

THE USE OF RADAR AT SEA

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Executive Secretary of the Institute of Navigation.

Foreword by Sir Robert Watson-Watt, C.B., F.R.S.
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British radar was produced for war purposes and was kept absolutely secret for a period of ten years. Only since the last war, and therefore fairly recently, has the device been made generally available.

Numerous articles and books published on the subject, some belonging to the popular variety and others of a largely technical nature, have stressed its many possibilities. Manufacturing firms have also supplied detailed descriptions of radar.

However, the science of radar may still be considered as being in the development stage, and for this reason it has only now become possible to undertake a sufficiently adequate account of its specific uses.

With this in mind, the Institute of Navigation, London, promoted the preparation of a manual entitled: *The Use of Radar at Sea*, compiled by Captain F.J. Wylie, with contributions from experts on the staffs of British public and private organizations concerned with radionavigation, such as Trinity House, the Ministry of Transport, Radio Advisory Service, Admiralty Signal and Radar Establishment, and others. This timely publication made its appearance in October 1952, and the fact that Sir Robert Watson-Watt, who developed British radar, wrote the preface gives it added significance. It does not describe instruments of individual make, and mainly deals with information of an essential nature enabling the navigator to make the best possible use of any radar apparatus as at present supplied by the manufacturers.

Books of this kind may easily have the defect of being too technical, and though they may prove useful to experts, of being too complex for users of the equipment. Others works attempting to explain the subject of radar are often too amateurish for the reader. This may be due to the fact that it is difficult for a person to be a tried technician and a skilful and experienced navigator at the same time. For this reason we are in entire agreement with the Institute of Navigation's idea of using the experience of thirteen different contributors with the set purpose of compiling a work that is so well-balanced in all its parts. The editor entrusted with the task of revising the book has moreover admirably succeeded in not losing sight of the purpose of the publication, which is to serve as a practical guide for the use of radar at sea and in the acquisition of a knowledge of the many factors affecting the results obtained when using the instrument. Although there is a lack

of uniformity in style and a few repetitions occur throughout the various chapters, this goal has certainly been reached. Particularly worthy of praise is the clear and simple phraseology of the work, enabling the fairly complex concepts involved to be readily understood.

The introduction states that the volume should be considered as being of a « provisional » nature and that it may show certain flaws and limitations, precisely on account of the collaboration involved. Navigators are therefore invited to criticize the work. Owing to this highly commendable attitude and the simple presentation we have already mentioned, which cannot fail to inspire confidence in the reader, it is certain that information, advice and critical opinion will not be found wanting. It will also be found that it constitutes a most valuable work for the navigator, students and naval colleges, and that subject to further improvement it provides a sound basis for an excellent text-book.

The publication does not deal specifically with radar techniques as applied to hydrographic surveying, which does not, however, prevent it from being of intense interest to hydrographers, as it constitutes a starting-point in the study of their particular problems, such as radar charts, radar reflectors, etc.

The work consists of 17 chapters and appendices followed by a short glossary of special terms used in the text and an analytical index. As of possible assistance, the various chapters are listed below with a rapid outline of their contents.

Chapter 1. — *Radar Principles and General Characteristics.*

After a brief account as to the instrument's background, the principle on which radar is based is described, together with the basic aspects of electromagnetic waves and their propagation. A short description of the PPI and its operation follows, with the characteristics of waves transmitted by the instrument. Sketches accompany the chapter illustrating the subject without the use of formulae that would be difficult of interpretation.

Chapter 2. — *The Radar Equipment.*

As pointed out at the beginning of the chapter, radar equipment is so described in this particular section as to enable the reader to grasp completely its method of operation and to understand fully the contents of the chapters following, without requiring him to have more than an elementary knowledge of electronics. (Chapter 16 contains a description of the instrument in greater detail, and Appendix VI a simple account of thermionic valve operation, in case the reader should desire to investigate the subject more thoroughly).

The transmitter, receiver and PPI are here described in a clear, simple, well-organized manner. Added effectiveness is obtained through the use of drawings showing the main circuits (including one of a complete set of radar equipment), and of photographs and diagrams.

Chapter 3. — *Operational Controls.*

This chapter clearly describes the necessary operations for testing and checking the different parts of the equipment.

Chapter 4. — *Propagation of Waves and Response of Targets.*

Chapter 4 is divided into two sections. By means of explanatory sketches and in straightforward terms, the manner in which the radar impulses reach and return from the target is described in the first section. In the second, the factors that determine whether objects should be classified as good or bad targets are discussed, and in this connection a review is made of the reflecting possibilities of radar waves by various objects of a definite geometrical shape. A study is then made of the behaviour as radar-reflecting targets of all objects that may be met with at sea, or signals and other structures on land.

It will be observed that the first four chapters deal in a general way with subjects appearing in other publications. Subsequent chapters as far as Chapter 13 inclusive, on the other hand, are of particular importance and usefulness to navigation in all its aspects, as the method of dealing with the subject-matter is based on a careful analysis of the actual performance of the instrument to date.

Chapter 5. — *Radar Meteorology.*

In dealing with the subject of electro-magnetic wave propagation in the preceding chapters, standard atmospheric conditions were assumed depending on specific values of pressure, temperature, and relative humidity.

Under the designation of « Radar Meteorology », the effects on propagation attributed to non-standard meteorological conditions are discussed, with particular reference to « sub-refraction » and « super-refraction », and various types of attenuation (loss of power) along the path of the waves, caused by atmospheric gases, fog, various types of precipitation and similar factors.

Considerations are limited here to 3.2 cm. radar, which is the type most frequently used on ships.

Chapter 6. — *Interpretation of the Display.*

The difficulties involved in the correct interpretation of the radar display, in the absence of adequate experience of the response of targets and distortions appearing on the PPI, are well known.

In order that the navigator may be better able to identify the radar picture, this chapter, with the help of numerous photographs of PPI displays of various types of targets and coastlines, describes different kinds of radar response depending on whether natural features such as land, ice, sea or clouds are involved, or artificial features such as buildings, roads, steel structures, chimneys, towers, ships, buoys, and the like. Movements of ships as they appear on the radar screen are moreover described.

Characteristics of those echoes which, if recognized, may be of navigational assistance to radar-users at sea have therefore been summarized. No definite solution

of the problem has obviously been given, since in order to use radar equipment to the best possible advantage, the available data must be complemented by the skill and experience of the navigator.

Chapter 7. — *Unwanted Echoes and Effects.*

Clearness of interpretation may sometimes be adversely affected by false echoes appearing on the PPI. Such echoes can be distinguished from the useful ones and may be grouped in two categories: those due to external causes and those arising from local sources, i.e. the ship and the radar equipment. This chapter attempts to show how to spot unwanted echoes caused by sea clutter, rain and rain clouds, hail, snow, sandstorms, fog, anomalous meteorological conditions influencing propagation, and second-trace echoes; by effects from other ships and sets; and by effects from the ship's structure, shadow sectors, distortion and the equipment proper.

This section has been developed to a largely adequate extent and is likewise profusely illustrated by photographs and drawings. It supplements the preceding chapter by supplying valuable information to the navigator on the manner of interpreting the radar display.

Chapter 8. — *Radar as an Aid to Navigation.*

The material under this heading is intensely significant and much of its value would be lost if an attempt were made to summarize it, as it is already a condensation or discussions that have occurred in recent years at meetings of experts sponsored by the Institute of Navigation, London. We shall therefore merely mention that this chapter describes, with the help of drawings and photographs, the use that may be made of radar in making a landfall and in coastal navigation (combined also with visual bearings), in piloting a vessel in harbours and ship channels, and in berthing. Possible radar errors are again referred to.

Emphasis is laid on the fact that radar is not infallible, that it must be used with care, and that an intimate knowledge is necessary of the instrument, its capabilities and possible sources of error.

The chapter ends with a brief description of the changes incorporated in British Admiralty Chart No. 2649 to make it suitable for radar use.

Chapters 9 and 10. — *Radar for Collision Warning.*

Radar and the Rule of the Road at Sea.

An attempt has been made in these chapters, through the use of examples, to evaluate the possibilities of radar as an aid to avoiding collisions, even though the other ship may not be radar-equipped, and the rule of the road as affected by radar. These questions are of course very difficult to define.

Chapter 11. — *Aids to Increasing Echo Strength and to Identification*

An account is given in this chapter of experiments so far carried out on radar reflectors of various shapes, with illustrations of echo diagrams relating to some of them, and on methods of grouping them in order to solve the problem of buoy identification.

Ramarks and racons are then examined, and a comparison is made of these two radar aids.

Chapter 12. — *Shore-based Radar.*

The part played by shore-based radar in enabling the pilot to bring the ship into port and to move the vessel within the harbour during fog conditions, while maintaining normal shipping movements at the port, is discussed in this chapter. The usefulness of radar during the various phases of the procedure is described, together with the actual operation of shore radar. An account of the well-known Liverpool Port Radar Station follows, with details of operational procedure.

Chapter 13. — *The Importance of Recording Experience.*

Merchant marine officers nowadays have a great deal of paper work to do, but the importance of radar is such that it was believed advisable to include a chapter explaining the reasons for keeping a log in order to record radar observations of interest.

Such a log, it is stated, might conveniently be divided into two main sections, a Log of Targets and Operational Log.

The first might contain such items in connection with set performance as identification of targets, state of weather and sea, and detection ranges; while the second part could consist of such information as periods of use, areas of use, reasons for which the instrument was needed, and benefits obtained as well as limitations observed.

Data of this type may not only be of assistance to radar designers but to ships' officers, enabling them to gain an intimate knowledge of their particular instrument and to refer to cases that have already been verified when interpreting the PPI under specific conditions.

Suggestions are then made as to the best method of making log entries, according to the author, and a sample sheet of an operational log is given.

Chapters 14 and 15. — *Simple Maintenance. — The Radar-efficient Ship.*

Rules for the maintenance of radar sets in good operating condition and faults that are likely to occur, together with their causes, are given in these two chapters.

Chapter 16. — *Components and Circuits in the Equipment.*

The brief technical description in Chapter 2 is sufficient for an adequate understanding of other chapters. For those with some knowledge of electronics wishing to acquire a more detailed knowledge of the technical aspects of radar equipment, however, this chapter has been added in which components and circuits are examined more closely, at first separately, and then as a complete set of equipment. Strictly technical language has so far as possible been avoided, however, and descriptions have been limited to effects rather than causes.

Chapter 17. — *Radar in the Future.*

The development of radar for use by merchant vessels has been exceptionally rapid in recent years, and its continued growth may be expected. Establishments that are capable of ensuring its further progress are few, however, and account must be taken of the cost involved in research, experiments and related projects.

In order to increase its value as an aid to navigation, moreover, the collaboration of technicians and experienced navigators is essential.

Various interesting ideas and desirable features relating to possible future improvements meeting the needs of the navigator are consequently discussed in this chapter. It has been considered useful in this connection to divide the latter into two sections dealing in turn with short-term and long-term developments.

Under the first of these headings, the following aspects are considered as being likely of improvement: reliability of sets, involving among other things a reduction in components and other parts of the instrument together with a betterment as to quality; stability of performance; detection range and identification of targets; resolution in range and bearing; PPI presentation, so that the display is likewise visible in bright daylight or in artificial light; aids to radar use; and the adaptation of standard charts for use with radar. Various suggestions are offered for effecting the above-mentioned improvements.

In the second section the author mentions that the tendency of the navigator is to demand that radar make him completely independent of the visibility in order to enable him unfailingly to reach port at the required time. He therefore considers that improvements should aim towards the elimination of obstacles due to fog, in order to ensure the safe handling of the vessel in open waters and avoidance of collisions, and to obtain an appreciation of movement and space equivalent to that with which, in good visibility, the mariner brings his ship to anchorage or alongside a wharf. In this connection radar still shows many shortcomings.

In order that the instrument may be made sufficiently reliable for collision avoidance, the author after discussing present difficulties, including the limitations of design to which ship-borne radar is invariably subjected, suggests several possibilities, of which one would consist in designing a set operating on a millimetric wavelength and used as an auxiliary to the main set.

As an aid to berthing, owing to the fact that handling the ship in good visibility is based on a series of personal and instantaneous observations of fixed and moving objects in the vicinity of the vessel that radar does not provide when there is fog, the author proposes that information in graphic form, rather than instructions, might be supplied to the man on the bridge from the shore. Such information might be transmitted as a television picture appearing on a special screen on the ship; it would be developed from appropriate observations obtained by means of shore-based radar. The system would be similar to that at present under development to assist the landing of aircraft.

The author concludes the chapter by enumerating several of the conditions which any aid to navigation should fulfil, and by stating that the suggestions contained in the chapter as to methods of improving radar are of a personal nature. In any case, he says, since the responsibility for safe navigation is a heavy and very personal one, wide differences of opinion are bound to prevail, and « it is important, therefore, that information and opinion should flow in from the sea, so that as many requirements as possible may be satisfied and that in time the sailor may regard fog, not with apprehension or irritation, but as an interesting exercise in the conjunction of two sciences — navigation and electronics. »

A.V.