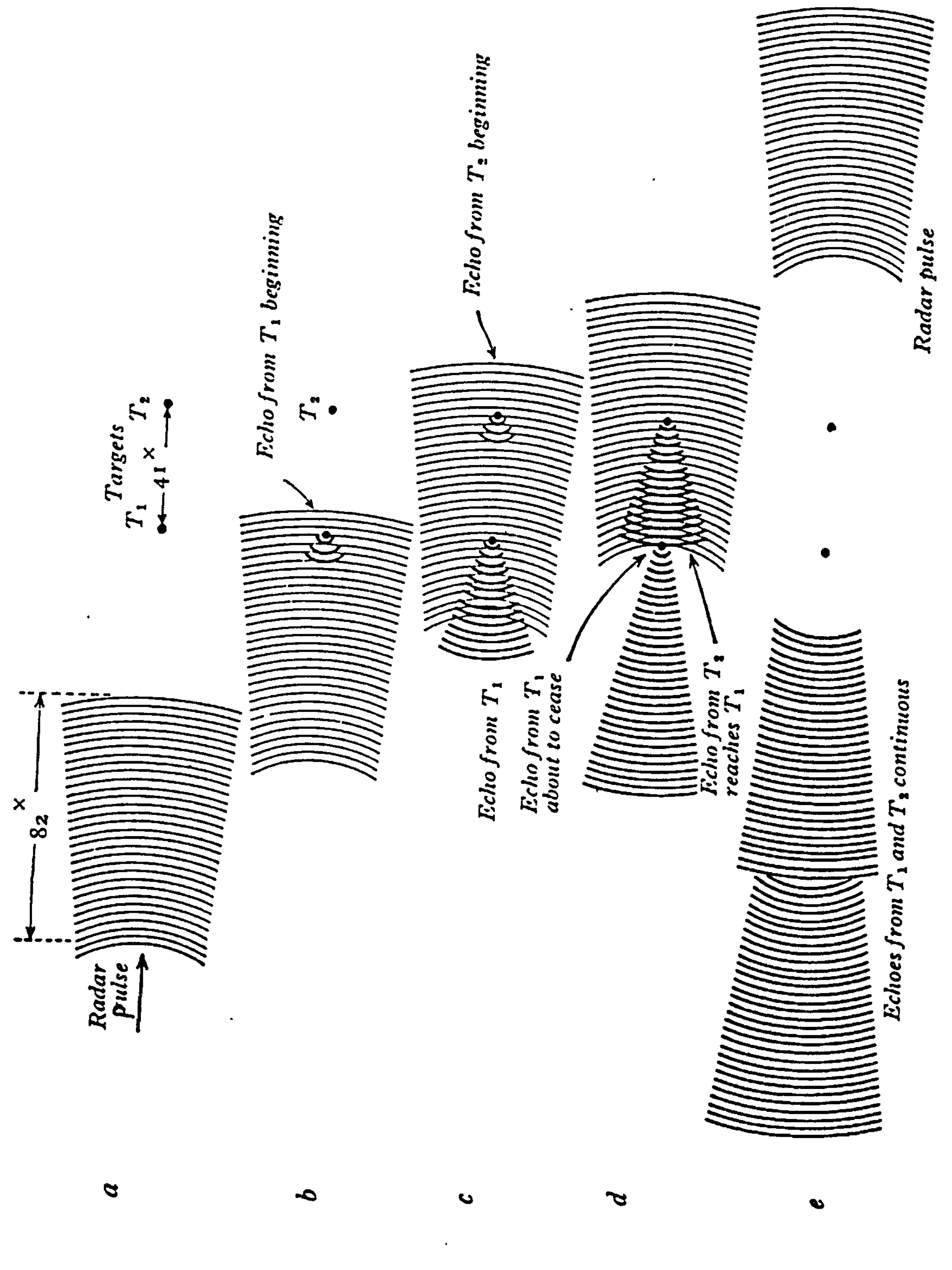
Pulse Repetition Frequency (PRF) is the number of pulses transmitted in one second.

If PRF is 1000, time interval between two consecutive pulses is 1000 μ seconds or 1 millisecond.

3.2.3 CHOICE OF PULSE LENGTH

On short ranges high resolution of picture and better range discrimination is required. For this purpose, short pulses are used on short ranges. Longer ranges require more energy to overcome losses through the atmosphere. Therefore, on longer ranges long pulses are used as they contain more energy.

3.2.4 On long ranges, low PRF is used to allow time between two pulses for echo pulses to be received and amplified in the receiver.



Range discrimination.

Fig. 3.1

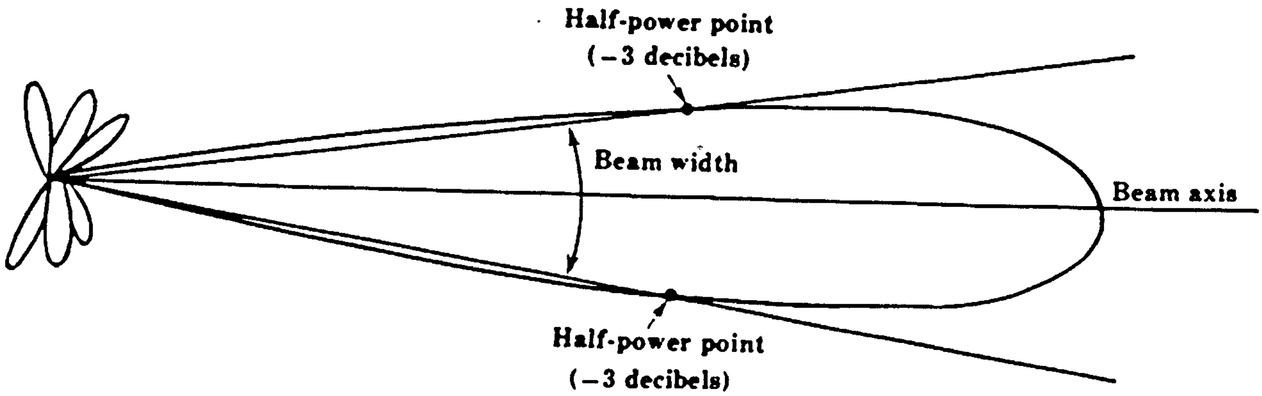


Fig. 3.2 Horizontal Beam Width

3.3 RANGE (RADIAL) DISCRIMINATION

Range discrimination of a radar system is its capability to show two close targets on same bearing as two distinct spots on the PPI.

3.3.1 The minimum distance between the two targets must be more than half of the pulse length for them to be shown as individual spots. (Fig.3.1)

For example, if a pulse length is 1 μ sec, the minimum distance between two targets must be more than

(1 μ sec * 299.7925 mtr/μ sec)/ 2 = 149.9 meters

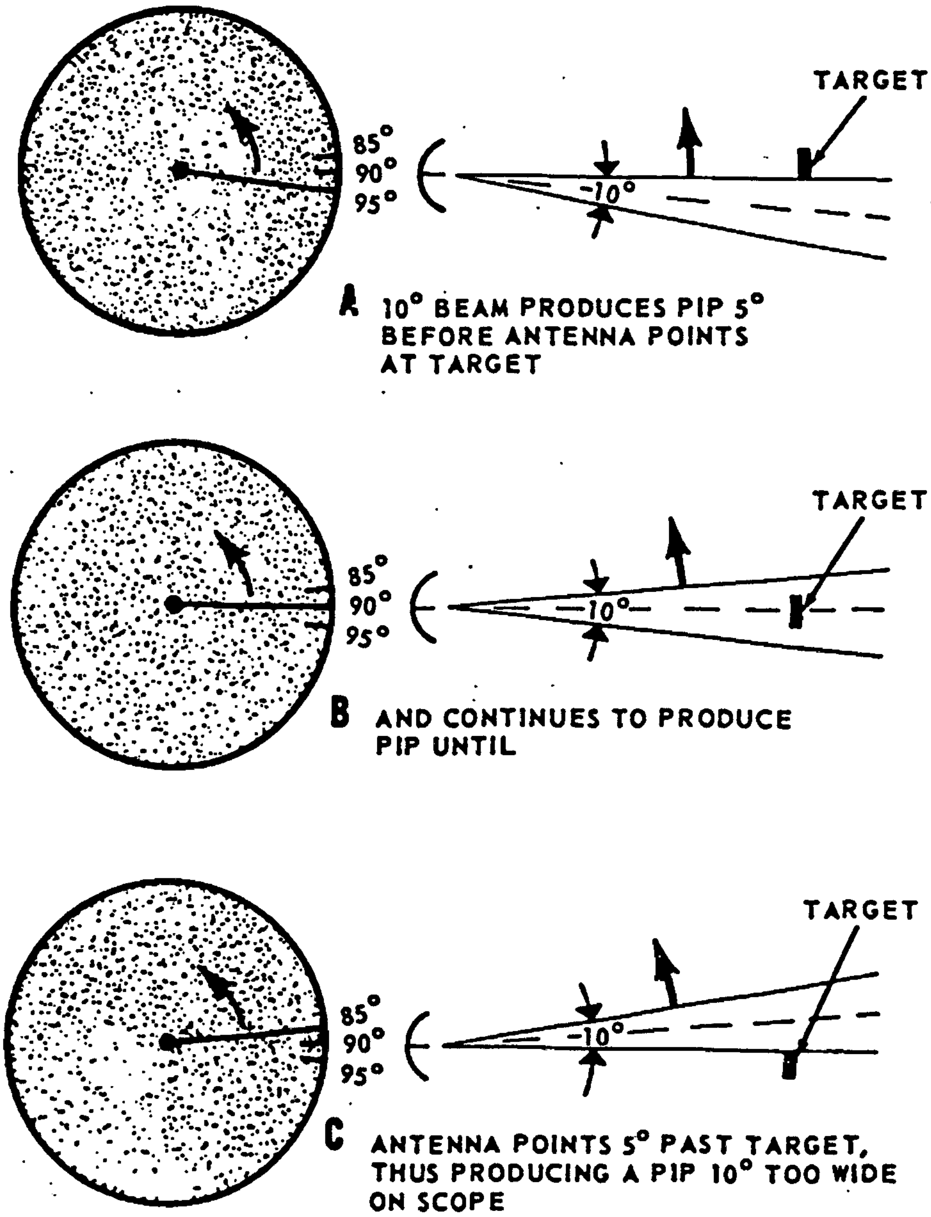
(minimum spot size of PPI not considered)

3.4 HORIZONTAL BEAM WIDTH (APERTURE)

Radar energy is transmitted through the antenna in a pattern shaped like a fan.

3.4.1 Horizontal beam width of the beam is measured at points having 50 % (half power) or 25 % (quarter power) of the transmitted power as shown in figure 3.2. These points are called -3 dB and -6 dB points respectively.

3.4.2 Horizontal beam width of S band (10 cm wave length) radars is generally larger than that of X band (3 cm wave length) radars.



TARGET PIP IS ALWAYS WIDENED ON THE SCOPE AN AMOUNT EQUAL TO THE BEAM WIDTH.

Fig. 3.3

3.5 AZIMUTH DISCRIMINATION

Azimuth discrimination of a radar system is its capability to show two close targets at the same distance as two distinct spots on the PPI.

3.5.1 The minimum distance between the two targets must be such that the angle at the antenna between them must be greater than the horizontal beam width.(Fig.3.3).

For example, if horizontal beam width is 1.5°, the minimum distance between two targets at a range of 6 nm must be:

$$(1.5^\circ * (2\pi/360^\circ) * 6 \text{ nm} * 1852) = 290.9 \text{ mtrs.}$$

For example, if horizontal beam width is 1°, opening of 100 mtrs. in breakwater will be seen distinctly at a distance of 3.09 nm.
(minimum spot size of PPI not considered)

3.6 FACTORS AFFECTING APPARENT SIZE OF TARGETS

3.6.1 PULSE LENGTH

The pulse length in meters is equal to pulse length in μ sec * 300 mtrs/μ sec. If the pulse length is 0.6 μ sec, even a point target will reflect a pulse of 0.6 * 300 = 180 mtrs. Since the spot on PPI travels at half the speed of the pulse to allow for the return journey of pulse and echo, the echo of the point target will be 90 mtrs. long on the PPI or about 2.5 mm in the above example.

3.6.2 EFFECT OF HORIZONTAL BEAM WIDTH

A point target will reflect radar waves while the beam sweeps across it. Therefore, the echo on the PPI will also subtend an angle at the centre equal to the horizontal beam width, representing an apparent size which depends on the range scale in use.

The point target will paint echoes on the perimeter of the PPI representing sizes in meters as shown in table 3.1.

Horizontal Beam	Range in nautical miles				
Width	3	6	12	16	24
0.9°	87	175	349	465	698
1.5°	145	291	582	776	1164
2.0°	194	388	776	1034	1552

Table 3.1 (Sizes of Point Targets in meters)

3.6.3 MINIMUM SPOT SIZE

It is the size of the smallest spot or the width of the thinnest line which the trace can draw on the PPI. The actual area represented by the spot on the PPI will depend on the range scale being used.

Typically the minimum spot size on commercial marine radars is 1 mm. Therefore, the apparent size of a point target on range scale 6 nm on a PPI of 400 mm diameter (200 mm radius) will be 55.56 mtrs.

$$\text{Apparent size} = \frac{(\text{ spot size in mm} * \text{range scale })}{\text{PPI radius in mm}}$$

$$= \frac{1 * 6 * 1852}{200}$$

$$= 55.56 \text{ mtrs.}$$

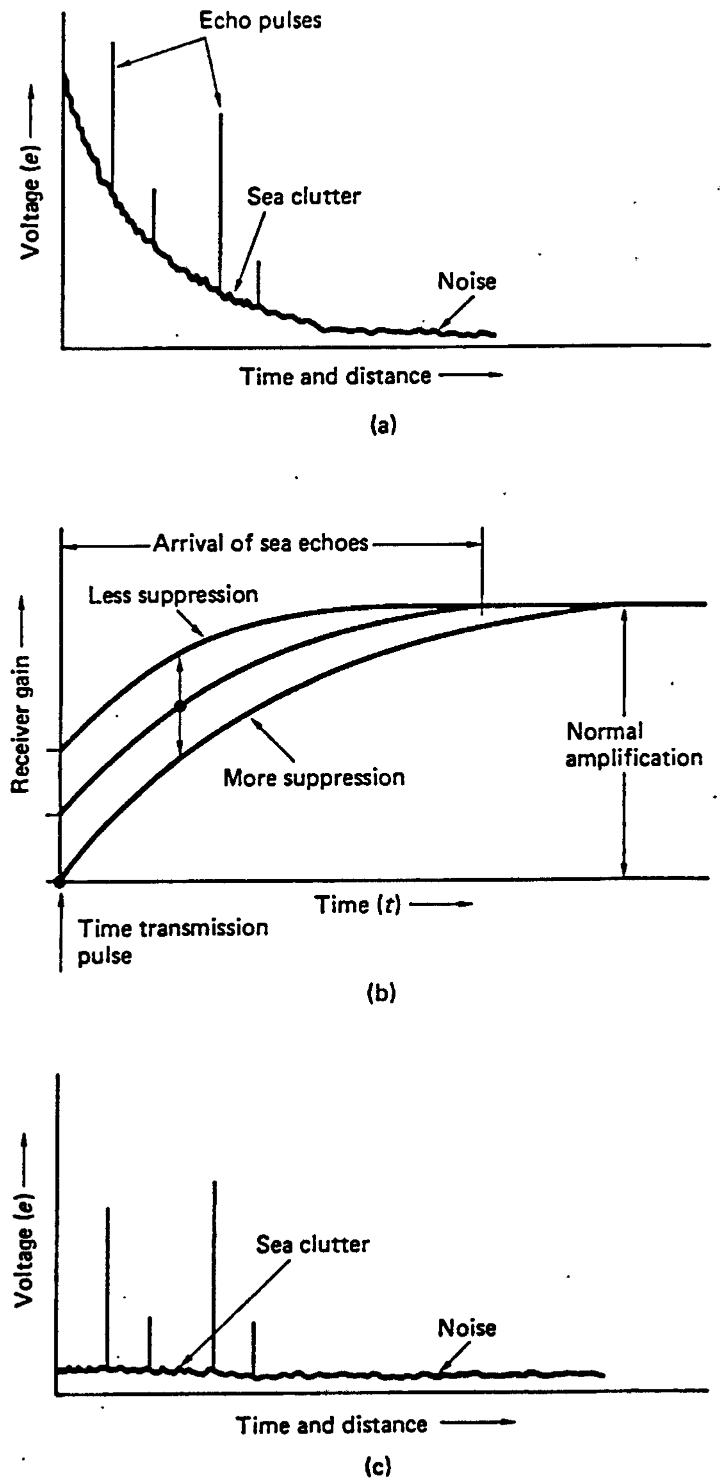


Fig. 3.4 *(a)* Sea echoes; *(b)* swept gain amplifies the nearby strong echoes less than the weaker echoes from a greater distance; *(c)* the sea echoes have almost disappeared

3.7 SENSITIVITY TIME CONTROL (STC) - ANTI SEA CLUTTER

3.7.1 The sea surface around the ship reflects radar pulses. These reflected radar pulses are displayed on the PPI as sea clutter. Displayed sea clutter depends on the pulse length, scanner height, wave length, wave direction and wave height amongst other factors. Echoes of small targets like buoys, wooden boats and small ships may be masked by the sea clutter and therefore not seen.

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3.7.2 To overcome this problem, it is necessary to clear the PPI of sea clutter. This is achieved by

- applying time (range) dependant amplification in increasing scale (Fig.3.4),
- by digital scan-to-scan or sweep-to-sweep correlation technique.

3.7.3 Scanners on large ships are sited very high above the sea level. They give more sea clutter. The sea clutter is more prominent on the windward side.

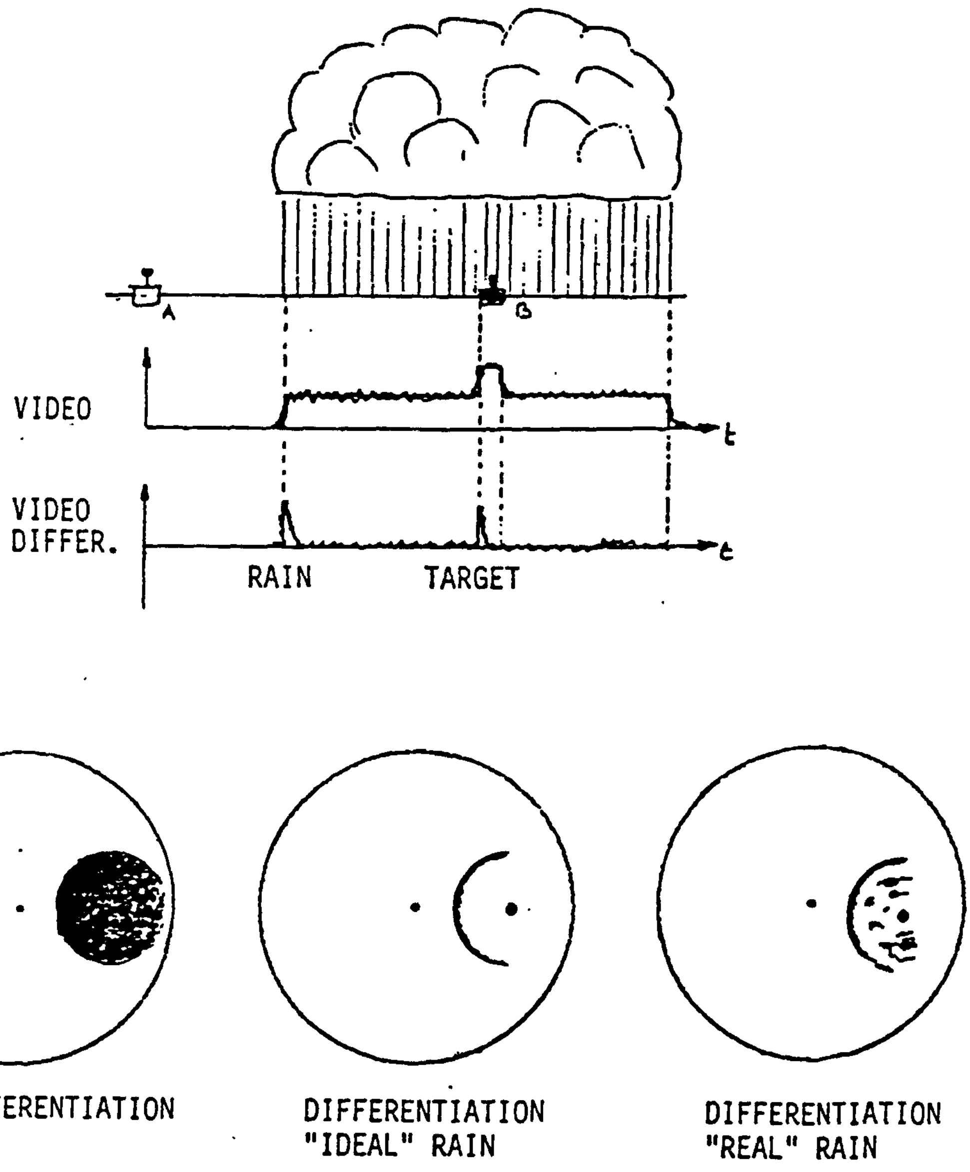

A
B
VIDEO
t
VIDEO
DIFFER.
t
RAIN
TARGET
NO DIFFERENTIATION
DIFFERENTIATION
"IDEAL" RAIN
DIFFERENTIATION
"REAL" RAIN

Fig. 3.5

3.8 FAST TIME CONSTANT (FTC) - ANTI RAIN CLUTTER-DIFFERENTIATOR

3.8.1 Heavy rain, hail and snow reflect radar waves and are displayed on the PPI as a compact area. Though echoes from ships are normally stronger than the rain clutter, they can be hidden due to saturation unless the clutter is suppressed.

3.8.2 The FTC control causes only those signals to pass which have rapid increases in their echo voltage levels, while suppressing the signals of steady level. This results in resolving large bright areas on the screen into smaller "spots". (Fig.3.5).

3.8.3 When applying anti rain clutter, it should be borne in mind that Racon signals are suppressed as they are of steady unchanging intensity.

3.8.4 There is a general tendency to reduce the gain when rain clutter is present. However, it should be noted that by reducing the gain, the echo strength of the target is also reduced alongwith the rain clutter. This may result in target echoes being painted very faintly or not being painted at all.

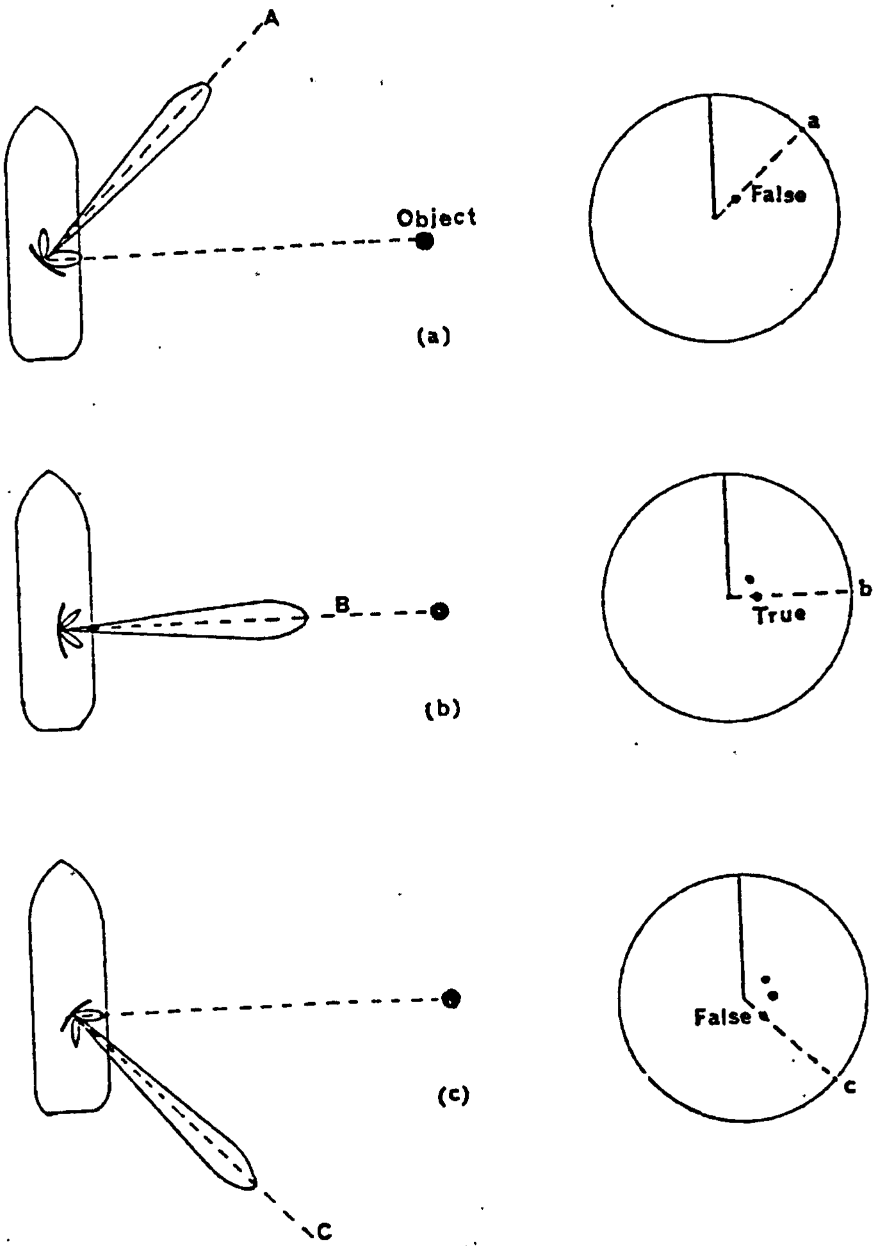


Fig. 3.6 Sidelobe Echoes

3.9 FALSE ECHOES - GHOST ECHOES

False echoes can be categorised as:

- side lobe echoes;
- multiple echoes;
- indirect echoes;
- disturbances and interference;
- second trace echoes;
- echoes caused by cables crossing channels.

3.9.1 GENERAL WARNING

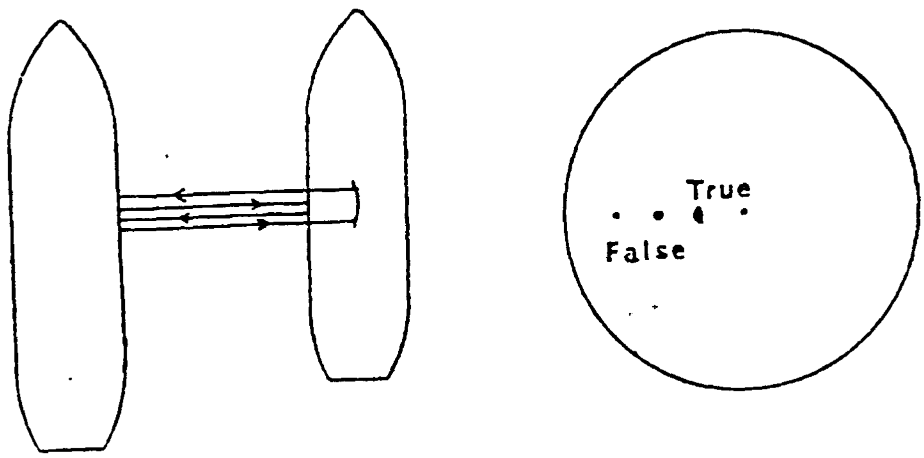
The occurance of false echoes should be borne in mind when operating ARPA on automatic mode. ARPA cannot distinguish between a false echo and true echo and will acquire and track a false echo. This may give rise to cluttering of the PPI with many vectors as well as many false alarms causing nuisance at best and confusion at worst. Added disadvantage is that many of these false echoes appear when large targets are in the vicinity. mối gây phiền toái

vùng lân cận

3.9.2 SIDE LOBE ECHOES

Side lobe echoes are caused by the side lobes of the antenna beam pattern and are shown on both sides of the main echo. Large targets at close ranges give rise to side lobe echoes (Fig.3.6). Besides cluttering the PPI, the side lobe echoes may create difficulties for the ARPA. In automatic mode, these echoes will be acquired and tracked by the ARPA as if they were echoes from a real target.

Side lobe echoes can be reduced in strength by reducing gain and increasing anti sea clutter judiciously.



MULTIPLE ECHOES

Fig. 3.7

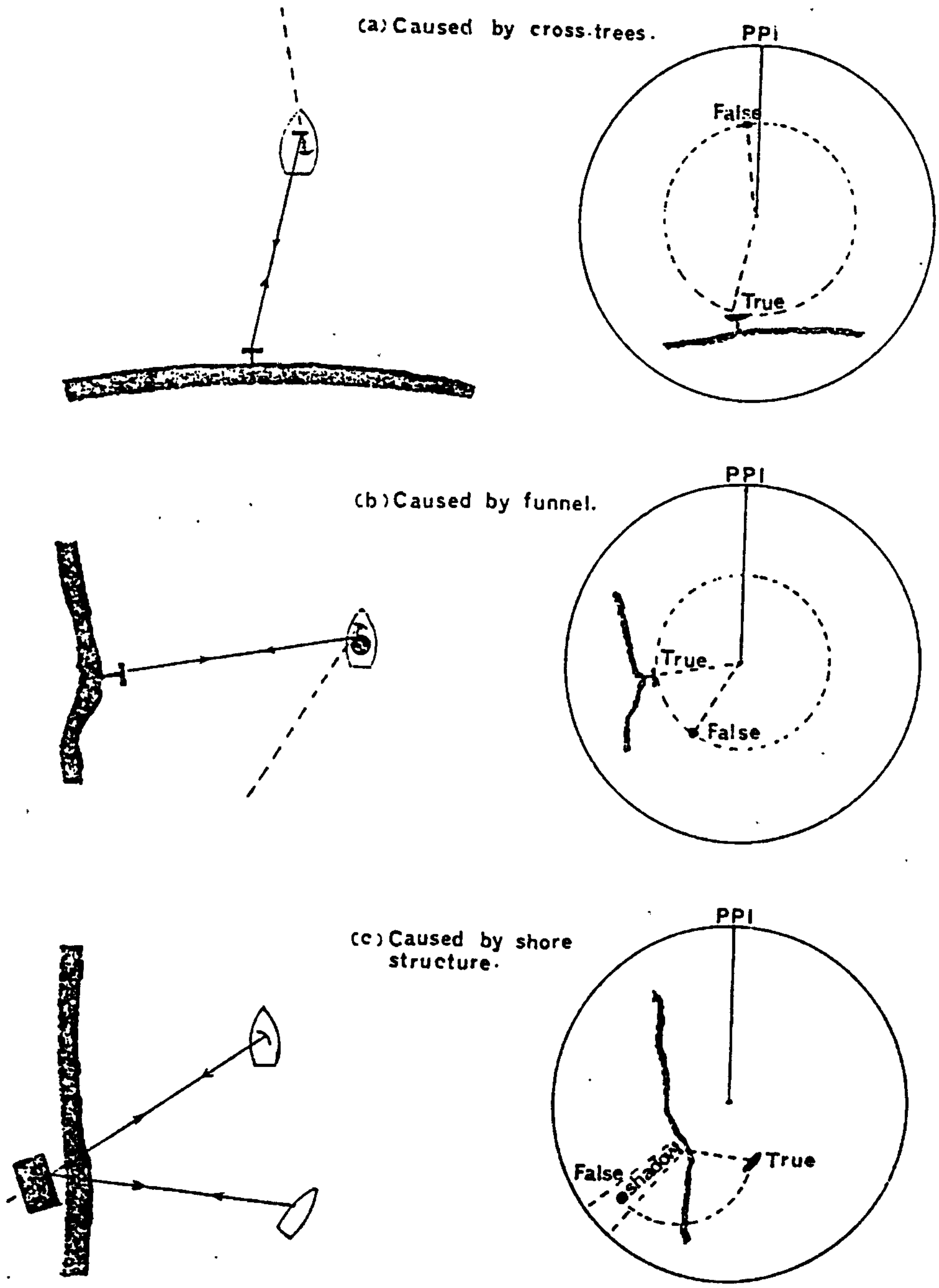


Fig. 3.8

INDIRECT ECHOES

3.9.3 MULTIPLE ECHOES

Multiple echoes are caused when more than one echo is received from a target. This may occur when a large target is nearby and the radar pulses are reflected repeatedly between target and own ship. Besides the main echo, one or more echoes are seen on the same bearing, equidistantly spaced and having ranges of multiples of true ranges. Main echo is nearest to the ship. (Fig.3.7).

Multiple echoes can be reduced by reducing gain or clutter judiciously.

3.9.4 INDIRECT ECHOES

Indirect echoes are caused by:

- ship's structures, e.g. cross trees, funnel;
- shore structures, e.g. sheds, bridges.

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The transmitted pulse is reflected by the cross tree etc. and the echo also returns via the same the path; and paints on the PPI in the direction of the structure. (Fig.3.8)

These can be reduced by reducing gain or increasing anti sea clutter control judiciously.

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It would be prudent to study the ship's structure with a view to understand possible sources of indirect echoes. Generally they occur in shadow or blind sectors.

3.9.5 DISTURBANCES AND INTERFERENCE

Disturbances are caused by

- internal disturbances of radar set,
- disturbances from electrical appliances.

Interference is caused by radar transmissions from other ships.

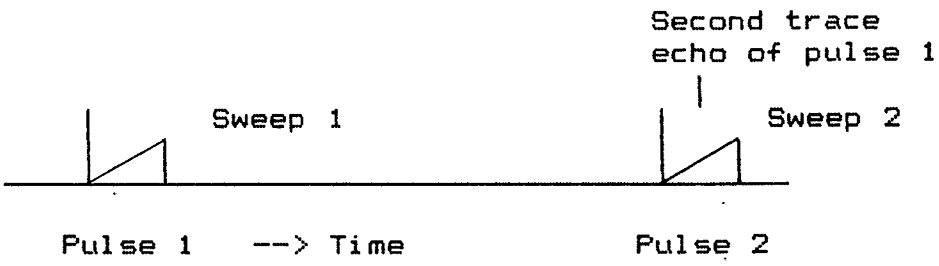
Interference caused by radar transmissions from other ships is displayed as a circular pattern if PRF of both ships are ideally the same and as a spiral pattern if PRF of both ships are slightly different which is usually the case. Both radars should of course, be operating on the same frequency band. Slight mistuning of own radar, changing of the range scale or switching off and on of the radar may be useful in reducing interference by other radars.

3.9.6 SECOND TRACE ECHOES

Second trace echoes occur when the echo pulse from a distant target arrives only after the next pulse has been transmitted and the sweep is active.

For second trace to occur, following conditions are necessary:

- strong reflecting target;
- super-refraction;
- characteristic distances.



The minimum and maximum distances for second trace echoes to occur can be calculated from the formulas:

Minimum distance = Time of repetition in μ sec * C/2
= (10^6 μ sec * 150 mtrs/ μ sec)/ PRF
Maximum distance = Minimum distance + Range scale

Table 3.2 shows minimum distances for different PRFs.

PRF	Minimum Distance
1000	81 nm
2000	40.5 nm
500	162 nm

Table 3.2

Crossing Cable

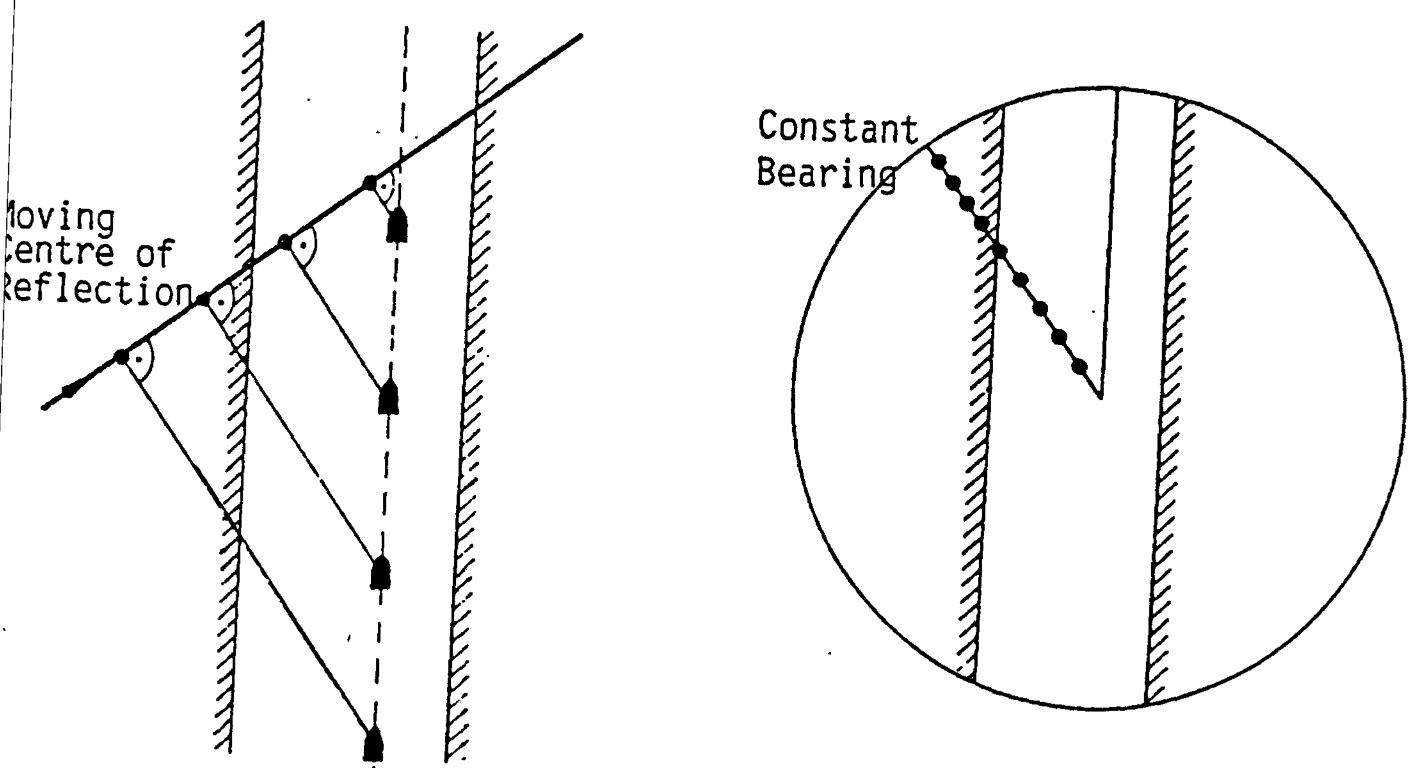


Fig. 3.9 False Echoes Caused by Crossing Cables

For example, on radar with PRF 1000 per second, range scale 12 nm, and echo at different distances, the echo will be seen on the PPI at distances as shown in Table 3.3

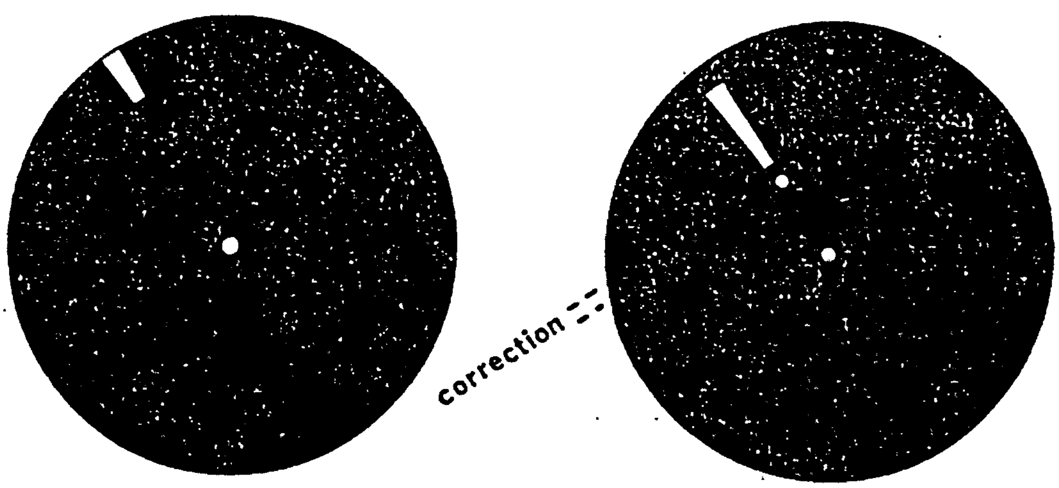
Target distance	PPI distance
81 nm	0 nm
82 nm	1 nm
87 nm	6 nm
92 nm	11 nm
93 nm	12 nm
95 nm	will not be seen

Table 3.3

3.9.7 FALSE ECHOES CAUSED BY CABLES CROSSING CHANNELS

A cable crossing a channel will reflect echoes towards the ship from one spot perpendicular to the direction of the ship.

These reflected echoes are seen on the PPI as those of a target on constant bearing and reducing range - a collision case. (Fig. 3.9).



RACON SIGNAL AT LONG AND SHORT RANGE

Fig. 3.10

3.10 RADAR BEACONS, TRANSPONDERS, RADAR REFLECTORS

3.10.1 RADAR BEACONS: RACONS

Following types of racons are in operation for navigational purposes:

- slow sweep racon;
- stepped sweep racon;
- fast sweep racon;
- fixed frequency or edge band racon;
- frequency agile racon.

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The racon may sometimes create interference problems. The racon signal obscures echoes of targets. It is possible to remove the racon signal by use of anti-clutter rain or differentiator control. However at close ranges, the use of this control will produce a black shadow on place of the racon signal. No other echo will be painted in this shadow and targets will be missed. Racon signals will not be painted if the polarisation of the radar and the racon are different. This should be borne in mind when using racons. Generally marine radars and racons have horizontal polarisation. But some radars may have vertical or circular polarisation.

3.10.2 RADAR REFLECTORS

Radar reflectors are generally made of metal plates creating mutually perpendicular surfaces. They serve to reflect most of the radar pulses in the reverse direction.

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They are used to boost up the echoes of small craft, wooden boats and buoys.

Under normal propagation conditions, the detection ranges of targets fitted with radar reflectors are as given below in table 3.4:

(Radar antenna height 15 mtrs above sea level)

Target	Range without radar reflector nautical miles	Range with optimum radar reflector nautical miles
Coast lines: ground rising to 60 mtrs	20	25
6 mtrs	7	14
Surface objects: ship of 5000 grt. any aspect	7	17 (reflector 15 mtrs above sea level)
Small ships 10 mtr in length	3	12 (reflector 4 mtrs above sea level)
Navigational buoy with effective echoing area of approx. 10 sq.mtr	2	10 (reflector 3 mtrs above sea level)

Table 3.4

3.10.3 TRANSPONDERS

At present, radar transponders are required on survival crafts as search and rescue transponders (SART). They operate in 9 GHz band. In IMO, the Maritime Safety Committee in its Safety of Navigation sub-committee has been considering use of transponders for identification and communication in collision avoidance situations. A new method for identifying radar targets as suggested by the author of this paper is enclosed at **Appendix A.**

3.11 FACTORS AFFECTING RANGE ACCURACY

Range accuracy of radar depends on the exact measurement of time interval between transmission of pulse and reception of echo. The following factors may affect the accuracy of the range measurement on radar:

- fixed errors due to length of wave guide (which are usually compensated at installation of the radar),
- calibration error upto 1.5 % of range scale,
- VRM alignment with leading edge of echo,
- range scale : higher scale - reduced accuracy,
- PPI curvature : reduced accuracy near edge,
- line voltage variations,
- frequency drift causing unequal division of time,
- PPI interpretation, esp. of coastlines.

IMO Performance Standards for Radar specify range measurement accuracy to be 1.5% of the maximum range of the scale in use or 70 mtrs, whichever is greater.

3.12 FACTORS AFFECTING BEARING ACCURACY

The following factors may affect the bearing accuracy on radar:

- horizontal beam width by an amount equal to one half of the horizontal beam width,
- target size - small target gives better accuracy,
- target rate of movement; slower target allows better accuracy,
- stabilisation of display; yawing causes less accuracy,

- heel of the ship (maximum error on relative bearings 45°, 135°, 225°, 315°),
- sweep centring error,
- parallax error, EBL gives better accuracy than mechanical cursor,
- heading marker alignment with centre line of ship,
- gyro repeater alignment with master gyro.

IMO Performance Standards specify bearing accuracy to be $\pm$ 1° or better when the echo is at the edge of the display.

CHAPTER 4

DIGITAL TECHNOLOGY IN MODERN RADARS

4 DIGITAL TECHNOLOGY IN MODERN RADARS

With the advent of microprocessor technology, it has become possible to digitise radar signals which can be stored in memory in real time (write cycle). Once the data is in memory, it can be read from the memory (read cycle) to be processed in various ways

- to obtain bright picture for day-light viewing,
- to reduce clutter by correlation technique,
- to quantise the signals for tracking of the targets.

The process of quantisation is described in Chapter 5, para 5.2.

4.1 BRIGHTNESS OF DISPLAY

Two different techniques are used to make the radar display bright for daylight viewing in the ambient light conditions obtained on the bridge.

- Interscan technique is used with conventional phosphor tubes,
- Rasterscan technique is used with T.V. screens.

4.2 INTERSCAN

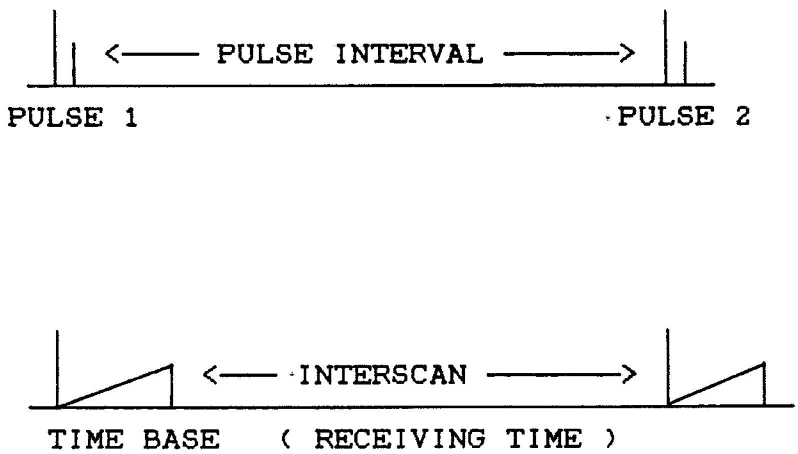


Fig. 4.1 Interscan

As shown in figure 4.1, the transmitter and receiver of a radar are idle during the period marked as interscan. This period depends on the PRF and range scale in use.

For example, on a radar with pulse length 1 μ sec., PRF 1000 and on 12 mile range, the interscan period is about 851 μ sec.

4.3 BRIGHTNESS OF DISPLAY ON PHOSPHOR COATED TUBES

Three different techniques are used to obtain brighter display for daylight viewing on a phosphor coated tube

- refreshing (repeating) the sweep cycle,
- expanding the sweep time,
- stretching and brightening the echo signal.

4.3.1 REFRESHING THE SWEEP CYCLE

On higher range scales, the interscan period is long. The processed radar signals are repeated more than once during the long interscan period. This effectively paints the echo on the PPI more than once and the picture becomes brighter due to repeated excitation of the phosphor coating.

4.3.2 EXPANDING THE SWEEP

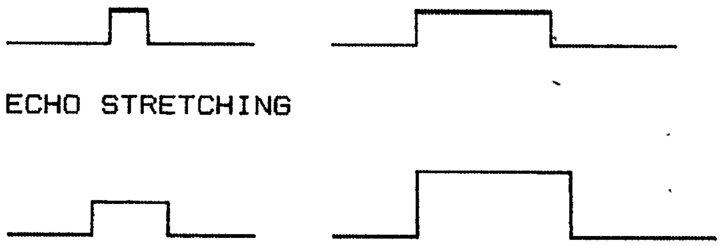
Time required for the electron beam to travel from centre to edge of the PPI (time base) is directly related to the range scale in use. On lower range scales, the time base is very short. For example, on 1,5 mile range scale, the time base is only 18.5 μ sec. This period is too short to excite the phosphor coating sufficiently for viewing in daylight. On a phosphor tube, the longer the electron beam strikes, the brighter is the picture.

Therefore, on lower range scales, by expanding the time base, the beam is made to travel slower, thus striking the phosphor for a longer period to produce a brighter picture. The beam travels at a fixed rate independant of the range scales in use.

4.3.3 STRETCHING AND BRIGHTENING THE ECHO SIGNALS

On 24 n.m. range with time base of 300 μ sec. a pulse length of 1 μ sec. is 0.0033th part of the time base. On 12 n.m. range scale it is 0.0066th part. Also distant targets subtend very small angles with the observing ship. Therefore, on higher range scales, the echo spots on the PPI are very short , narrow and weak. Such targets may not be detected unless their echoes are made larger and stronger. This is achieved by echo stretching and echo brightening.

(a)



ECHO STRETCHING

(b)

ECHO BRIGHTENING

Fig. 4.2

Detection of echoes which would otherwise go undetected helps acquisition and tracking of the targets. The echo signals are stretched to occupy longer part of the time base and strengthened by amplification as they are read out og the memory and therefore can be easily detected. The echoes appear of same size and strength irrespective of the actual target size.

Echo stretching is inhibited in the area of clutter.

Radars employing the interscan technique, called as "the first daylight radars" were the fore-runners of the rasterscan screens.

4.4 SYNTHETIC LINES

During the idle interscan period, the electron beam can be made to move to a desired position and to a desired length to produce a line. The resulting line can be used as the EBL or as navigation (mapping) line. The lines can be rotated with the cursor control and extended with the variable range marker control.

4.5 RASTERSCAN

Television screens are known as Rasterscan displays. The rectangular area scanned by the electron beam as it is deflected horizontally and vertically, is called "raster". The raster consists of horizontal lines, each line being made up of pixels. Typically, there are 525 lines each with 525 pixels making a total of 275,625 pixels. The number of pixels determines the resolution quality of the screen. The more pixels, the better the resolution.
For radar signals to be displayed on rasterscan screen, they have to undergo digital scan conversion.

4.6 DIGITAL SCAN CONVERSION

Conventional radars present target range and bearing in polar coordinates. The location of the target echo on the display is indicated in degrees and in miles with relation to the heading marker and the centre of the display respectively. In order to represent the same location on a rasterscan screen, it is necessary to convert the polar co-ordinates into cartesian co-ordinates. This is done by assigning the corresponding row numbers (X axis) and line numbers (Y axis) to the echo. The pixels thus designated, light up to produce a spot.

On the screen, the display is refreshed 30 times every second. This eliminates flicker and also makes the picture brighter. The brightness is homogeneous over the entire PPI.

Because reading out of signals from memory can be controlled by the microprocessor, the after-glow smearing on conventional CRT caused by manoeuvres or change of range scales is eliminated on rasterscan displays. The display is simply cleared and the entire display is refreshed with renewed signals.

Many manufacturers use part of the rasterscan screen to display a variety of graphical and alpha-numeric information of targets besides the radar picture of the vicinity. The information relates to

- own ship course and speed,
- display status: mode, range scale;
- variable range marker,
- electronic bearing line,
- warnings.

4.7 REDUCTION IN CLUTTER

Clutter can be reduced by

- scan-to-scan correlation,
- sweep-to-sweep correlation,
- setting threshold limits.

4.7.1 SCAN-TO-SCAN AND SWEEP-TO-SWEEP CORRELATION

As mentioned in Chapter 3, para 3.9.2, digital scan-to - scan or sweep - to - sweep correlation technique is used to reduce clutter. The strength of clutter caused by sea and by radio frequency interference and other noise sources is random in nature.

It also does not occur in the same azimuth and at the same range even over short periods of time. This randomness is helpful in reducing clutter by correlation.

One rotation of the antenna is one scan and one cycle of the electron beam from the centre of the PPI to the edge of the PPI is a sweep.

The digitised radar signals corresponding to a sweep or a scan are stored in memory known as registers.
The registers of target signals are compared to eliminate random echoes and to allow only those echoes which register for " m out of n " scans or sweeps. This is known as correlation technique to reduce clutter.

Figure 4.3 shows the register with echoes of targets and of clutter. The register is retained in the memory of the processor for subsequent comparision with the next register on the same bearing.

On successive scans or sweeps, data from first register is transferred to second register, from second to third register and so on for a predetermined " n " number of scans or sweeps. If a particular cell is " filled " for specified " m " number of times, the echo in that cell is acquired as a target. Usually if the cell is filled 3 times out of 3 sweeps, the signal is acquired as a firm target (plot). All other echoes are rejected. The " m out of n (MOON)" process thereby filters out clutter.

Time difference between two successive sweeps of a radar with PRF 1000 is 1 m sec (1000 μ sec). During such a small period, the clutter due to sea waves will not differ appreciably and therefore will not be rejected in the correlation process. Therefore, the scan-to-scan correlation is more effective than the sweep-to-sweep correlation in reducing clutter.

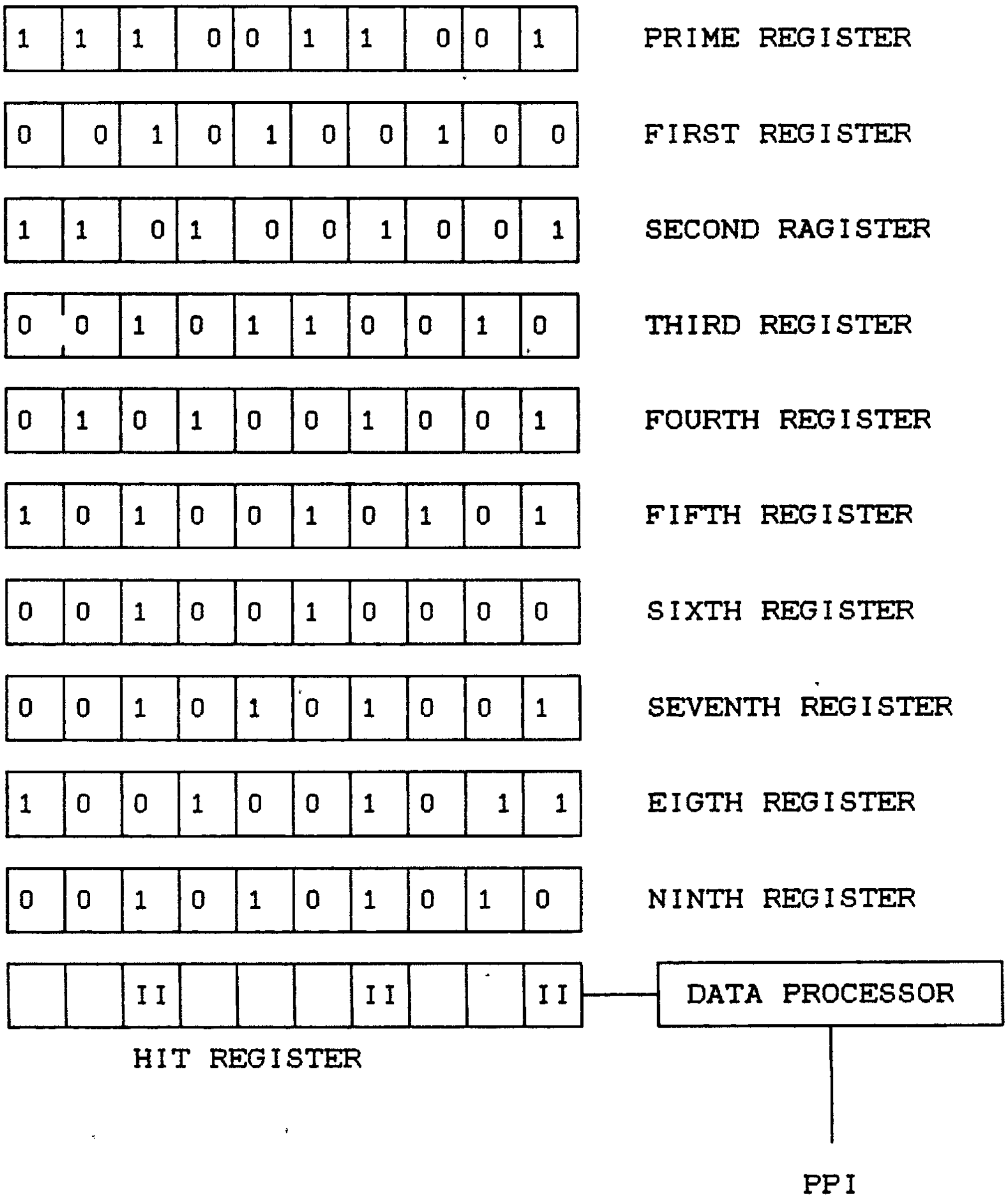


Fig. 4.3 Digitised register of echoes.

In order to reduce clutter to a great extent, the "cells" need to be made as small as possible. This is achieved by increasing the range and bearing discrimination of the radar system. However, there is a limit to which the cell can be made smaller. This aspect is further discussed in para 5.7 "Automatic Tracking".

4.7.2 THRESHOLD LIMITS FOR REDUCTION IN CLUTTER

Clutter can also be reduced by comparing the processed video output with predefined threshold limits for echo strengths. Any return which crosses the threshold limit is accepted and displayed on the PPI. The threshold is set at a level below which most of the clutter echoes will lie and therefore be rejected. It should be remembered that any target which is below the threshold will also be rejected and not displayed on the PPI. (Fig.4.4).

The threshold can be related to range, average noise level and strength of actual target video signal.

The threshold is controlled by hardware alone or by feedback from calculations in a processor. A radar system may have one or more threshold limits; in such systems the echoes will be displayed on the PPI in varying shades of brilliance.

To provide 1 threshold level, the video signals will be stored as (1) strong (Target existing) and (0) as weak (target not existing). This will require 1 bit of computer memory for every cell to be stored.

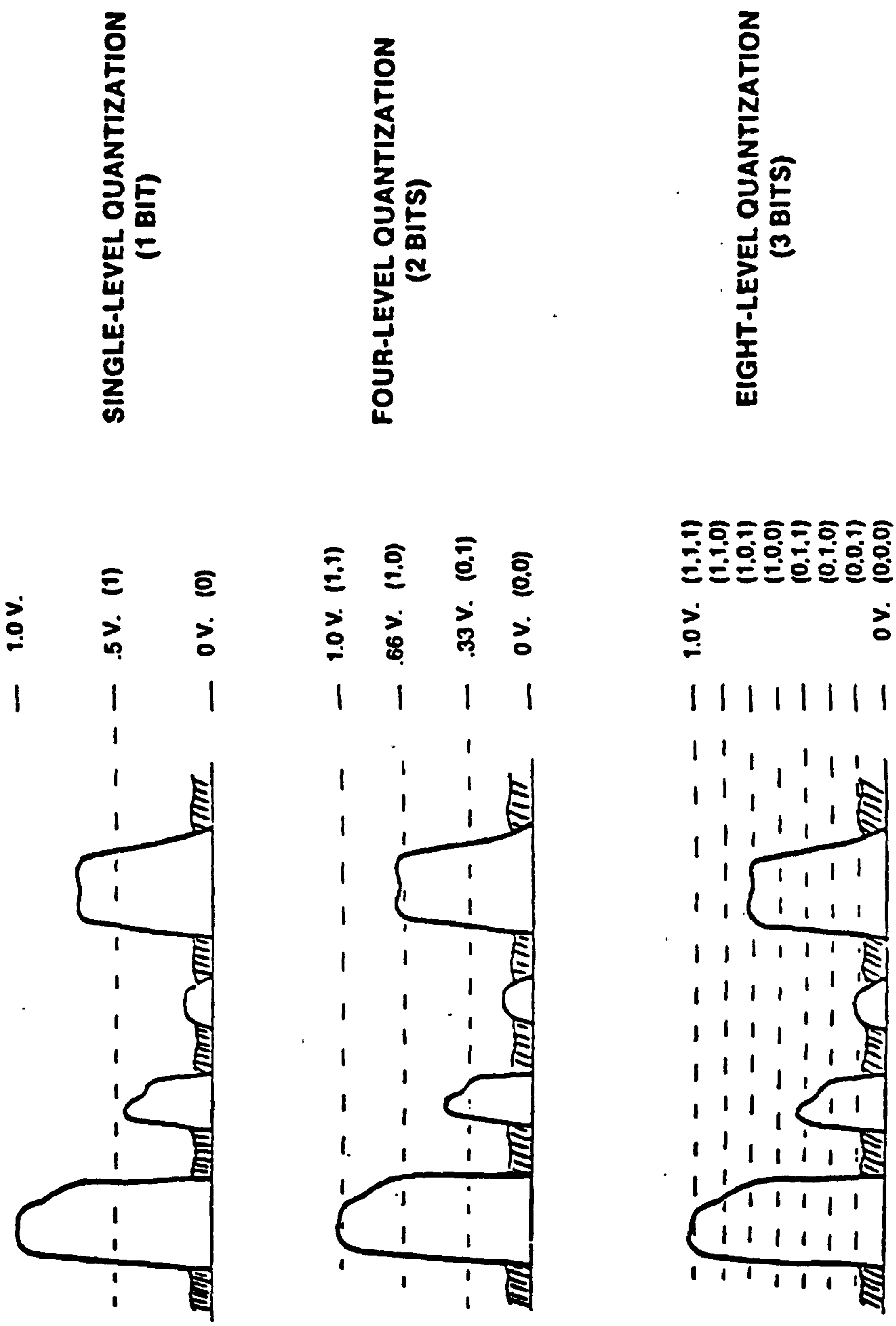

SINGLE-LEVEL QUANTIZATION
(1 BIT)
1.0 V.
.5 V. (1)
0 V. (0)
FOUR-LEVEL QUANTIZATION
(2 BITS)
1.0 V. (1,1)
.66 V. (1,0)
.33 V. (0,1)
0 V. (0,0)
EIGHT-LEVEL QUANTIZATION
(3 BITS)
1.0 V. (1,1,1)
(1,1,0)
(1,0,1)
(1,0,0)
(0,1,1)
(0,1,0)
(0,0,1)
0 V. (0,0,0)

FIG: 4.4

For 7 threshold levels, the video signals will be stored in 3 bits for every cell.

000 = 0 = No target
001 = 1
010 = 2
011 = 3
100 = 4
101 = 5
110 = 6
111 = 7 = Very strong target.

It will be seen that to provide 7 threshold levels, the computer will need 3 times the memory required for 1 threshold.

CHAPTER 5

THEORY OF
AUTOMATIC RADAR PLOTTING AIDS

5 THEORY OF AUTOMATIC RADAR PLOTTING AIDS

5.1 WHAT IS AN AUTOMATIC RADAR PLOTTING AID?

A radar provides the range and bearing of targets around own ship. However, it is necessary to know the closest point of approach and direction and speed of movement of the target to analyse the threat presented by the target to own ship.

This is possible only if the target is tracked by plotting its position at regular intervals. The plotting can be done

- on radar plotting sheets or manoeuvring board,
- on reflection plotter,
- by automatic radar plotting aids (ARPA).

dần

The first two methods are manual and suffer various handicaps. The biggest handicap is that any alteration of course or speed by own ship or target ships makes the plot useless. Any change in range scale in use creates discontinuity and necessitates re-plotting the targets. Moreover, one officer is fully occupied in plotting and he too can only plot and monitor limited number of targets, say 2 or 3 at a time.

cản trở?

đòi hỏi cần phải

The technique of digitising analogue radar signals has made it possible to process radar data by data processors for simultaneous and automatic plotting and tracking of multiple targets. The plotting and tracking is done by Automatic Radar Plotting Aids (ARPA).

The whole process of target detection, tracking, calculation of parameters and display of information is known as radar plotting.

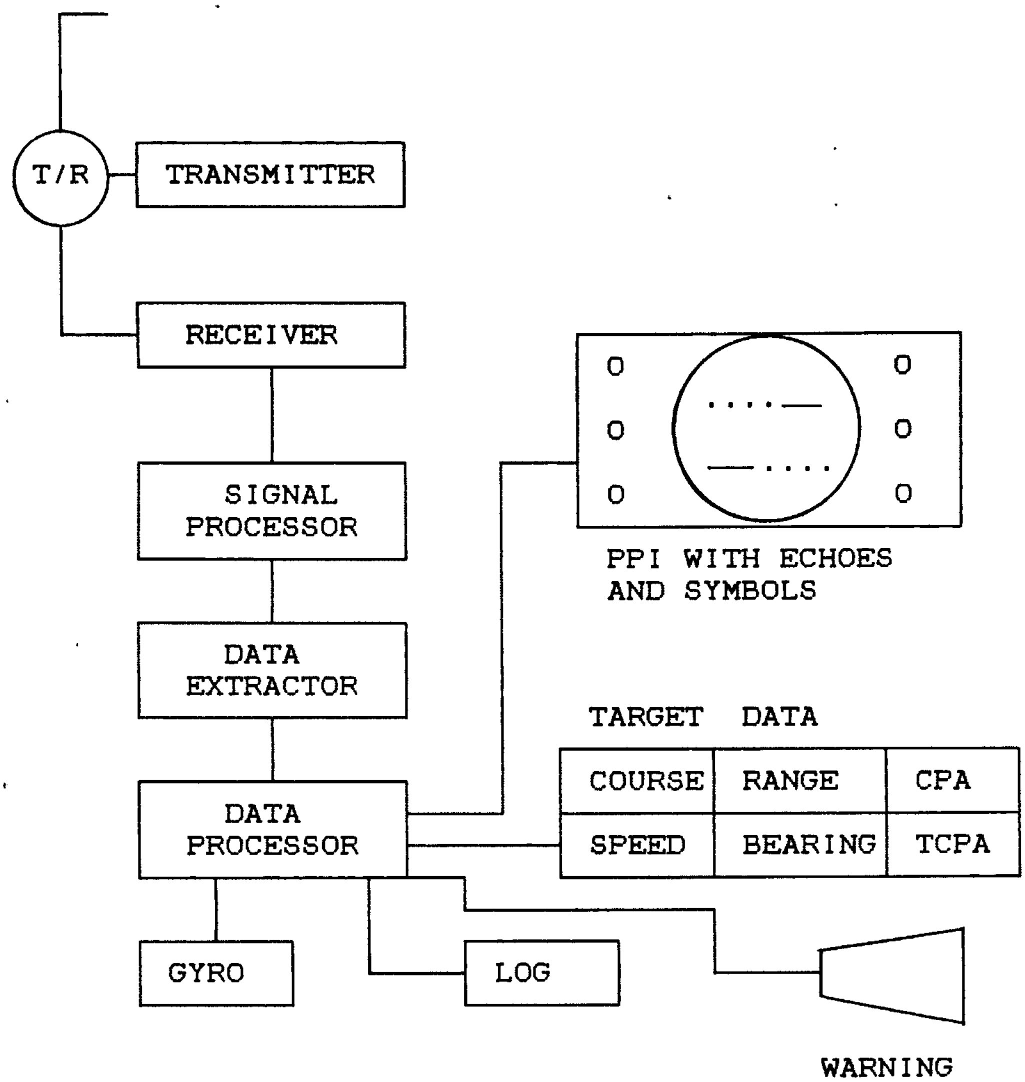


Fig. 5.1 ARPA BLOCK DIAGRAM

The process of observing the sequential changes in the position of a target to establish its motion is called tracking.

Trích dẫn

The following can be cited as some of the advantages of ARPA:

The automatic plotting frees the officer on watch from the tedious and time consuming task of plotting and tracking ships around his own ship.

Human errors in mechanical task of manual plotting are eliminated.

ARPA provides continuous, accurate and rapid information concerning closest point of approach (CPA), time to CPA (TCPA), speed and course of more targets and quicker than is possible manually in an encounter situation.

The information is provided to the officer in true or relative vector form and digital displays which can be Tiếp thu easily assimilated. Alarms based on operator selected limits of CPA and TCPA warn the officer about impending or developing close quarter situations.

đe dọa, sắp xảy ra

Trial manoeuvre facility assists operator in choosing safe avoiding actions in close quarter situations.

Tracking continues even after change in course or speed of own ship and / or of targets and after change in range scale in use.

ARPA itself does not make any decisions regarding manoeuvres or avoiding actions to be taken by own ship in close quarter situations. However, it is a powerful tool in the hands of the officer who can make the most use of this electronic aid.

5.2 QUANTISATION

Echoes of targets are received and displayed on radar PPI in polar co-ordinates, i.e. azimuth and range. In order to enable the computer to process the target data, it is necessary to convert the azimuth and range information into digital signals. The process of converting target data into digital form is known as quantisation.

Quantisation in range and in azimuth is carried out on video signals from the amplifier before being displayed on the PPI.

Quantisation is achieved by dividing the sea area around own ship into resolution cells. The size of the cells is determined by the pulse duration and the horizontal beam width.

When the cells are made smaller, a target may cover more than one cell. The processor calculates the centroid of the cells thus covered and assigns the co-ordinates of the centroid to the target.

5.3 QUANTISATION IN RANGE

To understand how quantisation in range is achieved, it would be useful to consider the time base to be divided into boxes called cells or bins. A series of cells making up one time base is a shift register.

The register not only receives pulses from echo signals of targets but also pulses from an oscillator clock synchronised with the transmission of radar pulse. The echo signals are stored in the appropriate cell depending on the range of the target. The oscillator clock pulses enable the cells to be "clocked" or numbered. The number of the cell is represented by a binary number which is used by the computer for processing. An example will make this clear.

Let us consider the radar to be on 6 mile range, and visualise a time base to be divided into sixty cells or bins. This will mean each successive cell represents an increase in range of one cable.

An oscillator will then provide a pulse every 1.24 μ sec. for each successive cell. Remember that an echo pulse from a target at 6 nautical miles will take
6 * 12.36 μ sec = 74.13 μ sec and there are 60 cells to be clocked in 74.13 μ sec. 74.13 μ sec / 60 = 1.24 μ sec.

The echo from a target at 5.2 nautical miles will be received after 64.27 μ sec and stored in a cell which will be clocked by the oscillator as 52.

Graphical representation is shown in the figure 5.2.

In the above example, it is assumed that the radar has range discrimination of one cable. The oscillator providing the clock pulses at 1.24 μ sec must have a frequency of 0.8 MHz.
(10^6 μ sec / 1.24 μ sec = 806452 cycles per second)

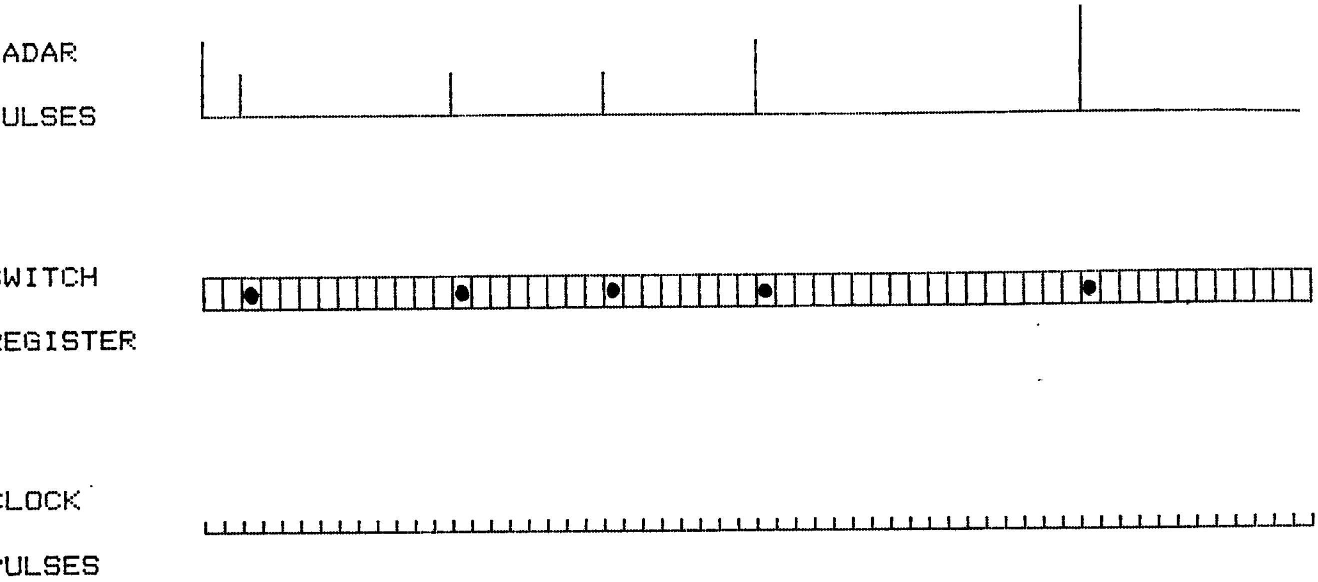
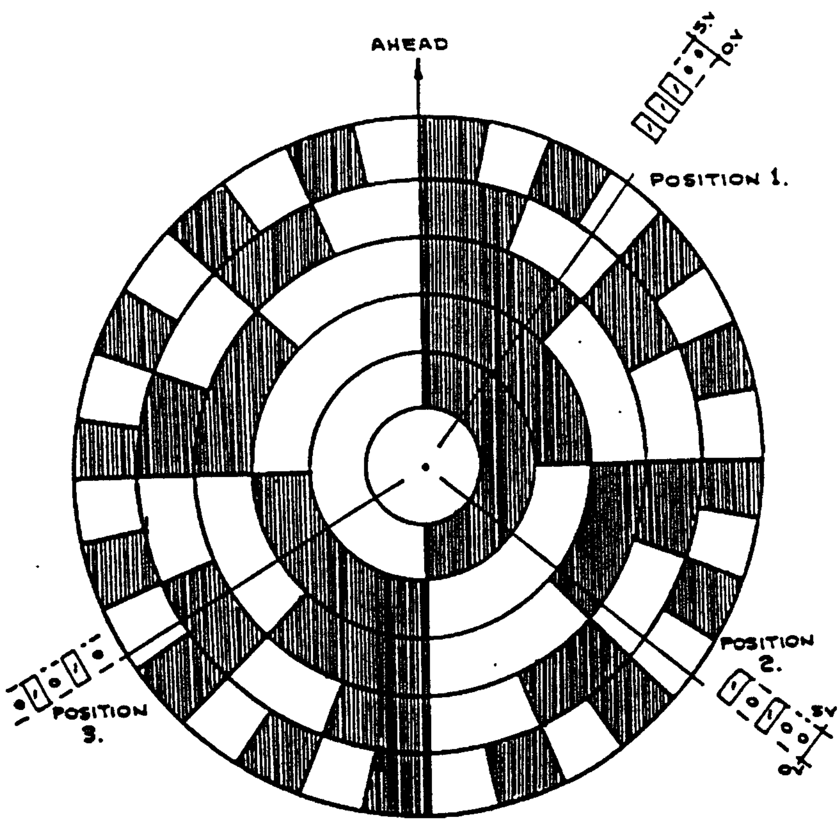


Fig. 5.2 Quantisition in Range



arrow, ray

Fig. 5.3 Mechanical shaft encoder
Shaded areas are connected to + 5 volts. Clear sectors are connected to 0 volts. The rotating wiper carries five brushes which have signals, as shown at position 1, 2, 3. These may be decoded as 1 and 0 to form a code. The code changes continuously as the wiper rotates in synchronism with the scanner.

To improve range discrimination, it would only require to divide the time base in larger number of cells, each representing a smaller range. This will mean that the oscillator frequency must also be increased in direct proportion to the increase in the number of cells.

For example, to have range discrimination of 37 mtrs. (0.02 nm), the shift register will contain 300 cells and the oscillator frequency will be 4 MHz.

5.4 QUANTISATION IN AZIMUTH

There are two techniques used to digitise radar bearings which can be processed by the computer:

- mechanical shaft encoder (shaft position encoder),
- pulse count.

5.4.1 MECHANICAL SHAFT ENCODER

A shaft encoder is a disk which has a number of concentric rings. Each outer ring is divided into twice the number of " segments " in the inner ring. The number is always a power of 2, e.g. 2^1, 2^2, 2^3, 2^6, 2^9, 2^{10}.
The number of rings depends on the desired accuracy of bearings.

The shaft encoder is built onto the antenna rotation mechanism. As the antenna rotates, a set of brushes travels over the shaft encoder in synchronisation with the antenna. The windows are made of conducting or insulating material as shown in figure 5.3.

query wire The brushes read the windows as 1 or 0. Conventionally, conducting windows are read as 1, while non-conducting windows are read as 0. The angular movement of the antenna which indicates the azimuth is thus quantised into digital signals.

chan say ouperIC

The windows can also be made opaque or clear, which are then "read out" by photo cells. The photo cells in turn produce electrical pulse (1) when against a clear window and no pulse (0) when against an opaque window.

If six concentric rings forming a shaft encoder are divided into 2, 4, 8, 16, 32 and 64 windows as shown in the figure, the bearing accuracy will be

$$360^\circ / 64 = 5.62^\circ$$

Each successive added ring will be divided into twice the number of windows, i.e. 128, 256, 512 etc, thereby increasing the discrimination to

$$360^\circ / 512 = 0.7^\circ.$$

Manufacturers generally use 10 rings which provides discrimination of

$$360^\circ / 1024 = 0.35^\circ$$

5.4.2 PULSE COUNT

In a radar system, the antenna rotates at an uniform rate and the pulses are transmitted at known PRFs. In modern radars, these two quantities are correlated to calculate the angular movement of the antenna.

An example will make this clear. Let us assume the antenna rotates at 20 RPM and the PRF is 1000 Hz.
The antenna rotates 120° in one second corresponding to 120° angular movement for 1000 pulses or 0.12° angular movement for every pulse.

In this case, 0.12° represents the bearing discrimination of the particular radar.

5.5 QUANTISED RADAR DATA

Quantised radar data is used as the input for a computer which processes the same to :

- reduce clutter
- automatically track and calculate true course and speed, relative course and speed, closest point of approach, time to closest point of approach, point of possible collision (PPC), predicted area of danger (PAD), sectors of danger and preference (SOD and SOP).
  Ưu tiên
- create other ARPA facilities e.g. automatic and manual acquisition including target detection on crossing guard zone, specifying exclusion areas to avoid acquiring echoes of unwanted targets, specifying priorities for automatic acquisition and cancellation of targets.

5.6 AUTOMATIC TRACKING

Modern marine radars employ the " track while scan " technique.

The process of tracking can be visualised if successive plots of a moving target are superimposed.

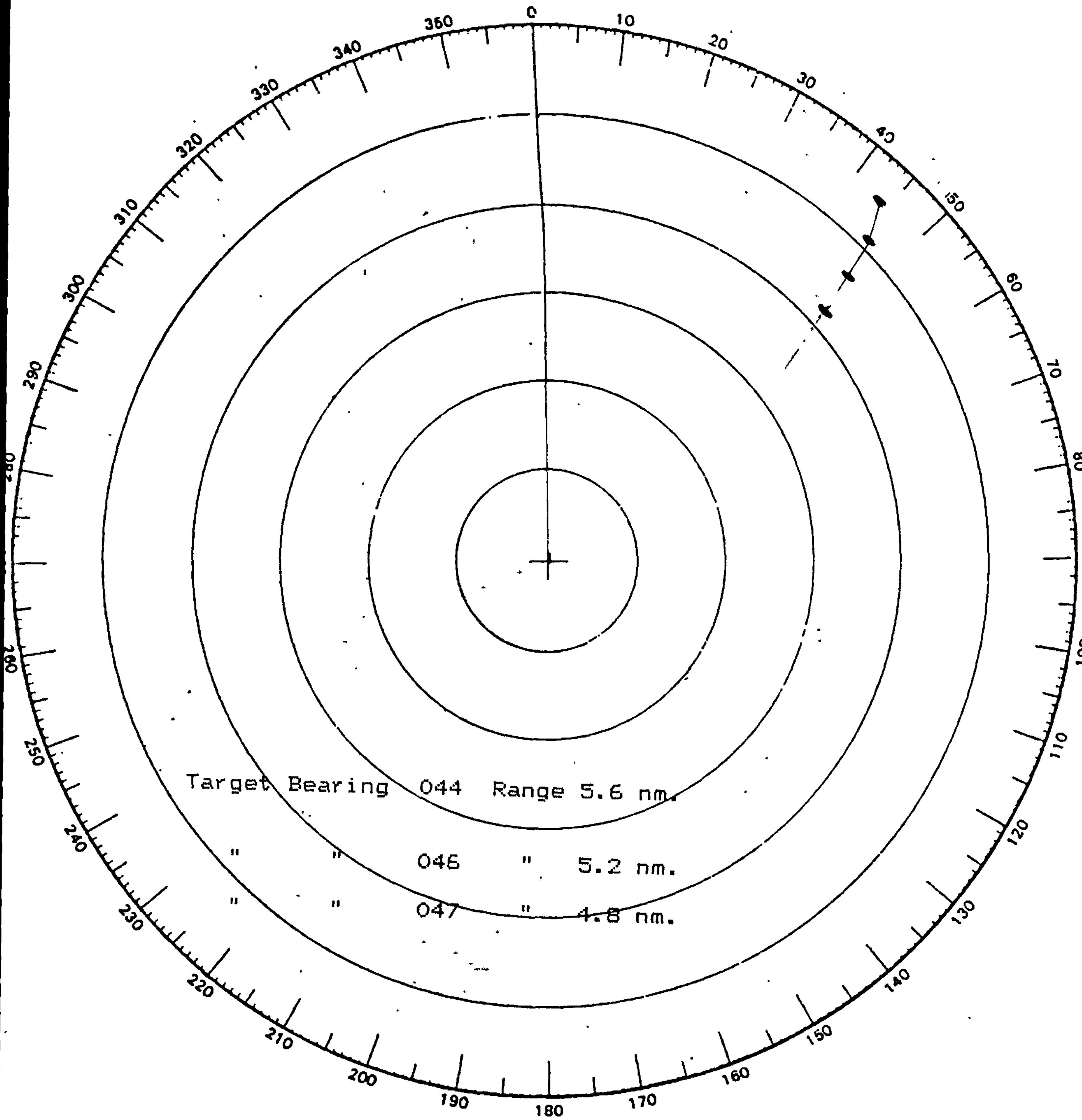
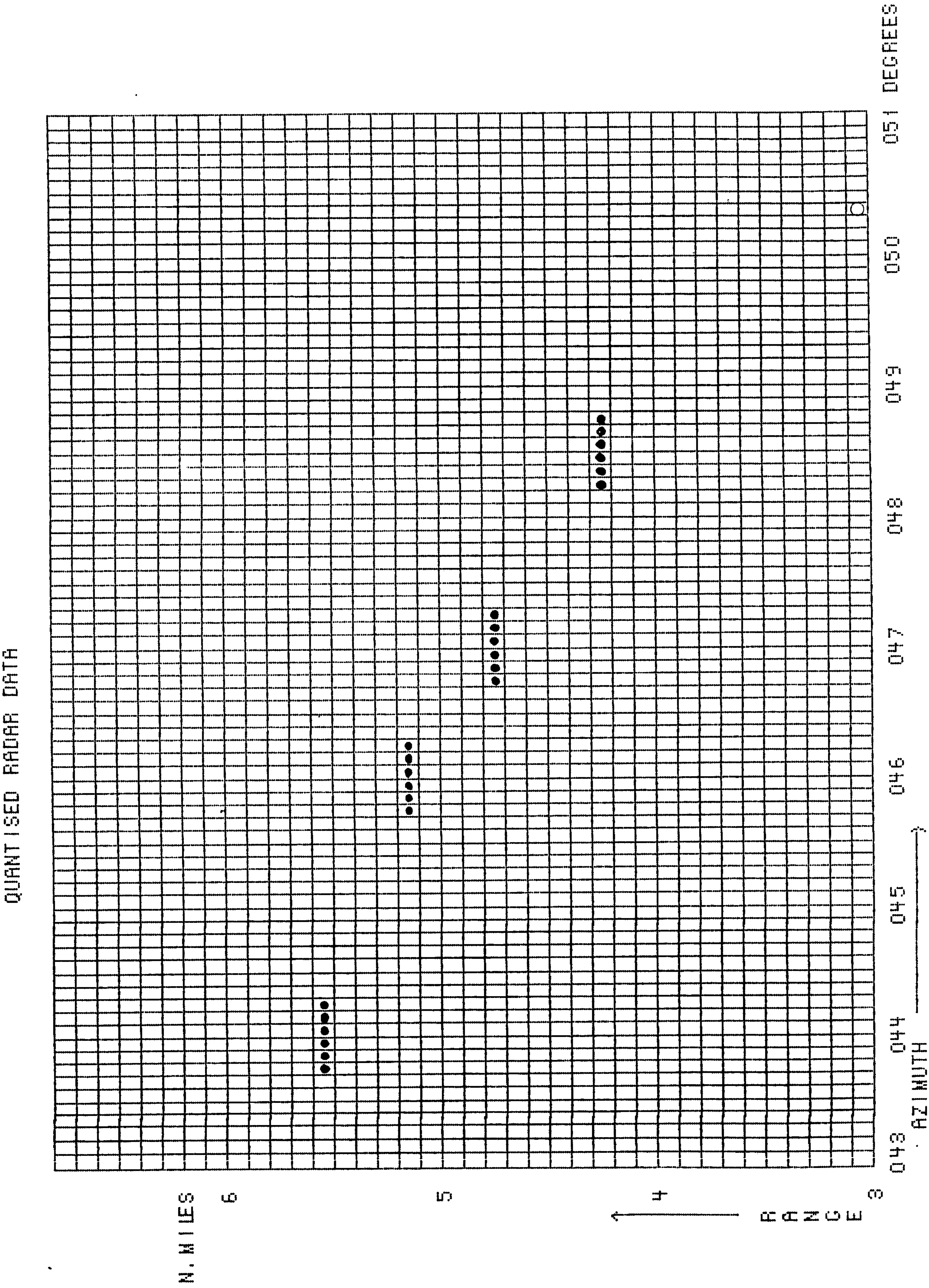


Fig. 5.4 Target as seen on PPI.



QUANTISED RADAR DATA
043
044
045
046
047
048
049
050
051 DEGREES.
AZIMUTH
3
4
5
6
N.MILES
RANGE

Fig. 5.5

The resulting line in case of a target having steady motion is composed of regularly spaced sequence of returns. This is very similar to marking the target on the reflection plotter at each scan with a chinagraph pencil.

IMO performance standards for ARPA contain following definitions:

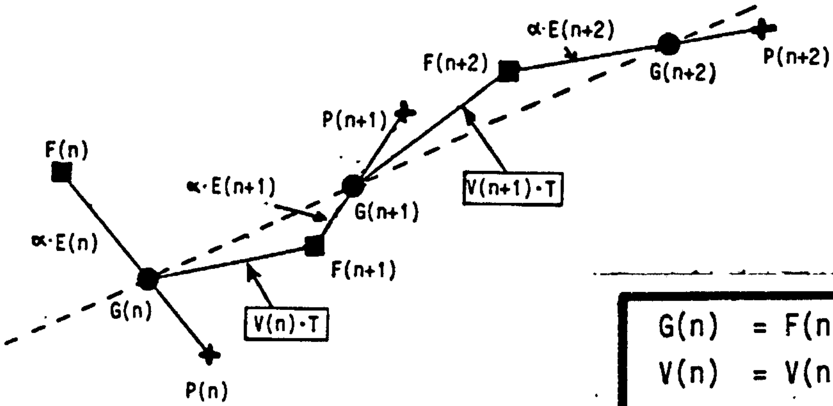
Target detection: The recognition of the presence of a target.

Target acquisition: The selection of those targets requiring a tracking procedure and the initiation of their tracking.

Target tracking: The process of observing the sequential changes in the position of the target, to establish its motion.

First of all, the signal processor detects the presence of targets and also eliminates clutter. The data extractor may be visualised as a "window" moving over the matrix of digitised signals of radar echoes. The window covers a pre-determined number of cells in the matrix. The target is acquired if it fills m out of n consecutive cells of the window, typically 4 out of 6.

The data extractor then calculates the centroid of all the cells covered by the target and assigns this value to the target. From this point the data evaluator takes over. Each target is individually identified and its velocity and other parameters calculated.



P(n) OBSERVED POSITION

F(n) FORECAST POSITION

G(n) ESTIMATED (FILTERED) POSITION

V(n) VELOCITY

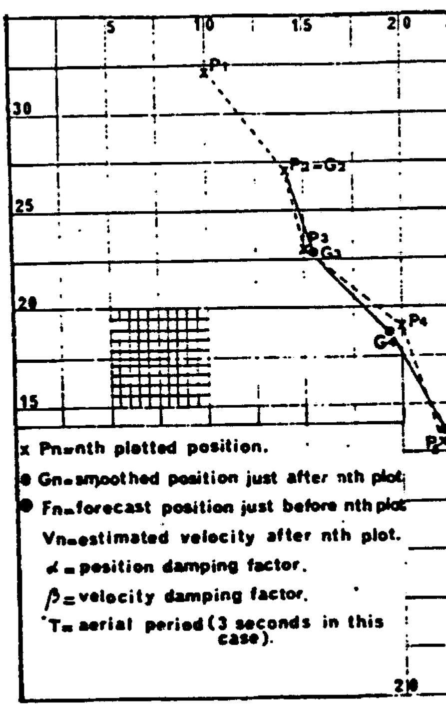
E(n) PLOT -ERROR (= P(n) - F(n)).

$$\boxed{\begin{aligned} G(n) &= F(n) + \alpha \cdot E(n) \\ V(n) &= V(n-1) + \beta/T \cdot E(n) \\ F(n+1) &= G(n) + V(n) \cdot T \end{aligned}}$$

Example: $\alpha = \dfrac{2(2n-1)}{n(n+1)}$

$$\beta = \frac{6}{n(n+1)}$$

Fig. 5.6 Alpha-Beta Filter



N	α	β	Px	Py	Gx	Gy	Fx	Fy	Vx	Vy
1	1.0	3.0	10	32	10	32.0	–	–	–	–
2	1.0	1.0	14	27	14	27.0	10.0	32.0	1.3	-1.7
3	0.83	0.5	15	23	15.4	22.8	17.9	21.9	0.8	-1.5
4	0.70	0.3	20	19	19.3	18.8	17.8	18.3	1.0	-1.4
5	0.60	0.2	22	13	22.1	13.6	22.3	14.6	1.0	-1.5
6	0.52	0.14	25	8	25.0	8.5	25.1	9.1	1.0	-1.6
N+1	0.52	0.14	29	5	28.5	4.4	28.0	3.7	1.0	-1.5
N+2	---	---					31.5	-0.4		
N+3	---	---								

$$\alpha = \frac{2(2N-1)}{N(N+1)} \qquad \beta = \frac{6}{N(N+1)}$$

$$\left\{\begin{aligned} G_n &= F_n + \alpha(P_n - F_n) && (1) \\ V_n &= V_{n-1} + \beta/T(P_n - F_n) && (2) \\ F_{n+1} &= G_n + V_nT && (3) \end{aligned}\right.$$

x P_n = nth plotted position.

● G_n = smoothed position just after nth plot.

● F_n = forecast position just before nth plot.

V_n = estimated velocity after nth plot.

α = position damping factor.

β = velocity damping factor.

T = aerial period (3 seconds in this case).

If smoothing pattern is based on N=6, calculate G_3 to G_7 & F_8.

Start with N=1, α=1, V_1=0; (all Ps are known).

From (1) $G_1 = P_1$

From (3) $F_2 = G_1 = P_1$ (1)

With N=2, α=1, β=1

From (2) $V_2 = 0 + 1/3(P_2 - P_1)$

From (1) $G_2 = P_2$

(3) etc.

Fig. 5.7 Tracking Loop and Smoothing Procedure

After initiating a track, an estimate of position and velocity of a target can be obtained from two consecutive target returns. The velocity is the ratio of change in position of target to time taken for such change as measured by radar scan time.

On the next scan, the echo from the same target is associated (correlated) with the track obtained earlier. This is named plot-track correlation logic.

Position of the target is predicted for the next scan, using current position and velocity. While predicting the area where the target would be at the next scan, estimated errors in position and velocity are taken into account. The area must be sufficiently large so that the target will be within that area. The area must also be small enough to reduce the possibility of two targets coming into it. In case of a manoeuvring target, the search area must be extended, considering the target's capability to manoeuvre. The extended search area is known as " manoeuvring gate ".

Once the target track is established, the estimate of target's position and velocity are improved upon using next echoes. This is known as " track filtering logic ". The filters are known as α, β filters.
(Fig. 5.4 and Fig.5.5)

The filters evaluate the errors between measured and predicted positions and use these errors to smooth the track prediction. Every successive measured and predicted position reduces the prediction error. As the number of scans after acquisition increases, the prediction error decreases, provided own ship and the target maintain their respective course and speed.

If many past positions are taken into account for track prediction, the filter reacts slowly. With a few past positions, the filter will react fast. Slow acting filter is appropriate to smooth a track whereas a fast filter will detect manoeuvre quickly. Therefore, a compromise is arrived at or automatic selection (adaptive) of fast and slow filters is used.

In case of a manoeuvre or presence of disturbance or if a target has just been acquired, the fast filter will come into operation. When the track of a target is well established, slow filter will be used.

Filtering takes time, about 10 to 30 rotations of the antenna. During this period, the displayed data is not accurate and should be used with caution.

The following parameters in respect of each track are stored in the data processor:

- track identification code,
- predicted position,
- actual (best estimated) position,
- filtered speed,
- time from last update,
- number of radar scans elapsed from initialisation,
- gain (α,β) of the tracking filter,
- quality measure of track,
- track status (new, tentative, firm, terminating, turning).

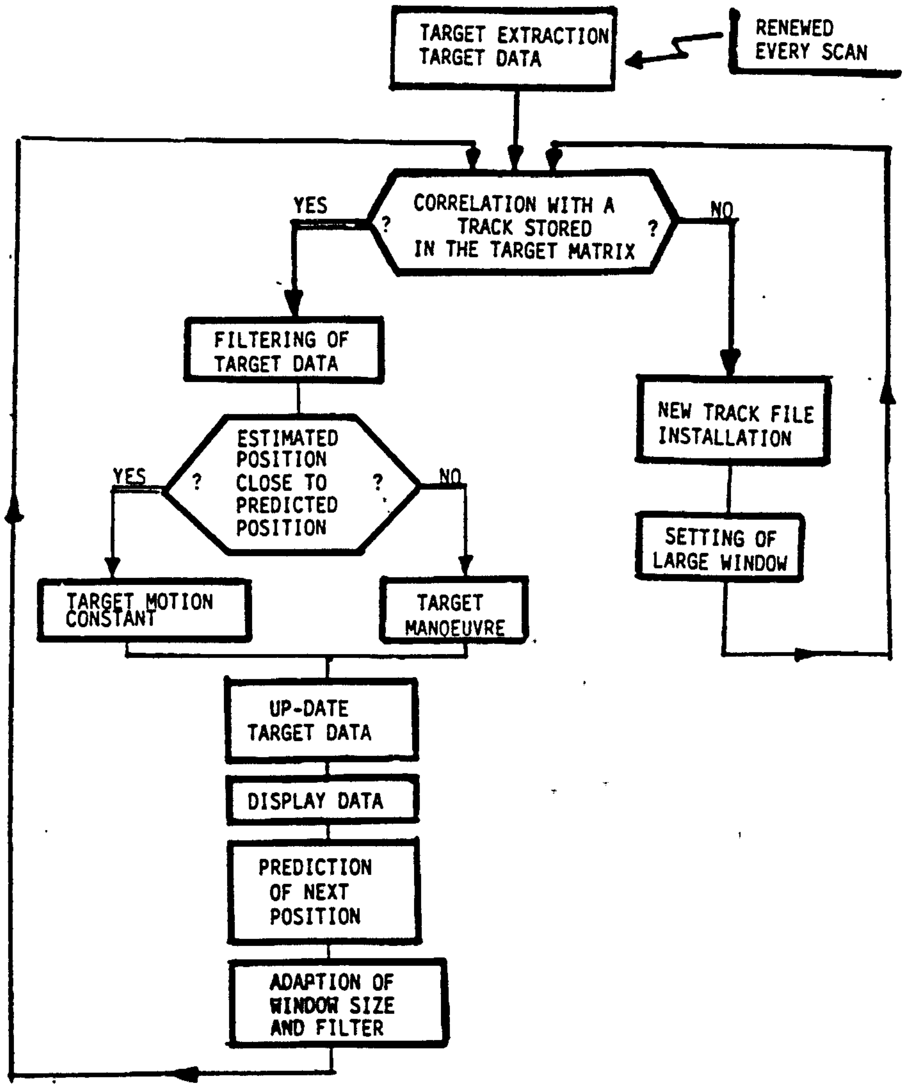


Fig. 5.8 Track- While-Scan (Tracking Loop)

5.7 CORRELATION TO INSTALL A NEW TRACK FILE

The concept behind correlation for tracking is comparision of the established tracks with new echoes, taking into account the radar range and bearing discrimination, track prediction accuracy and target manoeuvre capability.

After initiation of tracking, the position of the target at the next scan is calculated and is surrounded by an area known as the "correlation area or tracking window". This area is of such a size as to enable the target to lie within that area and at the same time to preclude two echoes falling in it.

When an echo does not correlate with an existing track, a tentative new track is initiated and process for confirmation of the new track is activated. Confirmation follows the same procedure - estimating velocity, predicting future position and velocity on the next scans and checking in the correlation area for the desired target. When the target is found several times over a number of consecutive radar scans, the track is established as a firm track. (Fig.5.6)

The size of the correlation gate is a function of:

- time,
- range,
- number of targets in the gate,
- actual target size,
- number of succeeding lost target samples.

6 IMO PERFORMANCE STANDARDS FOR ARPA

6.1 GENERAL

IMO has specified " Performance Standards for Automatic Radar PLotting Aids " by Resolution A.422 (XI).

The performance standards include the following:

- acquisition and cancellation,
- area rejection boundaries / area suppression boundaries / exclusion areas,
- guard zones / rings,
- automatic tracking,
- display of course and speed information,
- past positions,
- trial manoeuvre,
- accuracy for different types of encounters,
- operational warnings.

Though all manufacturers incorporate the minimum performance standards as laid down by the IMO, many manufacturers provide additional features or adopt different methods of providing the information required by the performance standards.(Fig.6.1)

6.2 SYMBOLS USED IN ARPA DISPLAYS

It should also be borne in mind that different manufacturers use different symbols on their ARPA. As yet, there has been no standardisation of symbols displayed on ARPA. IMO is presently working towards the standardisation of the symbols. A chart of symbols used by various manufacturers shows that the symbol for dangerous target used by one manufacturer is used by another for a safe

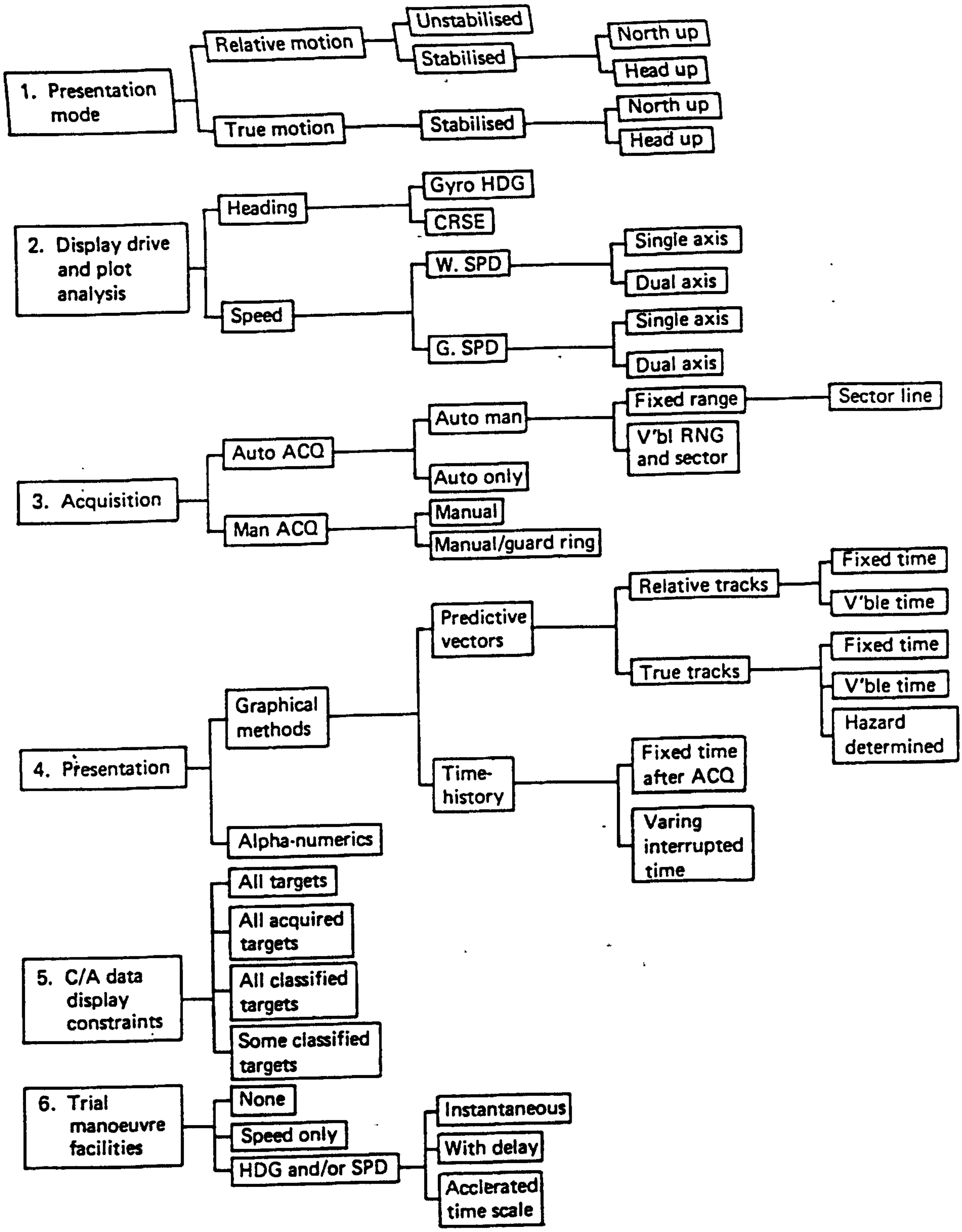


Fig. 6.1 Choice of system features

Table on ARPA Symbols

JAPANESE PILOT'S ASSOCIATION MAY, 1987.

NATION	MANUFACTURER	ARPA (SYMBOL)	1. SAFE TARGET	2. DANGEROUS TARGET	3. ACQUISITION MARK	4. APPROACHING TARGET TO GUARD RING	5. OTHER SYMBOLS (EXTRACT)
JAPAN	JAPAN RADIO CO.	JAS-800MⅡ	○—	△— DANGEROUS ◇— VERY 〃	Λ	☆	+ Joystick Mark.
JAPAN	FURUNO ELEC. CO.	FAR-1660	○— AUTO ACQUI. □— MANUAL ACQUI.	◎— AUTO ACQUI. ⊖— MANUAL ACQUI.	○ AUTO ACQUI. □ MANUAL ACQUI.	▽	△ CO. SP'D DISPLAY MARK
JAPAN	ISHIKAVAJIMA-HARIMA HEAVY INDUSTRIES	RADARMATE	RADAR ECHO & VECTOR	□—	×	◇	△ STATUS CHANGE MARK
JAPAN	TOKYO KEIKI	340 CAS & CAS Ⅱ			VECTOR - BROKEN LINE	Λ	□ JOYSTICK MARK
JAPAN	KYORITU RADIO RADIO	AUTORAP	○—	◉—	○	◇	◎ OWN SHIP MARK △ MANUAL PLOTTING MARK □ TRACKING TARGET ON TRIAL MODE
USA	RAYTHEON	RAYPATH	RADAR ECHO & VECTOR	✳—	BRIGHT SPOT	×	○ CO. SP'D DISPLAY MARK ▽ LEAST DAGEROUS TARGET × TRUE(FREE) MARK
ITALY	SELESMAR	AUTOTRACK	RADAR ECHO & VECTOR	THE SYMBOL BLINKS	+	⊥	△ TARGET FOR AUTO DRIFT □ CO. SP'D DISPLAY MARK
GERMANY	KRUPP ATRAS	RADAR ATRAS 7600/8600	□—		[ ]	SYMBOL BLINKS	× CO. SP'D DISPLAY MARK
UK	RACAL MARINE RADAR	ARPA 1690	RADAR ECHO & △—			▽—	□ BAD ECHO ○ JOYSTICK MARK
NORWAY	NORCONTROL	DATABRIDGE-7	RADAR ECHO & VECTOR	□—	×	⬡	○ JOYSTICK MARK △ PREDICTED COLLISION POINT
UK	KELVIN HUGHES	RADTRAK	◇—	□—	×	× (BLINKS)	△ DANGEROUS TARGET(TRIAL MODE) ○ JOYSTICK MARK
UK	MARCONI INTERNATIONAL MARINE	MARCONI ARPA	○—	THE VECTOR BLINKS	○	○	◎ CO. SP'D DISPLAY MARK + JOYSTICK MARK

REMARK: SOME OF THE SYMBOLS ARE DISPLAYED AS BROKEN-LINED/BLINKING/COLOUR SYMBOLS.

Fig. 6.2

Symbols Meaning

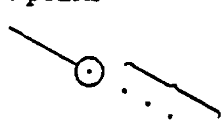
VECTOR, SYMBOL	MEANING	REMARKS
○————	Safe target	
△————	Dangerous target	With visual alarm (Danger lamp)
◇————	Very dangerous target	With visual and audible alarm
∧	Initial acquisition mark	Appearing after acquisition until vector presentation
Flickering symbol (∧, ○, △, ◇)	Target's numerical data indicated	When numerical indication is designated by joystick, symbol of associated target starts blinking.
○- - - - - - △- - - - - - ◇- - - - - -	Lost target (indicated when it cannot be tracked for some reason.)	With visual (Lost target lamp) and audible alarm
☆	Target incoming into guard ring	With visual (Guard ring lamp) and audible alarm
+	Joystick mark	Designating a target for manual acquisition, cancel and numerical indication Setting NAV–LINE (navigation line) and SUPPRESSION AREA (NOTE: No presentation with IND 1 and IND 2 of EBL mode.)
+ (Flickering)	Start point of NAV–LINE or SUPPRESSION AREA	Indicating the start point for setting NAV–LINE and SUPPRESSION AREA
4 points 	Past position of target	Presentation with PAST POSITION on, only
⧖	Land mark	In case of Total Navigator system (option)

Fig. 6.3 JAS 800 ARPA SYMBOLS

target (Fig. 6.2). Fig. 6.3 shows various symbols used in one make of ARPA.

The layout of control knobs on different makes of ARPA is also not standardised. Such lack of standardisation may cause confusion and misunderstanding in the minds of observers, especially when operating two different types of ARPA in a short span of time.

period

It cannot, therefore be overemphasised that it is of utmost importance to study and understand the symbols and controls on ARPA installed on board before proceeding to sea.

6.3 FEATURES OF ARPA

6.3.1 ACQUISITION AND CANCELLATION OF TARGETS

	ACQUISITION	CANCELLATION
MANUAL	By use of joystick or rollball arrangement	
AUTOMATIC	All detected targets, including targets crossing guard zones, subject to exclusion areas set up by observer using exclusion lines.	Targets meeting certain criteria

Table 6.1

Manual acquisition and cancellation facility is required on all ARPA. However, automatic acquisition and cancellation is optional. Manual acquisition and cancellation is achieved by selecting the required target by positioning the "joystick" or "rollball" symbol on the echo and operating the relevant switch.

Automatic acquisition is achieved by:

- acquiring all detected targets within selected area
- acquiring targets entering selected guard zones.

In automatic tracking mode, when the number of targets being tracked saturates the capacity of the ARPA and new targets are presented for tracking, the least dangerous target as determined by pre-defined criteria is automatically cancelled. In case no suitable target is found for cancellation, an overflow alarm is sounded.

The description of criteria employed for priorities for automatic acquisition and cancellation is required to be provided to the observer. This is generally included in the technical literature (manual) provided by the manufacturer with the ARPA set.

In one make of ARPA, the priority for acquisition is defined by following parameters:

First priority zone: One sector of 90°; 45° from stem on each bow.

Second priority zone: Two sectors of 45° each, forward of port and starboard beam.

Third priority zone: All remaining sector abaft the beam on port and starboard side.

Similarly, automatic cancellation of targets is performed in accordance with criteria specified by each manufacturer. Description of these criteria is also included in the technical literature.

In one make of ARPA, automatic cancellation occurs only if automatic acquisition is in operation and only if all of the following criteria are satisfied.

The target shall be:

- abaft the beam,
- increasing in range,
- at a range greater than 6 n.miles, than by any
- at a range greater than the innermost or only guard ring,
- not being used for target lock.

In another make of ARPA, when necessary, least dangerous target having highest CPA and TCPA is automatically cancelled in favour of dangerous targets .

In yet another make of ARPA, targets which have missed 60 scans are cancelled automatically if they do not violate the CPA and TCPA criteria. Targets are also cancelled automatically if their negative TCPA is more than 3 minutes and which are more than 10 nm away and abaft the beam.

In some ARPAs, targets have to be cancelled manually when an alarm indicates targets in excess of capacity are present when the ARPA is in automatic acquisition mode.

6.3.2 AREA REJECTION BOUNDARIES / AREA SUPPRESSION BOUNDARIES / EXCLUSION AREAS

In automatic acquisition mode, ARPAs which acquire all targets will soon become saturated i.e. no new targets can be acquired and tracked because the capacity of acquisition is exausted. This may happen when land echoes or large number of small boats are present as ARPA cannot distinguish between land echo and ship echo.

In order to prevent ARPA from acquiring and tracking unwanted echoes, lines / boundaries or sectors can be set up, demarking areas from where ARPA will not acquire and track targets. Such areas are known as exclusion / suppression areas.

It may be said that the area rejection boundaries "cordon off" part of the matrix in respective ranges and bearings and targets enclosed in such areas are not presented to the data processor.

In manual acquisition mode, area rejection / area suppression boundaries are not required.

6.3.3 GUARD ZONES / SECTORS / RINGS

Automatic acquisition can also be achieved when a target crosses observer - selected guard zones around own ship. Two guard zones are generally provided. The guard zones are locked onto own ship i.e. they move with own ship.

The guard zones can be placed at any desired distance. An alarm is sounded when a target crosses the guard zone.

Since manufacturers adopt different configurations of guard zones, it is essential to be familiar with the system provided on ARPA.

mistake

However, all guard zone systems have one shortcoming in common. If a target is detected after entering the guard zone, considerable time and distance may elapse [illegible] before it is acquired. If the target is weak, it may be detected only after it enters the innermost guard zone. In this case, the target may not be acquired at all and no alarm may be sounded.

6.3.4 TRACKING

Though IMO specifies automatic tracking, updating and display of information of at least

20 targets with automatic acquisition

10 targets with manual acquisition,

manufacturers provide varying capacities on their ARPA. In order to avoid saturation of the tracker by unwanted echoes, clutter due to sea, rain and other radio wave interference is reduced as mentioned in Chapter 5, para 5.6.

6.3.5 DISPLAY OF INFORMATION

Following information of all tracked targets is available on request in alpha-numeric form on ARPA:

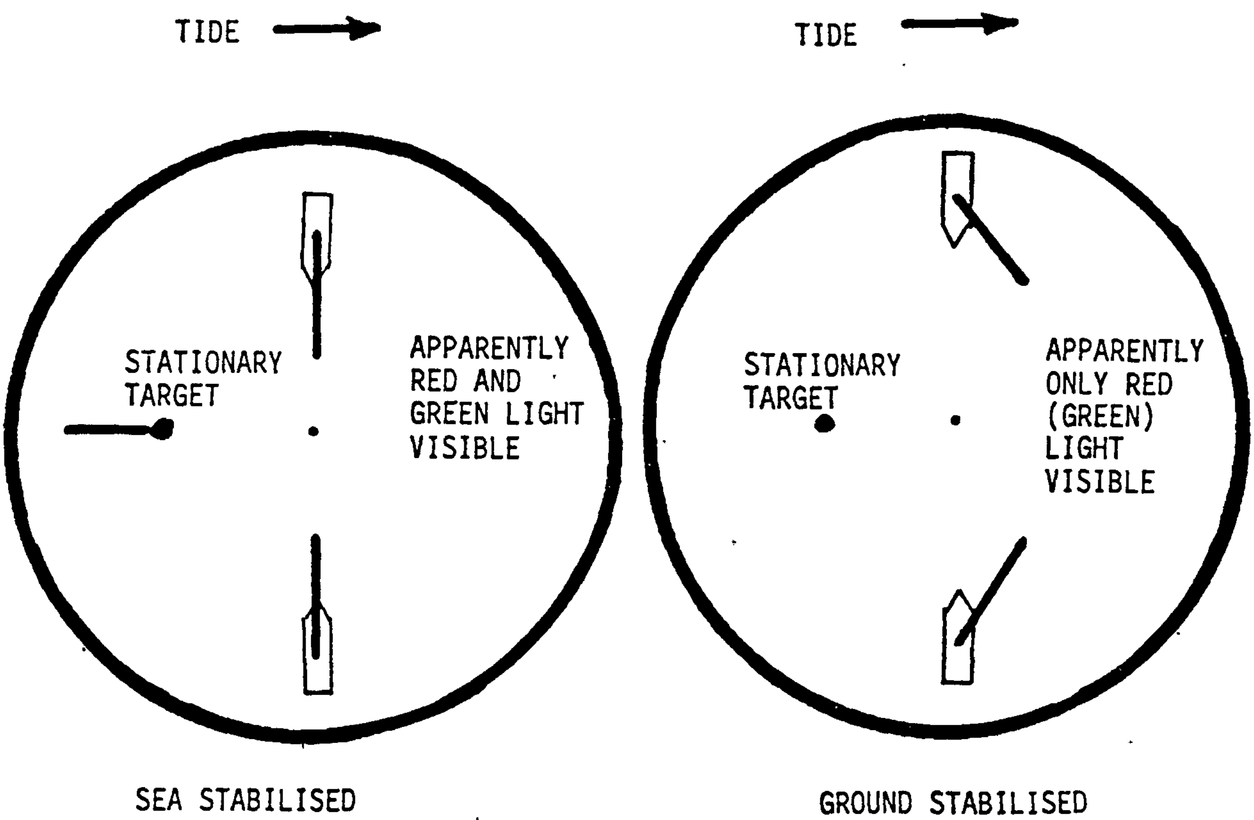
- present range of target,
- present bearing of target,
- predicted target range at the CPA,
- predicted time to CPA (TCPA),
- calculated true course of target,
- calculated true speed of target.

Some ARPAs also provide bow crossing distance and bow crossing time for targets.

The course and speed information of acquired targets is also displayed in vector or graphic form. True or relative vectors can be selected for display. The vectors may be adjustable for time or may have certain set time scale.

True and relative vectors have associated advantages and it is necessary to make use of both types of vectors to derive full benefit of ARPA.

SEA AND GROUND STABILISATION



SEA STABILISATION }
GROUND STABILISATION } DIFFERENT ASPECTS

→

ANTI-COLLISION ROLE :	SEA STABILISATION
NAVIGATION ROLE :	GROUND STABILISATION

Fig. 6.4

Relative vectors indicate, at a glance whether a risk of collision is present. If time adjustable, the relative vector can be extended to graphically indicate CPA and TCPA.

True vectors indicate the true course and speed of the target and are useful in choosing suitable avoiding action. When the display is sea stabilised, the aspect of the target can be determined from true vectors.

It is important to remember that the true vectors displayed on ARPA are calculated using speed and course inputs from own ship's log and gyro compass. Any error on these inputs will result in errors on true vectors displayed. (Fig. 6.4).

When ARPA is being used with true vectors for anti-collision purposes, the input is required to be speed of own ship "through the water", i.e. sea stabilised mode.

For navigational purposes, the speed input should be "speed over the ground", i.e. ground stabilised mode.

6.3.6 PAST POSITIONS

At least four equally time-spaced past positions over a period of at least eight minutes are required to be available on the ARPA. The past positions are stored in computer memory which has 4 levels. On obtaining new data, the oldest of the 4 position data is removed from the memory.

The past positions are displayed from computer memory; they are not recalculated and thus show the "true history". They show how the situation has developed and therefore are useful in determining if the target has manoeuvred in the recent past.

When reducing speed, considerable time may elapse before required speed is attained. In such cases, the new relative motion line may be nearer to own ship than indicated by trial manoeuvre where speed reductions are taken as having instantaneous effect.

Uneven tracks of targets may indicate unsatisfactory tracking of the target and displayed information should be treated with caution.

6.3.7 TRIAL MANOEUVRE

Trial manoeuvre facility provides a simulation of effects of own ship's intended action on all tracked targets.

Trial manoeuvre simulation may be presented in either of two modes:

- dynamic vector presentation,
- static vector presentation.

In dynamic vector presentation, the vectors move along the projected relative course. Such movement is accelerated 10 to 30 times. Own ship manoeuvring characteristics may be incorporated roughly into the system at the time of installation and are slightly adjustable during simulation. Since own ship manoeuvring characteristics vary depending on draft, trim, weather, current, speed, rudder angle etc., it is important to know the characteristics used for trial manoeuvre. combine

During this simulation, vectors move away from their respective echoes. This should be borne in mind. Most ARPA provide a facility to select trial speed and manoeuvre delay i.e. time to implement manoeuvre.

In static vector presentation during simulation of trial manoeuvre, the vectors remain attached to their respective echoes and respond to the selected course and speed as if the manoeuvre is immediately effective.

The projected paths and static vectors may also be depicted by use of multiple segments. There are usually 3 segments for present and 2 for final path. In such cases, the time to manoeuvre may be specified.

Trial manoeuvre simulation can be achieved via a spring loaded switch or a function key with clear indication provided on the PPI by letter "T" or"SIM" or similar symbol.

Since the simulation provides a possible future scenario, provided all targets maintain their courses and speeds, it may be useful in planning future course and speed of own ship. It may also be possible to see if any of the targets would need to manoeuvre for avoiding navigational dangers or collision situation. Own ship manoeuvre may then be planned accordingly.

6.3.8 ACCURACY

IMO has specified accuracy values (95 percent probability) for four different scenarios for information to be provided within one minute and within three minutes after steady state tracking. It should be noted that the accuracy values given are for environmental conditions inducing rolling of upto plus and minus ten degrees.

For each of the following scenarios, predictions are made at the target position defined after previously tracking for the appropriate time of one or three minutes:

Scenario 1

Own ship course	000°
Own ship speed	10 knots
Target range	8 nautical miles
Bearing of target	000°
Relative course of target	180°
Relative speed of target	20 knots

Scenario 2

Own ship course	000°
Own ship speed	10 knots
Target range	1 nautical mile
Bearing of target	000°
Relative course of target	090°
Relative speed of target	10 knots

Scenario 3

Own ship course	000°
Own ship speed	5 knots
Target range	8 nautical miles
Bearing of target	045°
Relative course of target	225°
Relative of target	20 knots

Scenario 4

Own ship course	000°
Own ship speed	25 knots
Target range	8 nautical miles
Bearing of target	045°
Relative course of target	225°
Relative of target	20 knots

The ARPA should present within **one minute** of steady state tracking, the relative motion trend of a target with accuracy values not less than those shown in Table 6.2.

Data / Scenario	Relative course (degrees)	Relative speed (knots)	CPA n.m.
1	11	2.8	1.6
2	7	0.6	
3	14	2.2	1.8
4	15	1.5	2.0

Table 6.2

The ARPA should present within **three minutes** of steady state tracking the motion of a target with accuracy values not less than those shown in Table 6.3 below.

Data / scenarios	Relative course (degrees)	Relative speed (knots)	CPA n.m.	TCPA mins.	True course (deg)	True speed (knots)
1	3.0	0.8	0.5	1.0	7.4	1.2
2	2.3	0.3			2.8	0.8
3	4.4	0.9	0.7	1.0	3.3	1.0
4	4.6	0.8	0.7	1.0	2.6	1.2

Table 6.3

When a tracked target, or own ship, has completed a manoeuvre, the system should present in a period of not more than one minute an indication of the target's motion trend, and display within three minutes, the target's predicted motion, in accordance with above tables.

The implication of these delays is that information provided immediately after acquisition may not be accurate, such accuracy improving with elapsed time of steady state tracking.

This also indicates that there is a delay after a manoeuvre by own ship or target before accurate information is provided again.

However, it should be noted that there is a limit to the improvement of accuracy of data with time with an ARPA due to the values used for track smoothing filters.

These accuracy values should always be borne in mind when evaluating CPA distances and other ARPA data. Tendancy to implicitly accept the small CPA distance as clear indication of safe passing distance will prove to be dangerous and should be discouraged strongly.

6.3.9 OPERATIONAL WARNINGS

IMO specifications provide following operational warnings by visual and / or audible signals:

- violation of minimum CPA distance and minimum TCPA selected by observer,
- target entering observer-selected zone,
- lost target,
- ARPA malfunction.

The targets involved in the above are identified and clearly indicated on the display.

Limit values for minimum CPA and minimum TCPA which observer can select are indicated in the technical literature of ARPA. Selected values are shown on the display.

Different makes of ARPA provide:

CPA limits between 0 to 9.9 n.m.

TCPA limits between 0 to 30 / 60 / 90 minutes.

The facility to set the CPA and TCPA limits is very useful, especially in areas of heavy traffic. However, the limits shall be so selected as to provide assistance in prioritising the information in dense traffic. The accuracy values for CPA as specified by IMO (ref. para 6.3.8) should be borne in mind when setting the limits as they represent the only specified performance standards which will be used to judge the adequacy of limits set by the observer.

Tendancy to use CPA and TCPA warnings to dilute watch-keeping is to be strongly discouraged.

6.4 ADDITIONAL FEATURES OF ARPA

Manufacturers of ARPA incorporate many features in addition to those specified in IMO performance standards. It is, therefore advisable to study the various ARPA features from technical literature provided by the manufacturer. Thorough understanding of the features not only helps in realising the limitations of the ARPA, but also to know its capabilities and potential as an effective electronic aid for collision avoidance and navigation.

6.4.1 NAVIGATION LINES

ARPA has the capability to display synthetic lines on the PPI. These lines which can be adjusted in desired position, direction and length are used to demarcate navigational dangers and widths of channels, as danger clearing lines or for parallel index techniques.

phân qual giới

The number of available points or segments of lines varies on different ARPAs.

Lines being used for parallel indexing should be fixed to own ship i.e. the lines should move with own ship.

Lines used for true tracks should be geographically fixed in ground stabilised mode. These lines move with the geographical point to which they are fixed.

6.4.2 ECHO REFERENCE / AUTO DRIFT

This facility enables the observer to select the echo of an isolated rock, light vessel, buoy or any such fixed point target to which the display can be locked on. In this case the display is said to be ground stabilised. The speed over the ground can be obtained and applied automatically for calculating true vectors in ground stabilised mode.

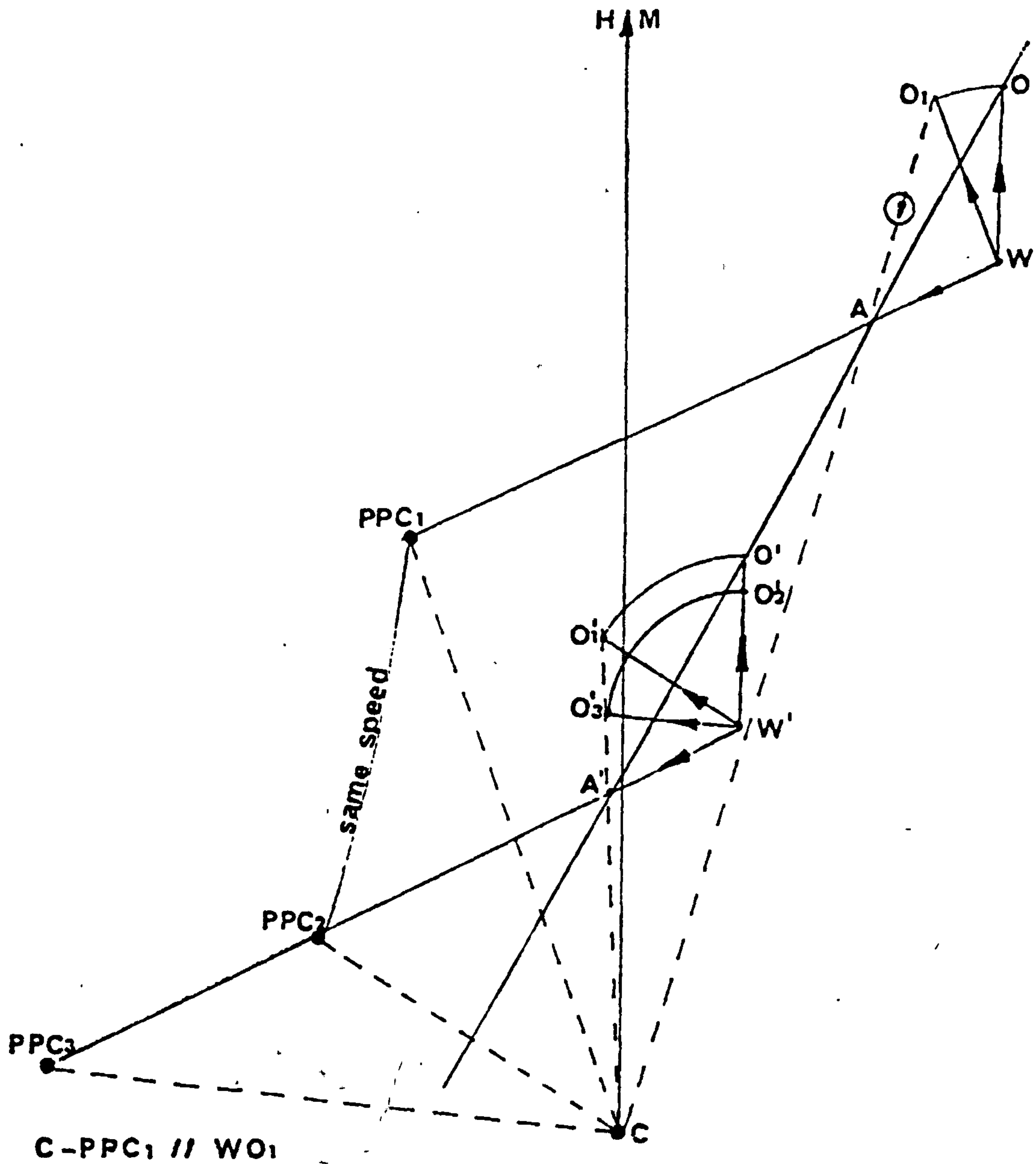
This mode is unsuitable for collision assessment.

The selected fixed point target is liable to "target swop" (ref. para 7.5.1) with a passing boat or adjoining land and should therefore be marked to recognise errors in its tracking.

6.5 ARPA INFORMATION FOR COLLISION AVOIDANCE

Besides providing CPA, TCPA, target course and speed, some ARPA provide graphical presentation of the collision threat. This is done by displaying:

- possible points of collision (PPC),
- predicted areas of danger (PAD),
- sectors of danger and sectors of preference (SOD and SOP).



C-PPC1 // WO1
C-PPC2 // WO'1
C-PPC3 // WO'3 where WO'3 = WO'2 = reduced speed.

CONSTRUCTION AND MOVEMENT OF PPC

Fig. 6.5

6.5.1 POSSIBLE POINTS OF COLLISION

In every encounter at sea, it is possible to calculate the course or speed which will take own ship to the possible point of collision (PPC). The method is only an extension of the concept of determining course to follow to achieve desired CPA. PPCs assist in quick identification of collision course. (Fig. 6.5).

The aspect of the target and position and speed ratio of the two ships involved will determine the points of possible collision.

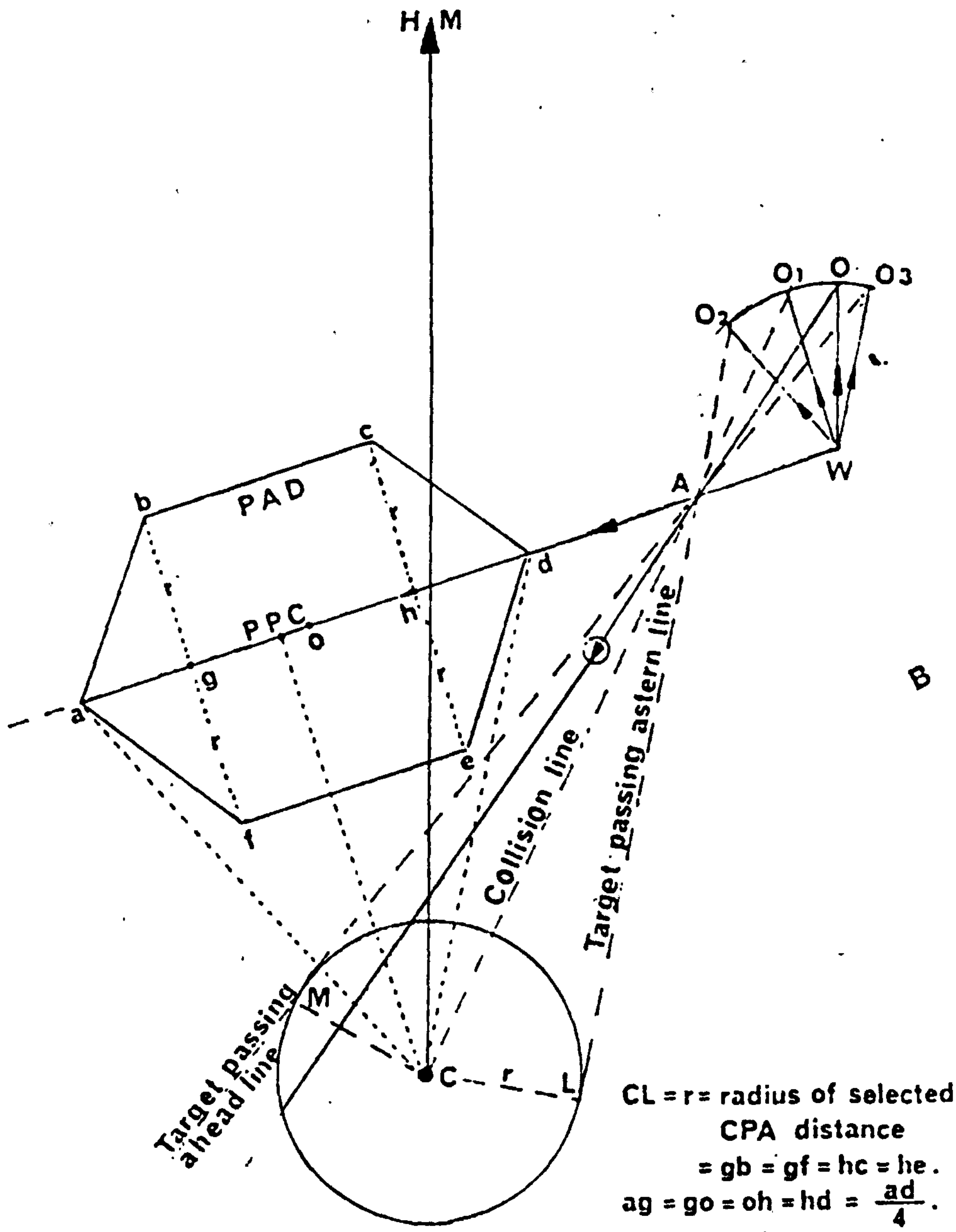
The PPCs can be displayed on the PPI. A PPC on the heading marker indicates collision course. For collision avoidance, the safe course to follow is the one which passes clear of all the PPCs. The PPCs are always on the track of the target. However, they may not be connected to them by a line and therefore it is necessary to relate the PPCs to their respective targets

6.5.2 PREDICTED AREAS OF DANGER

Predicted areas of danger are PPCs surrounded by a hexagonal shape depicting the area within which the CPA of the target with own ship will be less than that selected by the observer.

Being their registered feature, only Sperry CAS ARPA have the facility to show predicted areas of danger (PAD)s. (Fig. 6.6).

PAD defines an area around the PPC depending on the CPA value set by the observer. The CPA-linked PAD symbol contains a permanent allowance for sensor and system



C - PPC // WO_1 = Collision heading.
C - a // WO_2 = Target passing astern heading.
C - d // WO_3 = Target passing ahead heading.

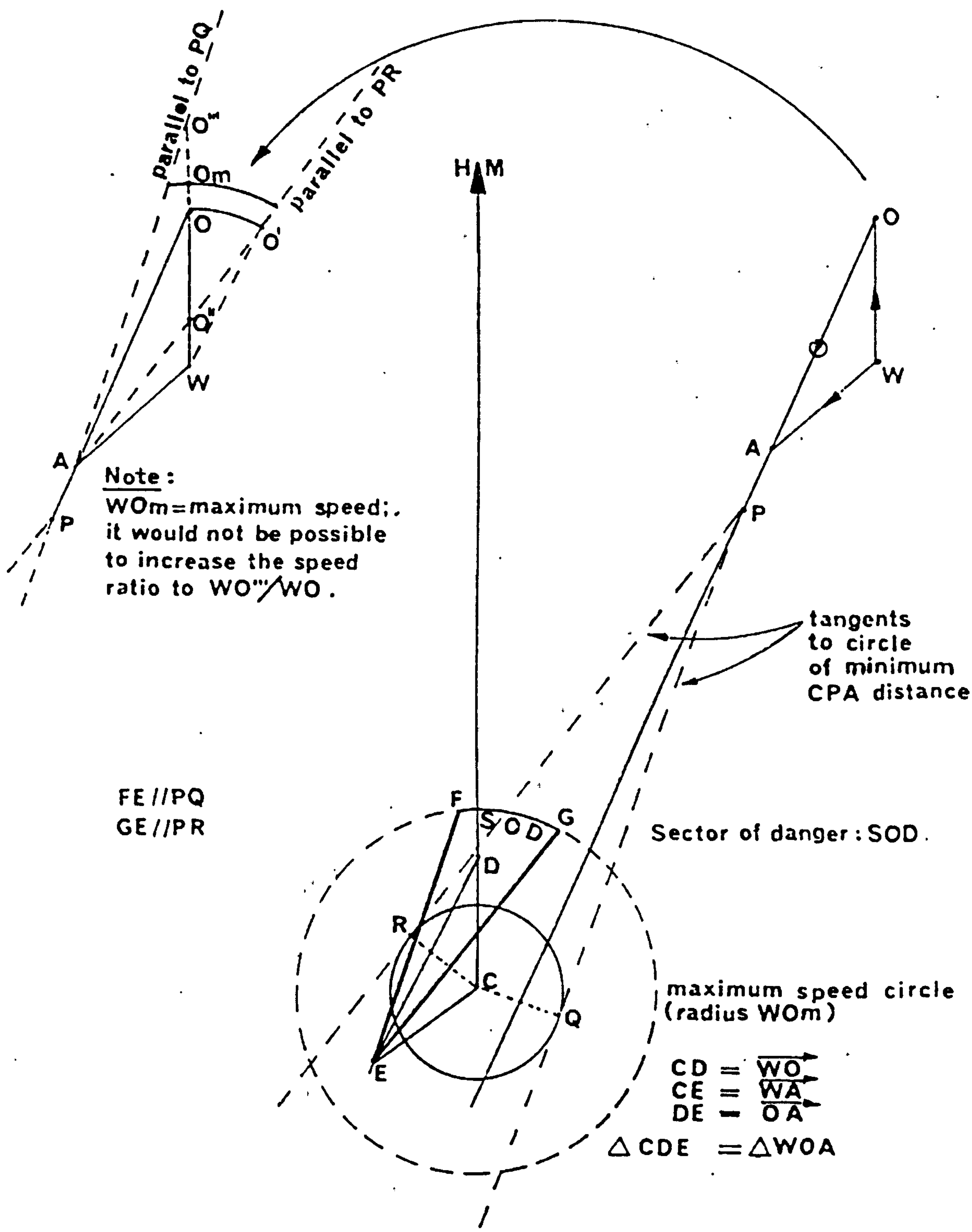
Fig. 6.6 CONSTRUCTION OF PPC AND PAD

errors. Hence, adopting a heading for own ship that is tangential to a PAD symbol when in steady motion will result in a CPA that is in excess of the pre-selected CPA distance. The PAD symbol provides a graphic presentation on the PPI of the area in which a close quarter situation for a particular target will occur.

PADs indicate the areas to be avoided and in a multiship situation, help to quickly determine course alterations for collision avoidance.

Following should be borne in mind when using PADS:

- When a suitable CPA value has been selected, it should not be reduced in a casual manner to reduce the area of coverage of the PAD symbol.
- Since PAD includes an allowance for system and sensor errors, it should not be used for the purpose of keeping a fixed distance off a navigational mark.
- The line joining PAD to target does not indicate speed. Short lines may be attached to fast targets and longer lines to slower targets.
- The PPC is not necessarily at the centre of the PAD.
- If own ship heading marker cuts the PAD, reduction of speed may cause the PAD boundary to move towards own ship.
- The distance to the target is not necessarily the distance which own ship must run before the situation is resolved and own ship can resume her course. For passing astern of target, the distance may be far less and for passing ahead, far more than the time implied by own ship heading marker.



SECTOR OF DANGER

Fig. 6.7

- PPCs on own ship display do not indicate either the existence or non-existence of collision dangers between other ships. If PADs overlap and are placed on own ship heading marker, the two targets will be involved in close quarter situation and may collide. Own ship should take this into account while planning avoiding action.
- Depending on the aspect of target and speed ratio of own ship to target, there may be one or two pads -one primary and one secondary. If the target is faster than own ship, there will be two PADs and two PPCs. If target is slower than own ship, there will be one PPC and one PAD.
- In automatic acquisition mode, too many PADs may be generated, creating a confused display due to too many synthetic lines.
- A PAD display cannot be used for determining the second course alteration e.g. to resume the course after alteration for collision avoidance, as there is no locational consistency to the PAD except in specific cases e.g. where the other ship is on a collision course. In all other cases, the PAD will change position with time.

6.5.3 SECTORS OF DANGER AND SECTORS OF PREFERENCE (SOD AND SOP)

Like PPC and PAD, SOD and SOP assist in determining a safe manoeuvre for collision avoidance. The concept is to keep own ship vector out of the SOD, either by altering course or by reducing speed. Keeping the head of own ship vector on the edge of the SOD results in CPA being equal to desired CPA. (Fig. 6.7).

CHAPTER 7

ERRORS AND LIMITATIONS
OF
AUTOMATIC RADAR PLOTTING AIDS

7. ERRORS AND LIMITATIONS OF ARPA AND PRECAUTIONS TO BE OBSERVED

7.1 TYPES OF ERRORS

ARPAs are subject to errors which may be classified (Fig. 7.1) in two groups:

- errors in displayed data,
- errors in interpretation.

Errors in displayed data can be further classified in two subgroups:

- sensor (hardware) errors i.e. radar, gyro, log
- processing (software) errors in algorithms for data processors.

7.2 PRECAUTIONS CONCERNING ERRORS

The observer has no control over the errors in the displayed data. However, it is neccessary to have knowledge of the causes of these errors. He must be able to understand the effects these errors have on the data so that his interpretation is accurate.

It is not the quantum of the sensor errors but the influence these errors have on the target data that is important. The true vectors, PPCs and PADs are affected by the gyro and log errors. The CPA and relative vectors are not affected by gyro and log errors but are affected by radar errors in measurement of range and bearing.

ERRORS IN AUTOMATIC RADAR PLOTTING AIDS

ERRORS IN DISPLAYED DATA

HARDWARE				SOFTWARE	ERRORS IN INTERPRETATIONS
RADAR		GYRO	LOG		
BEARING	RANGE				
- TARGET GLINT - ANTENNA BACKLASH - UNSTABLE PLATFORM - PARALLAX DUE TO OWN SHIP ROLLING - ASSYMETRICAL ANTENNA BEAM - AZIMUTH QUANTISATION	- ROLLING OF OWN SHIP - RANGE QUANTISATION - TARGET GLINT	- ROLLING - GIMBALLING - YAW	- TOO HIGH OR TOO LOW INPUTS RESULTING IN - INCORRECT VECTORS OF TARGETS - INCORRECT ASPECTS OF TARGETS	- TARGET SWOP - TARGET LOSS - FAILURE TO DETECT AND ACQUIRE TARGETS (AUTOMATIC ACQUISITION) - TRACK SMOOTHING	- TRUE/RELATIVE MOTION - VECTORS - PADS, PPCS - PAST POSITIONS - NAVIGATION LINES - FAILURE TO DETECT AND ACQUIRE TARGETS (MANUAL ACQUISITION) - UNCRITICAL ACCEPTANCE OF DISPLAYED DATA - INCORRECT INPUT OF SPEED AND/OR COURSE

Fig. 7.1 Errors in Displayed Data

It should also be noted that the accuracy values specified by IMO (ref. para 6.3.8) are valid only when the ARPA is interfaced with radar, speed log and gyro complying with respective IMO performance standards and for environmental conditions inducing not more than plus and minus ten degrees of rolling. When own ship is rolling more than ten degrees, the ARPA data should be treated with caution.

7.3 SENSOR ERRORS

7.3.1 Following sensor errors are appropriate to equipment complying with IMO Performance Standards for shipborne navigational equipment.

Note: σ means " standard deviation ".

1. RADAR

TARGET GLINT: (scintillating) (for 200 m length target)

Along length of target σ = 30 metres (normal distribution)

Across beam of target σ = 1 metre (normal distribution)

ROLL-PITCH BEARING: The bearing error will peak in each of the four quadrants around own ship for targets on relative bearings of 045°, 135°, 225°, 315° and will be zero at relative bearings of 0°, 90°, 180°, 270°. This error has a sinusoidal variation at twice the roll frequency.

For a 10° roll the mean error is
0.22° with a 0.22° peak sine wave superimposed.

BEAM SHAPE: - assumed normal distribution giving bearing error with σ = 0.05°

PULSE SHAPE: - assumed normal distribution giving range error with σ = 20 metres.

ANTENNA BACKLASH: - assumed rectangular distribution giving bearing error $\pm$ 0.5° maximum.

QUANTISATION:

Bearing: - rectangular distribution $\pm$ 0.01° maximum.

Range: - rectangular distribution $\pm$ 0.01 nautical miles maximum.

Bearing encoder assumed to be running from a remote synchro giving bearing errors with a normal distribution σ = 0.03°.

2. GYRO COMPASS:

Calibration error 0.5°.
Normal distribution about this with σ = 0.12°.

3. LOG:

Calibration error 0.5 knots
Normal distribution about this 3 σ = 0.2 knots.

7.4 OTHER ERRORS OF SENSORS

7.4.1 BEARING ERROR DUE TO UNSTABLE PLATFORM OR TILT

e in radians = 0.5 * B^2 * sin θ * cos θ
B = angle of heel in radians
θ = relative bearing of target from own ship

OR

$$e \text{ in radians} = \frac{-(T^\circ)^2 * \sin 2A}{230^\circ}$$

T = angle of tilt in degrees

A = relative bearing of target

7.4.2 BEARING ERROR DUE TO ROLL OF OWN SHIP

$$e \text{ in degrees} = \frac{180 * L \sin B * \cos \theta}{\pi R}$$

L = antenna height above roll axis of ship in meters

B = angle of roll

θ = relative bearing of target

R = range of target in meters

7.4.3 BEARING ERROR DUE TO AZIMUTH QUANTISATION

This error is related to the bearing accuracy of the ARPA as described in Chapter 4 para 4.2.4. With a 12 ring encoder, the error will be 0.09° / 2 = 0.045°

7.4.4 BEARING ERROR DUE TO GYRO TRANSMISSION SYSTEM

Transmitters for gyro repeaters are of two types

- stepper,
- synchronous.

Whereas synchro transmitters give continuous signals, stepper transmitters give signals in steps. If there are six steps for one degree, the bearing accuracy is 0.17°.

7.4.5 RANGE ERROR DUE TO ROLLING OF OWN SHIP

Error in distance in meters = $L * \sin B * \sin \theta$

L = height of antenna roll axis of ship

B = angle of roll

θ = relative bearing of target.

7.5 SOFTWARE ERRORS

As described in Chapter 4, radar data is quantised by microprocessors. In this process, some limits and inaccuracies may be caused by the limitations of the algorithms or by limits of accuracies accepted. The main effects of software errors are

- target swop,
- target loss,
- failure to detect and acquire targets,
- delay caused by track smoothing.

7.5.1 TARGET SWOP

As described in Chapter 5, para 5.7, the data processor establishes a "tracking window" or "correlation gate" to search for the tracked target at the next scan. The size of the tracking window is defined by the parameters chosen by the manufacturer and written into the algorithm. If during tracking, echoes of two targets come within the same window or if two tracking windows overlap, gối lên the processor cannot distinguish between the two. There is a likelihood that data processor will assign the calculated parameters, vectors and past positions of one target to the other (Fig. 7.2.c). This is known as target swop. Due to target swop, a dangerous target may lose its vectors and be assigned vectors of a non-dangerous target.

ấn định

Areas where traffic density is high or where targets approach very close to each other, perhaps because of their sizes, target swop is more likely to occur. By careful monitoring of targets and their displayed data, target swop can be detected.

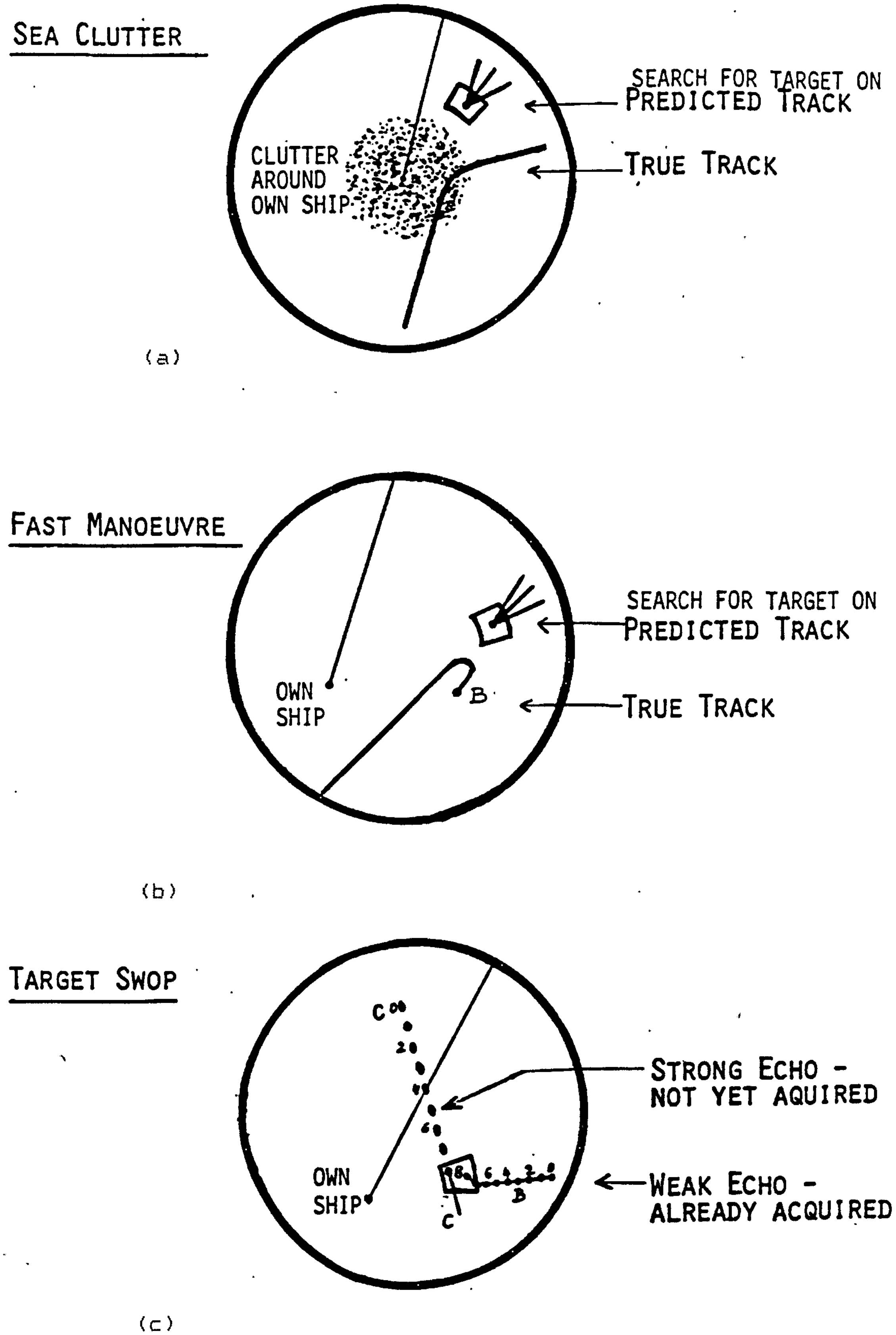

SEA CLUTTER
SEARCH FOR TARGET ON PREDICTED TRACK
TRUE TRACK
CLUTTER AROUND OWN SHIP
(a)
FAST MANOEUVRE
SEARCH FOR TARGET ON PREDICTED TRACK
TRUE TRACK
OWN SHIP
B
(b)
TARGET SWOP
C
STRONG ECHO - NOT YET AQUIRED
WEAK ECHO - ALREADY ACQUIRED
OWN SHIP
B
C
(c)

Fig. 7.2

It is also important to remember that own ship may be involved in a situation where own ship is subject to "target swop" on the ARPA of another ship.

When using the echo reference facility, care should be taken to mark the position of the fixed point in order to recognise "target swop" involving the fixed point and a passing boat or adjoining land echoes.

7.5.2 TARGET LOSS

As described in Chapter 4 para 4.7, a target is acquired only if it is deteccted in " m out of n (MOON)" scans. IMO performance standards specify that tracking should continue if a target is clearly distinguishable for 5 out of 10 scans.

It may sometimes happen that due to being surrounded by clutter or being in the radar shadow of a large target, a tracked target is not detected and is therefore lost.(Fig.7.2.a).

It is also possible that the ARPA starts to track the clutter instead of the tracked target. In such a case, there is no lost target alarm indicated immediately. When such an alarm is finally given, the last position indicated may be that of the clutter and not of the target.

Targets may escape detection due to large changes of bearings in a very short period of time, especially at close ranges. This may be caused by fast manoeuvres of own ship or target (Fig.7.2.b), or by significant change in the gyro error over a short period of time due to gyro drift or adjustment of gyro heading while targets are being tracked.

When the target is not found in the tracking window established for it, the data processor enlarges the tracking window and searches for the target. When the target is not found in the tracking window which is enlarged to a predetermined size, the target is lost.

In case of fast manoeuvre of a target, the vector may be seperated from the echo because of the time consuming filtering process.

An alarm is sounded when a tracked target is lost. It is necessary to note the position of the target when lost target alarm is sounded because after the alarm, the target is dropped from memory and is not retrievable.

7.5.3 FAILURE TO DETECT AND ACQUIRE TARGETS

Targets are detected only if their echoes are above the specified threshold values and acquired if they successfully pass through the MOON test.

When ARPA is on automatic acquisition mode, echoes may not be of sufficient strength and being unable to cross the threshold value, are not detected. Such targets may be dangerous ones and constant monitoring of radar by observer is essential to detect such targets.

Targets detected after crossing into the guard zone do not sound alarm.

7.5.4 TRACK SMOOTHING ERRORS

The data processor calculates the target course and speed from quantised information in respect of target range and bearing. Due to limitations in accuracy of measuring and quantising ranges and bearings, resulting from target glint and antenna backlash, the track would look like a jagged line (Fig. 7.3). In order to predict target vectors, track filtering logic is used to smooth the tracks as described in Chapter 5, para 5.7.

The filtering introduces delay in the displayed data when own ship or the target manoeuvres. During such manoeuvres, the displayed CPA and TCPA will have errors and should therefore not be relied upon. It will take upto three minutes before data with accuracy required by IMO performance standards is once again displayed.

Due to track smoothing algorithms used, small alterations of courses by target ships may not be detected immediately. It is also true that this can occur on the ARPA of another ship. Therefore, it is necessary that any course alteration by own ship should be substantial to be quickly detected by other ships. A number of small alterations of course should always be avoided as they result in inaccurate information on ARPA of other ships.

7.6 ERRORS IN INTERPRETATION

Correct interpretation of the displayed data and understanding of the various errors and limitations is essential in the use of ARPA as a collision avoidance and navigational aid.

Errors in interpretation are likely to be made by the observer through misunderstanding, inexperience or through casual observation. They may also occur due to different features on different software versions running on the same hardware. Though the observer may not know the differences, it again emphasises the need to familiarise

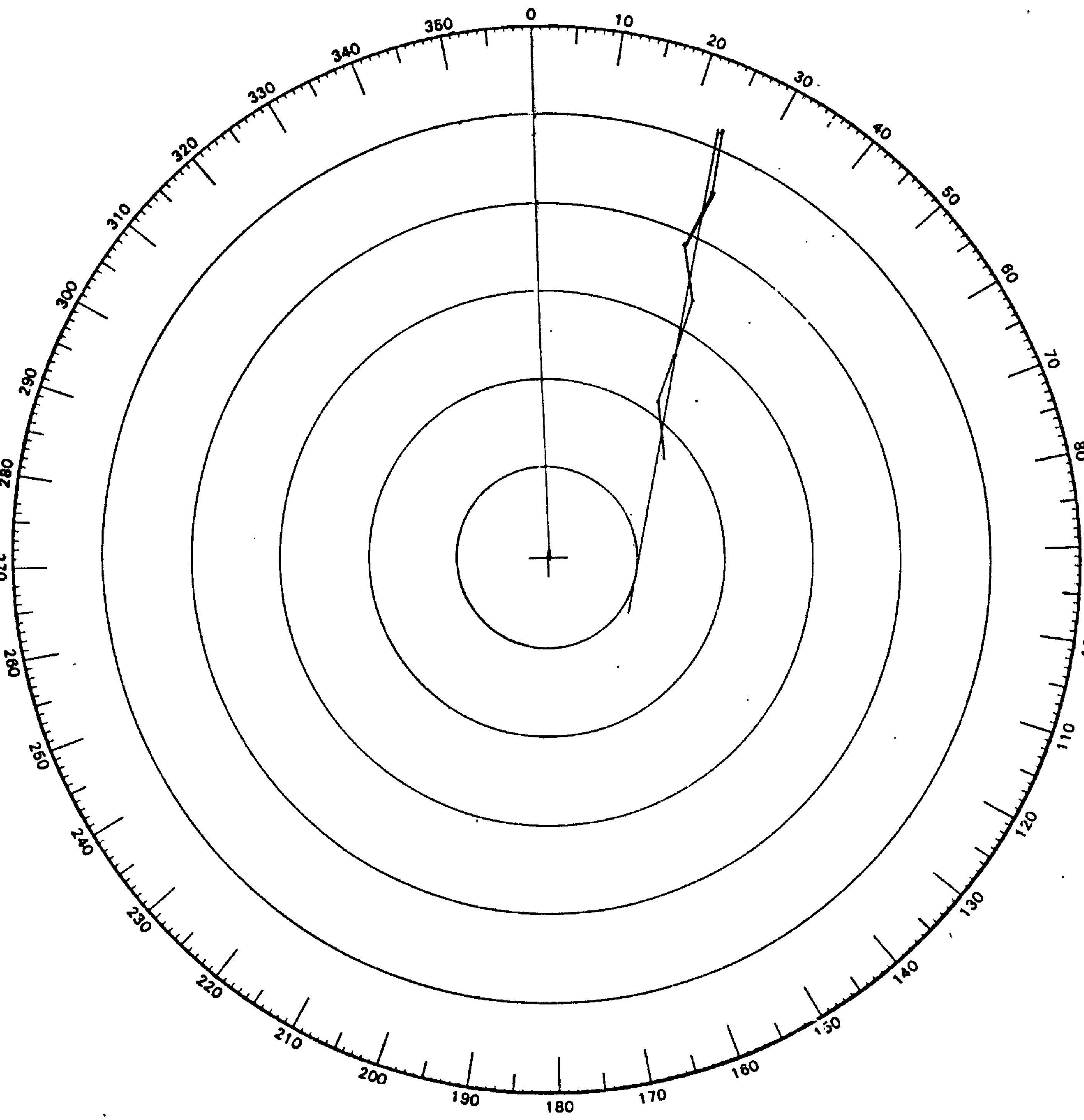


Fig. 7.3 Target Track Before Smoothing

oneself with the ARPA on board and not to take the similarities if any, with previously used ARPA, for granted. These errors could be termed " live-ware " errors.

These errors are likely to be made in the observation and misinterpretation of

- true or relative motion display presentation mode,
- true or relative vectors,
- failure to detect or acquire targets manually,
- incorrect speed and/or course input,
- uncritical acceptance of displayed data,
- predicted areas of danger,
- possible points of collision,
- past positions.

7.6.1 DISPLAY PRESENTATION MODE

IMO performance standards for ARPA specify that the ARPA should be capable of being operated with relative motion "north up" and either "course up" or "head up" azimuth stabilisation. True motion may be provided. Manufacturers provide different modes for display presentation. It is necessary to understand which mode is in use.

The observer should select the mode he is comfortable with, taking into consideration the advantages of the various modes of display for different purposes.
For collision avoidance, relative motion display is optimum as this display is not susceptible to input errors in own course and speed. North up true motion display is optimum when navigating in poor visibility when navigational obstructions and traffic has to be considered. Course up relative motion presentation is optimum to compare radar picture with what is actually seen around the ship.

When correlation technique is used for reduction in clutter, unstabilised display should not be used. In this mode, the target relative bearing shifts due to own ship yawing and therefore target may be lost in the correlation process.

7.6.2 TRUE AND RELATIVE VECTORS

Targets being tracked display either true or relative vectors as desired by the observer. The most common mistakes that occur with vectors are that attempts are made to obtain CPA and TCPA from true vectors or true course and speed from relative vectors.

Vectors indicate any alteration of course or speed by target. In the true vector mode, own ship will always display a vector when making way. In the relative vector mode, own ship will not have a vector.

It is always a good practice to cross check vector data with alpha-numeric data.

7.6.3 FAILURE TO DETECT OR ACQUIRE TARGETS MANUALLY

A target can only be acquired if it has been detected. Such detection is performed by the radar. For this reason, it is essential that the radar is properly tuned and adjusted for best performance. The gain and brilliance controls should be adjusted for best picture. Optimum seting of controls cannot be overemphasised as the success of ARPA depends on proper use of radar and ARPA controls.

When using manual acquisition mode, the observer has to decide which target to acquire. However, it is possible that the observer may fail to realise that a dangerous situation is developing and therefore not acquire the target. To guard against such incidents, it is prudent to either manually plot or to do mental calculations before deciding not to acquire the target.

Weak echoes of small or poor targets may not be detected during interrupted or cursory observation of PPI. Continuous examination of the display will prevent such occurrence.

7.6.4 INCORRECT SPEED AND / OR COURSE INPUT

Incorrect speed and course input will result from malfunction of the respective sensors, i.e. log and gyro compass. Since calculation of true vectors are dependant upon the correct inputs of speed and course through the water, it is essential to ensure proper functioning and adjustments of the log and gyro compass and incorporation of the drift angle in the course input. Effects of incorrect speed input on the true vectors is shown in figure 7.4.

7.6.5 UNCRITICAL ACCEPTANCE OF PRESENTED DATA

It is important to remember the performance standards for ARPA laid down by IMO. Great care should be taken to cross check the data provided by ARPA against radar data, by manual plotting if necessary. Information obtained from graphical presentation should be compared against alpha-numeric data.

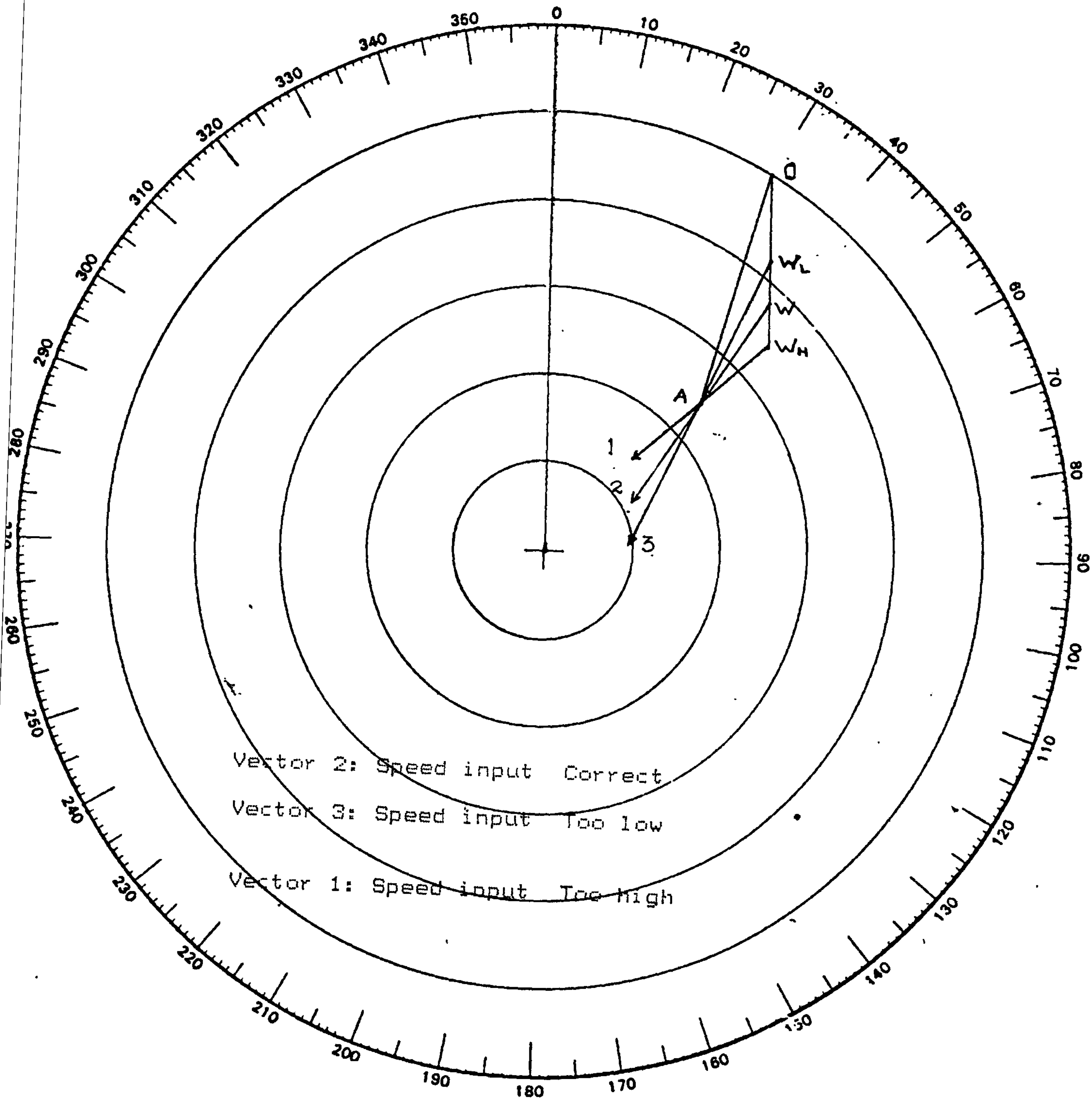


Fig. 7.4 Effect of Incorrect Speed input

In case of manoeuvres by own ship or target ship, the ARPA will take time, typically 3 minutes, to again display correct data. During such period, the displayed data will not be accurate and therefore should not be relied upon.

The ARPA is just another navigational aid and critical evaluation rather than blind acceptance of data will contribute to enhanced safety.

7.6.6 Errors in interpretation of PPCs, PADs and past positions have been dealt with in Chapter 6, para 6.5.1, 6.5.2 and 6.3.6 respectively.

CHAPTER 8

CONCLUSIONS AND RECOMMENDATIONS

8. CONCLUSIONS AND RECOMMENDATIONS

8.1 CONCLUSIONS

.1 The Shipping Corporation of India owns and operates a fleet of ships equipped with ARPA. However, many masters and navigating officers have not received any formal training in the operational use of ARPA.

.2 STCW 78 and IMO Resolution A482 (XII) require that masters and navigation watchkeeping officers be trained in the use of ARPA.

.3 It is necessary to conduct courses on operational use of ARPA for masters and navigation watchkeeping officers working in the Shipping Corporation of India. The facility can also be used for the benefit of other Indian as well as foreign participants.

8.2 RECOMMENDATIONS

.1 Simulator with ARPA planned to be acquired should have 4 own ship cubicles with capacity for more own ships to be added in future. It should be possible to interface various navigational equipment and projection system with the simulator.

.2 Specialised ARPA training should be given to the instructors for the ARPA course. They should also be trained on the simulator by the manufacturer.

.3 The instructors should be encouraged to attend and participate in the International Radar and Navigation Simulator Lecturers' Conferences.

.4 Periodic voyages on board ships should be arranged for the instructors.

.5 A competent technician with adequate background in electronics and computers should always be available. The technician should be trained by the simulator manufacturer in maintenance and repairs of the equipment.

.6 Comprehensive records of participants should be maintained for analysis in future.

APPENDIX A

TARGET IDENTIFICATION
ON
RADAR

Appendix A.

TARGET IDENTIFICATION ON RADAR

ABSTRACT: It has often been stressed that in an encounter at sea, communication between the ships would greatly assist in avoiding a close quarter situation.

Unique identification of ships entering a vessel traffic system will facilitate better control of ships and traffic.

The paper suggests a configuration of radar, accurate navigation receiver, reliable communication facility and a microprocessor unit which can provide unique identification of radar targets.

Marine radars have proved their value as an aid to avoiding collisions at sea. They are able to detect targets at various ranges and thus provide the observer with information to assist him to decide his actions. Radars have also been useful as navigational aids. However, they suffer from a major shortcoming in that they are unable to correlate the echo of a target with its unique identity.

It has often been stressed that in an encounter at sea, communications between two ships would greatly assist in exchanging information regarding course and speed and more important, confirmation of avoiding action being taken in case of close quarter situation.

In a Vessel Traffic System (VTS), surveillance radars are used in areas of high traffic density. Rapid and unambiguous identification of ships will assure VHF radio communication to exercise better control of the ships.

Problems of communications with target ships can be overcome if their callsigns or other unique identification could be obtained; preferably in written form. Calling up on VHF to exchange information would then be a relatively simple matter.

When the presence of a ship is detected on own radar, her position can be calculated with a certain degree of accuracy. A call directed to and picked up by a ship in the calculated position will alert her to incoming communication.

It is suggested that a configuration consisting of radar, accurate navigation receiver and reliable communication facility for data transfer can provide an excellent system for this purpose.

HOW THE SYSTEM WILL WORK

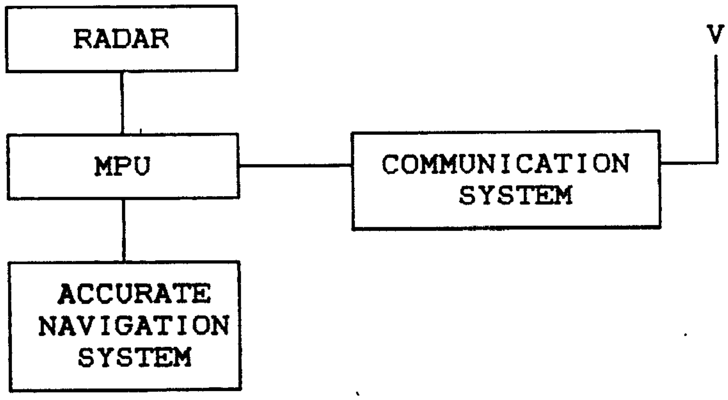


Figure 1.

As shown in the figure 1, a radar and navigation receiver will be interfaced with a microprocessor unit (MPU). When a ship is detected by the radar, the observer wishing to communicate with her will select the corresponding target on the PPI and instruct the microprocessor to calculate the position of the target ship. Since own ship navigation receiver is interfaced with the MPU, it will be possible to determine the position of the target in latitude and longitude.

Having obtained the position of the selected target, the MPU will then send a signal addressed to the target at the calculated position.

The signal will include the following information:

- position of the target in latitude and longitude,
- own ship identity denoted by callsign and/or identification number or selective call number,
- own ship position in latitude and longitude, course and speed,
- intended action: alteration of course and or speed by appropriate symbols, and time for such alteration.

The target ship should be similarly equipped. The target ship communication receiver will receive the signal and send it to its MPU. The MPU will in turn correlate the position contained in the incoming signal with her own position ascertained by navigation receiver on board and on successful correlation, alert the watchkeeper with a visual and suppressible audible alarm.

For such correlation, a "correlation gate" of certain radius can be established, taking into account the accuracy of both, the navigation system and the radar.

In ships fitted with ARPA, the course and / or speed of the target ship can be used for correlation. The ARPA calculates the course and speed of targets with known accuracies. This known target course and speed can be transmitted in addition to target position in latitude and longitude and can be used by the target ship MPU for correlation. The correlation criteria in such cases will be a certain sector encompassing target course. For speed correlation, a gating method could be established.

Having obtained satisfactory correlation, the MPU of the target ship will calculate the range and bearing of the calling ship from the transmitted position and identify the calling ship by an appropriate symbol on the PPI.

Other information contained in the signal, e.g. callsign, course , speed and intended action can be presented alpha-numerically on the PPI or on separate screen or paper. Intended action can be displayed by suitable symbols. Since the callsign of the calling ship is known to the target ship, she can establish communications on VHF or can in turn transmit a signal on her communication terminal addressed to the calling ship for display on her PPI. The MPU can be programmed to transmit such information automatically on being triggered by the incoming signal.

The information can be used to validate the data displayed on ARPA and also to draw an appropriate symbol to depict the aspect of the target.

Once the information contained in an incoming signal is associated with a particular echo on the PPI, the information can be retained in the memory and displayed on the PPI whenever required by the observer.

Such an installation will enable rapid and positive identification to be made of ships entering into the VTS area.

Communication sets with navigation receivers can also be placed on shore positions needing to be positively identified for navigation purposes. With the development of electronic sea charts, it will become necessary to check the electronic sea chart with the radar picture of the ship's vicinity. For this purpose, radar conspicuous points will need to be provided. It is felt that equipment as suggested above will be most suitable to positively identify the radar conspicuous points as well as ascertain their position on the PPI.

Small boats are often lost in the clutter. It may become possible for them to transmit their identification and position and thus accentuate their echo on the radars of ships in their vicinity.

REQUIREMENTS FOR NAVIGATION AND COMMUNICATION SYSTEM

The navigation receiver should be able to obtain accurate position continuously, regardless of weather and time of day.

The communication system forms a vital link and therefore has to be free of disturbances and interference. The range does not have to be greater than say, 24 miles for use with radar for identification purposes.

In both the above requirements, satellite technology can prove very accurate and adequate.

Global Positioning System (GPS) or GLONASS satellite navigation systems provide an accuracy of better than 100 meters for civilian users and will be suitable for obtaining positions. Reliable communications link for data transfer can be provided by dedicated VHF frequencies or by narrow band direct printing, NBDP, (frequency shift keying) on medium wave frequencies similar to NAVTEX.

Other satellite based systems combining positioning and communication services e.g. Geostar can also be considered.

It is considered that given the present state of technology, such an installation is possible at a reasonable cost and will prove useful.

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