SHIPBORNE RADAR AND ARPA

NUTSHELL SERIES
BOOK 3

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Dedicated to my mother, without whose patient and constant encouragement, this book would not have been possible.

Capt. Indrajit Singh
Captain Superintendent,
Training Ship 'Rajendra'

Foreword

The skills and proficiency of navigating officers have necessarily to keep pace with the rapidly advancing marine technology. Effective use of radar and the correct interpretation of radar information will contribute immensely towards the safety of crew, ship and cargo.

The need for good text books and reference books suited to the requirements of our merchant navy personnel whose number is ever increasing cannot be over-emphasized. The availability of a number of technical books on shipping by Indian authors in recent years augurs well for the future. Self-sufficiency in this vital field is a very desirable national objective and the efforts of young authors like Capt. Subramaniam are indeed laudable. I understand that this is the third book written by Capt. Subramaniam who is a distinguished alumnus of Training Ship "Dufferin" and has considerable experience of teaching Merchant Navy Officers appearing for the Ministry of Transport Examinations for Mates and Masters. As Captain Superintendent of the training ship, I warmly commend his efforts.

In this book, the author has dealt with the theoretical and practical aspects of the use of

Radar on board ships. Besides covering the entire syllabus for Radar Observer Course, the book is unique in that the problems are set in such a way that one plotting sheet can be used for working as many as ten problems without erasing any of them. Further the author has incorporated work sheets wherein the solutions to all the given problems are readily available for reference by students.

With lucid explanations of True Motion and True Plotting along with clear sketches and diagrams, the book is bound to be of immense value to the officers studying for Certificates of Competency Examinations and to all those desirous of mastering the use of Radar in ships.

Bombay,
1st January 1980

(INDRAJIT SINGH)

Preface

Every author who writes a technical book, does so with a certain purpose in mind, to suit a specific need. This book is intended not only to make an officer competent in the use of radar, but also to serve as a reference book that he would like to carry with him at sea.

I have tried to give radar plotting the importance it deserves by devoting nearly half the book to it. Work sheets, showing the working of each exercise, have been included so that quick revision is possible whenever desired.

In the second edition, minor changes have been made in parts I, II and III to keep uptodate especially in view of IMO's Performance Standards for Navigational Radar for sets fitted after September 1984. No changes have been made in Part IV – radar plotting.

In the third edition, two new chapters have been added in Part I, namely 'Developments in basic radar' and 'The raster scan display'.

A new part - Part V 'ARPA' - has been added. This has been intentionally included *at the end* after radar plotting, with a separate index, so that the student may study radar first without too much information coming to him prematurely.

Minor revisions have been made throughout to incorporate changes contained in IMO's 'Performance Standards for Navigational Radar' for radar sets fitted after 1st January 1999.

My grateful thanks to my colleagues at the college for their valuable suggestions.

Mumbai H. SUBRAMANIAM.
26th October 2001

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Part II – INTERPRETATION

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Abbreviations

AC	Alternating current.
ACC	Automatic clutter control.
AFC	Automatic frequency control.
ARPA	Automatic Radar Plotting Aid
CRT	Cathode ray tube.
DC	Direct current.
EBL	Electronic bearing line.
EHT	Extremely high tension.
ERBL	Electronic range and bearing line.
FTC	Fast time constant.
HBW	Horizontal beam width.
HM	Heading marker.
HT	High tension.
IF	Intermediate frequency.
Kn	Knot/s
KW	KiloWatt.
LED	Light emitting diode.
LO	Local oscillator.
m	Metre/s.
M	Mile/s (nautical).
MHz	MegaHertz.
PL	Pulse length.
PPI	Plan position indicator.
PRF	Pulse repetition frequency.
PW	Pulse width.
RF	Radio frequency.
RH	Radar horizon.
RM	Relative motion.
RPM	Revolutions per minute.
SART	Search and rescue transponder.
STC	Sensitivity-time control.
TM	True motion.
VBW	Vertical beam width.
VRM	Variable range marker.
WL	Wavelength.

CHAPTER 1

HOW MARINE RADAR WORKS

1. General description

Marine radar is an instrument of near perfect synchronisation. It needs no calculator or computer to do its basic functions. Range and bearing are obtained by the fact that each component does a specific job at the correct time.

Marine radar consists mainly of four units – the transmitter, the aerial or scanner, the receiver and the display unit. The **transmitter** sends out short powerful bursts of electro-magnetic energy, called pulses, through the **scanner** at a specific number of times per second, called the pulse repetition frequency (PRF) or pulse recurrence rate (PRR). These pulses travel at the speed of light (300 metres per microsecond* or 6.173 microseconds per nautical mile) and when they strike any object (target) in their path, they are reflected back to the scanner as echoes. The **receiver** processes each echo and causes it to show up visually as a bright spot, called a blip, on the screen of the display unit.

The **display** unit has a circular screen representing on a scale, an actual area around the ship and is called the plan position indicator (PPI) because it gives a bird's eye view (or plan) of the positions of targets. The distance represented by the radius of the screen is called the range scale in use and this can be varied, by a switch, as desired by the observer.

The underside of the screen is coated with a phosphor compound that glows when struck by a stream of electrons and then fades off slowly. This slow fading off, of the spots on the screen, is called the persistence or after-glow of the screen and helps the observer to view the screen at leisure.

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* Symbol for microseconds is μ. $10^6\ \mu = 1$ second.
1.852 kilometres = 1 nautical mile, 1 kilometre = 0.54 nautical mile.

A thin stream of electrons is made to strike the underside of the screen and move radially across from the centre to the edge of the screen, at a number of times per second equal to the PRF, thereby creating one radial line (called the trace) on the screen for every pulse sent out through the scanner. When an echo is received and processed by the receiver, a sudden brightening and fattening of the tracing spot occurs momentarily. Though the tracing spot is moving continuously during this time, the blip created by it (referred to as the paint) remains stationary and visible due to the persistence of the screen. This is how radar detects the presence of a target in the vicinity.

2. Range determination

As explained earlier, there is one trace created for every pulse transmitted. The tracing spot leaves the centre, on its radial path, at the same instant that the pulse leaves the scanner. The tracing spot is made to move at a scale speed equal to half that of radio waves (i.e. at a scale speed of 150 metres per micro second), so that in the time taken for radio waves to travel 2 miles, the tracing spot would have travelled a scale distance of 1 mile on the screen.

If a target was situated at a range of 3 miles, the pulse would travel 3 miles to the target and the echo would travel 3 miles back, a total distance of 6 miles. During this time, the tracing spot would have travelled a scale distance of 3 miles, from the centre of the PPI, so that when the echo causes the tracing spot to brighten and fatten, the paint so created would be at a scale distance of 3 miles from the centre of the PPI. That is to say, since the radius of the screen represents a definite distance, the distance of the paint from the centre of the screen, using the same ratio, gives the range of the object.

In order to accurately obtain the range of a target, as described above, two methods are provided on the display unit:

2.1. **Range rings**: A series of concentric, equidistant circles, called range rings or calibration rings, are made to appear, centred over the PPI. Each range ring represents a definite value of range and hence the range of a target can be visually estimated with reasonable accuracy, even if a range ring does not exactly pass through the paint of the target on the screen.

2.2. **Variable range marker**: A circle with a variable radius is provided, the radius being controlled by a rotary knob. The value of the radius, in miles and decimal of a mile, is indicated by a digital display. The radius of the circle is adjusted until its circumference passes through the nearest edge of the paint of a target on the screen and the range is read off the digital display.

3. Bearing determination

The energy sent out by the scanner is made unidirectional (it is beamed in one direction at a time). The scanner is made to rotate clockwise (when viewed from above) at a very constant speed (between 20 & 30 RPM). The trace on the screen is also made to rotate and is synchronised with the scanner such that when the scanner points right ahead, the trace is at the 12 o'clock position of the PPI and when the scanner points to the starboard beam, the trace is at the 3 o'clock position, and so on. The PRF is so high (500 to 4000) compared to the RPM (20 to 30) that the angle rotated by the scanner, between the transmission of a pulse and the arrival of the echo from a far off target (i.e., the time taken for the tracing spot to go from the centre to the edge of the screen), is negligible. So the paint of a target would appear in such a position on the PPI that the relative bearing of the target is the angle at the centre, measured clockwise from the 12 o'clock position of the PPI to the paint. This can be read off using a concentric, circular scale fixed around the PPI, graduated from 0° to 359° in a clockwise direction, with its 0° at the 12 o'clock position of the PPI. A stationary radial line, called the heading marker, extending from the centre of the PPI to the zero of the bearing scale, is constantly visible for reference. To facilitate reading off, of the relative bearing, two methods are provided on the display unit:

3.1. **Mechanical cursor**: A separate, circular, perspex sheet is fitted, centred over the PPI. It has a diametrical line etched on it called the mechanical cursor. The cursor is rotated until this line passes through the target on the screen and the reading where it passes over the graduated scale is the relative bearing. When the display is gyro-stabilised, the bearings indicated will be true.

3.2. **Electronic bearing line**: A radial line is made to appear on the screen, when desired. This line can be rotated about the centre of the screen by a control knob. The angle rotated by the line, in a clockwise direction from the heading marker, is indicated by a digital display. The line is rotated until it passes through the blip on the screen and the relative bearing read off, from the digital display. When the display is gyro-stabilised, the bearing will be true.

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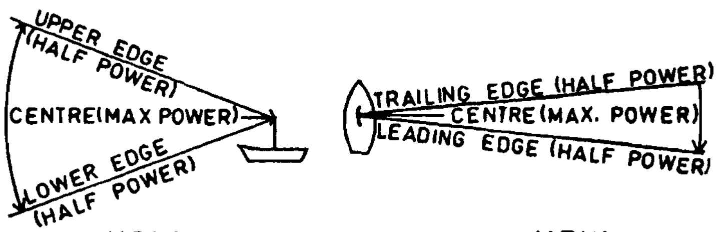
CHAPTER 2

IMPORTANT CHARACTERISTICS

OF A RADAR SET

1. Vertical beam width (VBW)

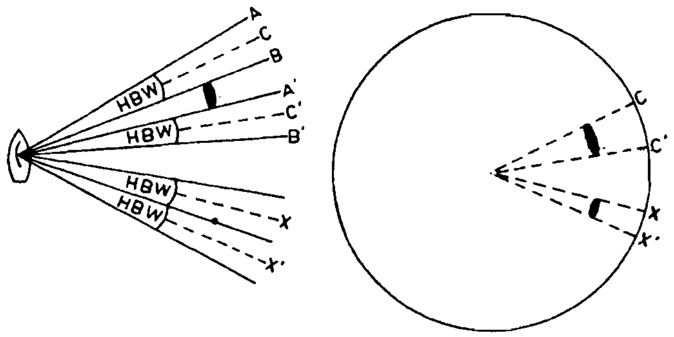
VBW is the vertical angle at the scanner contained between the upper and lower edges of the radar beam. The upper and lower edges of the beam are taken to be the lines joining the half-power points above and below centre of the beam. If the VBW was too small, targets would be missed due to rolling and pitching. If the VBW was too large, the radar energy sent out through the scanner would be spread out over a large vertical angle. This means a decrease in the intensity of the beam whereby the amount of energy striking unit area of a target would be small, resulting in loss of echo strength and consequent decrease in the range of first detection of each target. As per Performance Standards for Navigational Radar (IMO), the radar should function without deterioration in performance when the vessel is rolling or pitching up to ±10°. In commercial marine radar sets, VBW is anything between 15° & 30°. The value of VBW depends on the constructional details of the scanner.



VBW HBW

2. Horizontal beam width (HBW)

HBW is the horizontal angle at the scanner contained between the leading and trailing edges of the radar beam. The leading and trailing edges of the beam are taken to be the lines joining the half-power points ahead and behind the centre of the beam, in the direction of rotation of the scanner. HBW causes all targets to appear larger in azimuth, by an amount equal to half the HBW on either side. This is because echoing from a target commences when the leading edge of the beam touches the target and continues until the trailing edge of the beam has left the target. During this time, the scanner and the trace would have rotated through an arc equal to the angular size of the target plus HBW. A point target thus appears as an arc subtending an angle equal to HBW, at the centre of the PPI. This is called beam-width distortion.



The foregoing figure illustrates beam-width distortion. Echoing commences when leading edge B strikes the target. The trace, aligned with the centre of the beam, is at direction C. Echoing continues until trailing edge A reaches position A′. At this time, the trace would be in the direction C′. Though the actual size of the target is only arc BA′, the paint on the PPI equals to arc CC′. Similarly, a very small target, such as a narrow chimney, will appear as arc XX′, equal to HBW, on the PPI. In the foregoing diagrams, the value of HBW has been exaggerated for illustration purposes.

When observing a small target such as a buoy, a light-vessel, another vessel, etc. pass the bearing marker through the centre of the target on the screen and read off the bearing. No appreciable error will result in this case.

When observing an end of land, the bearing obtained on the PPI is that of the expanded end of the land, which will be in error by about ½ HBW or a little more. Such bearings should, therefore, be avoided wherever possible. Where it is not possible to avoid taking such a bearing, the fix so obtained should not be implicitly accepted as accurate. Beam-width distortion also affects bearing discrimination, which is discussed in the next chapter.

In actual practice, beam-width distortion for closeby objects may be slightly more than HBW. This is because the edges of the radar beam are taken to be the half-power points on either side of the line of maximum power. Some energy is transmitted beyond these 'edges' and it is likely that closeby targets may respond to this, resulting in greater beam-width distortion than HBW.

The value of the HBW of a radar set depends on the type of scanner (see chapter 6) and its horizontal size - the larger the horizontal size, the smaller the HBW and vice versa⋆. In commercial marine radar sets, HBW is between 0.6° and 2°.

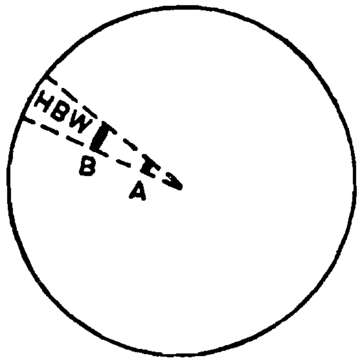
It is because of HBW that a peculiar phenomenon sometimes occurs with radar, contrary to that associated with vision. With vision, an object appears larger and larger as we progressively approach it and smaller as we go away from it. With radar, the opposite sometimes happens - as the range of a small♣ target decreases, its paint on the PPI decreases in horizontal size and as the range increases, its paint on the PPI increases in horizontal size, as illustrated in the figure on the next page.

At A, a small♣ target has expanded to be painted as an arc

♣ For this purpose, a small *(or large)* target is one that subtends an angle, at the scanner, which is less *(or greater)* than HBW.

⋆ The horizontal size of the scanner is also governed by the wavelength of the set, as discussed later in this chapter.

equal to HBW. At B, the same target, expanded to be an arc equal to HBW, is now larger in azimuth than before, though B is at a greater range than A. However, this effect is not noticeable in the case of large* targets because the angle subtended by the target, at the scanner, decreases considerably as range increases.

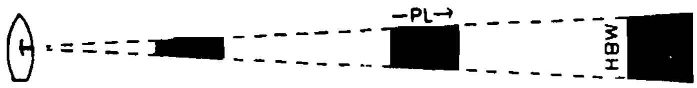


3. Pulse length (PL)

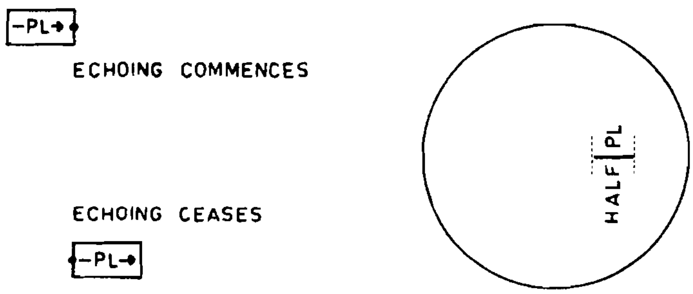
PL is the time taken for a pulse to leave the scanner i.e., the interval between the instant the leading edge of the pulse leaves the scanner and the instant the trailing edge does so. PL is therefore, usually expressed in micro-seconds but, the speed of radio waves being taken to be 300 m/μ, PL may also expressed in metres, if and when required to do so. PL, also referred to as PW (pulse width), is controlled by the transmitter.

When an echo returns from a target, it will be the same length as the pulse. When the leading edge of the echo enters the receiver, the tracing spot on the screen becomes fat and bright and remains so until the entire echo comes in. When the trailing edge has come in, the tracing spot reduces to its original size. The tracing spot, therefore, becomes a blip (referred to as paint) for a time interval equal to PL. During this interval, the tracing spot would have covered a distance equal to half the PL in metres, on its steady, radial path (its scale speed is half that of radio waves). The paint on the PPI would hence appear to have a radial depth equal to half the PL in metres.

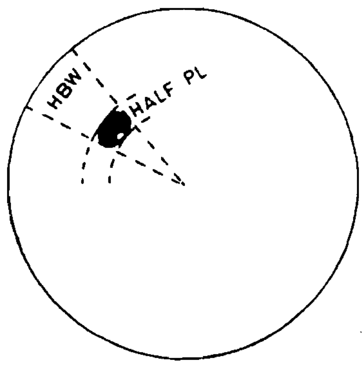
PULSE LENGTH



EFFECT OF PL ON PPI



COMBINED EFFECT OF
PL AND HBW ON PPI



To ensure range accuracy, the tracing spot is synchronised with the leading edge of the pulse. *Hence the correct range of a target is the range of the nearest edge of its paint on the screen.*

PL therefore, does not affect range accuracy. PL does affect range discrimination. This is discussed in the next chapter. Short pulses are suitable for the shorter range scales as they give better range discrimination. To cover longer ranges, however, long pulses would have to be sent out to allow for attenuation (loss of energy) in the atmosphere. Long pulses would be unsuitable for short ranges because all targets painted on the screen would appear too large in the radial direction. Hence, paint created by echoes from sea waves and raindrops would be especially troublesome, as there would be considerable overlapping of such paint on the screen.

Commercial marine radar sets may have three or four values of PL, automatically changed over when the range scale selector switch is operated. A PL selector switch, having two positions marked SHORT and LONG, may also be provided. An idea of the PL (in micro-seconds) that may then be available, is given below:

Position of PL selector switch	Short range scales (3 M and less	Medium range scales (6 & 12 M)	Long range scales (24 & 48 M)
SHORT	0.05μ	0.25μ	0.75μ
LONG	0.25μ	0.75μ	1.00μ

The actual values provided for each set will be given in the operating manual supplied by the manufacturer. *During normal operation, short pulses should be used.* When searching for specific targets such as buoys, lightvessels, etc., or when making landfall, long pulses may be used.

4. Pulse repetition frequency (PRF)

PRF is the number of pulses sent out through the scanner in one second. The unit, if used, is Hertz. Commercial marine radar sets usually have two or three values of PRF, between 500 and 4000. PRF is also referred to as pulse recurrence rate (PRR).

A high value of PRF is preferable for a clear and detailed picture (good picture resolution). On longer range scales, this is not possible because a greater interval between pulses is required, for each pulse to go long distance and come back, necessitating a low PRF. Longer range scales therefore have a low PRF while the shorter range scales have a high PRF.

The picture resolution of a radar set is governed by its RPM-PRF relationship. Consider a radar set having a scanner RPM of 20, a PRF of 2000 on the shorter range scales and a PRF of 1000 on the longer range scales. In one minute the scanner sweeps 20 revolutions or in one second it sweeps 120°.

On the shorter range scales, while the scanner sweeps 120° in one second, it also sends out 2000 pulses i.e., over 16 pulses are transmitted per degree of scanner rotation, which means that 16 echoes from a target form one degree of paint on the screen. The picture on the screen would therefore be very clear and accurate, showing great detail - excellent picture resolution.

On the longer range scales, while the scanner sweeps 120° in one second, it also sends out 1000 pulses i.e., over 8 pulses per degree of scanner rotation, which means that at least 8 echoes from a target form one degree of paint on the screen. Though the picture resolution is fairly good, it is not as good as that on the shorter-range scales. It is hence clear that the picture resolution of a radar set depends on its RPM-PRF relationship.

In addition to the RPM and PRF, the value of HBW also plays and important part in picture resolution and detection range. In the foregoing example, suppose the HBW was 1.5 °. By the time the scanner sweeps 1°, over 16 pulses (actually 16⅔) were sent out on the shorter-range scales and over 8 pulses (actually 8⅓) on the longer-range scales. So by the time the scanner sweeps 1.5° (i.e., HBW), 25 pulses would be sent out on the shorter range scales and over 12 on the longer range scales, thereby ensuring that even the smallest target in the vicinity would return 25 echoes or 12 echoes, depending on range scale in use, resulting in greater detection ranges.

5. Wavelength (WL)

WL of a commercial marine radar set may be either 3 cm (9300 to 9500 megahertz called the X band) or 10 cm (2900 to 3100 MHz called the S band). Radar pulses of different wavelengths are influenced differently by external factors, as described below. Hence the wavelength of a radar set directly affects its performance. After a radar pulse has left the scanner, its path of travel and energy content are influenced by two main factors - attenuation and diffraction.

5.1. **Attenuation in the atmosphere**: Is the loss of energy caused by scattering, absorption, diffraction, etc., while the energy passes through the atmosphere. Attenuation in the atmosphere is greater when using waves of shorter length. Therefore, echoes of 3 cm pulses, coming from far off targets, may be completely attenuated before returning to the scanner whereas echoes of 10 cm pulses coming from the same far off target, may still be strong enough to paint, even though the original power of transmission was the same in both cases. The picture obtained by 10 cm radar is less affected by sea-clutter and rain-clutter.

5.2. **Diffraction**: When a ray of energy passes very close to an object, it is bent slightly towards the object. This effect is known as diffraction. When radar waves pass very close to the surface of the earth, they are diffracted downwards and follow the curvature of earth for some distance. Longer waves are diffracted more and hence 10 cm waves follow the curvature of the earth to greater distances than 3 cm waves. The surface detection range, of far off targets, using longer waves is thus greater than when using shorter waves.

The following figure shows the paths followed by radar waves of different wavelengths due to diffraction.

Summing up: When using *10 cm radar waves, attenuation* in the atmosphere *is less* and *diffraction is more* than when using 3 cm waves. That is why a cliff 60 miles off may be detected by 10 cm radar but may not be detected by 3 cm radar of same power. 10 cm waves are hence good for long distance radar.

WAVELENGTH AND DIFFRACTION

10 cm waves are not generally preferred for the main radar of a merchant ship because of two reasons:

(a) Detection of small objects nearly is poor compared to that of 3 cm waves. This is due to interference caused by energy being reflected off the sea surface. This reflected energy has the effect of lifting the radar beam somewhat and this effect is greater for 10 cm waves than for 3 cm waves. For example, with a scanner height of 18 metres above sea level, for a target 5 miles off to be painted, it would have to be only 3.5 metres high if using 3 cm wavelength but around 11.5 metres high (over three times as big) if using 10 cm wavelength.

(b) To have the same HBW as a 3 cm radar set, the horizontal size of the scanner of a 10 cm radar set would have to be increased threefold. This is not easily practicable on merchant ships.

In view of the foregoing points, 3 cm wavelength is generally preferred for the radar of a merchant ship. However, when two radar sets are fitted, both would be 3 cm sets or one set of 3 cm wavelength and the other set of 10 cm wavelength. Inter-switching arrangements for the display units may then be provided so that failure of any one transceiver and/or display unit, would not deprive the ship of the use of radar.

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CHAPTER 3

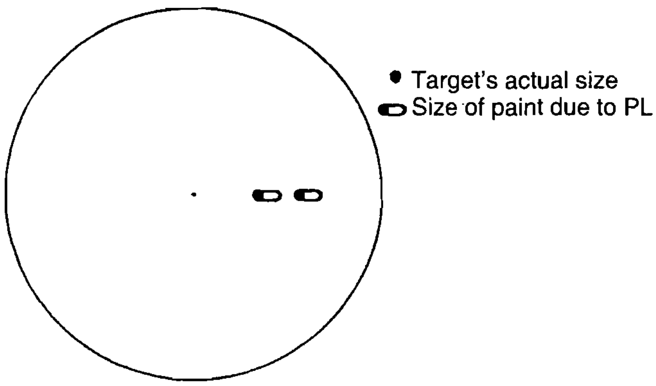
SOME LIMITATIONS

OF A RADAR SET

1. Range discrimination

Is the ability of a radar set to clearly distinguish two small targets, on the same bearing and slightly different ranges, as two separate targets on the PPI. The factor that governs this is the PL which causes all paint to expand radially outwards by ½ PL in metres, as explained earlier in chapter 2.

Considering the two small targets that are on the same bearing and close to each other, the paint of the nearer target would expand towards the other, on the PPI, by ½ PL in metres. If the distance between the two targets is equal to or less than ½ PL, their paints would merge on the PPI and show as if they were one target. If the targets are further apart then ½ PL, they would paint as two separate targets on the PPI.



Example: If a radar set has a PL of 0.2 μ, how far apart must two small targets on the same bearing be for the radar to paint them as two separate echoes on the PPI? In other words, what is the range discrimination of a radar set of PL 0.2 μ?

PL = 0.2 x 300 = 60 metres.
Range discrimination = ½ PL = 30 metres.

i.e., the two small targets on the same bearing must be more than 30 metres apart for the radar set to paint them as two separate targets.

As per Performance Standards for Navigational Radar (IMO), two small similar objects on the same bearing, separated by 40 metres in range, should be separately indicated when using a range scale of 1.5 M when they lie between 50% and 100% of the range scale in use.

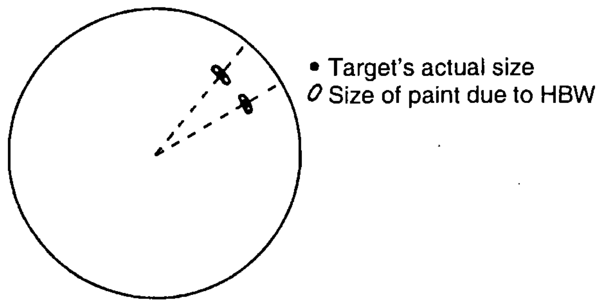
Note: In actual practice, range discrimination will be more than ½ PL in metres, depending on the scale size of the tracing spot. Suppose the diameter of the screen is 30 cm and the diameter of the spot is 0.5 mm. When using the 1.5 M range scale, the radius of the screen (150 mm) represents 1.5 M. So the spot size (0.5 mm) would represent 9.25 m, rounded off to 9 whole metres. The range discrimination would, in this case, be ½ PL + scale size of the spot = 30 + 9 = 39 m.

The scale size of the spot increases as range scale is increased. In the foregoing case, the scale size of the spot would be 18.5 m on the 3 M range scale, 37 m on the 6 M range scale, 74 m on the 12 M range scale, etc.

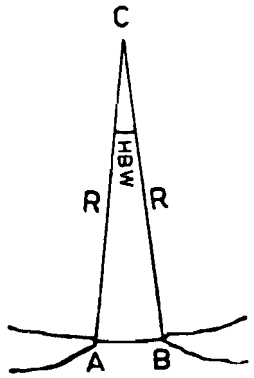
2. Bearing discrimination

Is the ability of a radar set to clearly distinguish two targets, on the same range and slightly different bearings, as two separate targets on the PPI. The governing factor is the HBW of the set.

As explained earlier, in chapter 2, HBW causes all targets on the PPI to expand in azimuth by ½ HBW on either side. The paints of the two targets, on the same range and slightly different bearings would, therefore, expand towards each other by a total of one HBW. If the angle subtended at the scanner, by the closer edges of the two targets, is equal to or less then HBW their paints would merge on the PPI and they would appear as one big target. If the angle so subtended is more than HBW, they would paint as two separate targets. Bearing discrimination is, therefore, usually expressed in degrees and, as per Performance Standards for Navigational Radar (IMO), it should not exceed 2.5°.



Example: A radar set of HBW 2° observes two targets both at 4 miles range. How far apart must they be if the radar set is to paint them as two separate targets on the PPI? In other words, what is the bearing discrimination of a radar set of HBW 2° at a range of 4 miles?



In the figure, C is the scanner, A & B are the closer edges of the two targets on the same range.

CA = CB = 4 miles range.

If A & B are to just merge on the PPI, angle ACB = HBW = 2°.

∴ Bearing discrimination = 2°.

In any circle, $L = \frac{R\,\theta^\circ}{57.3} = \frac{4 \times 2}{57.3}$ miles $= \frac{4 \times 2 \times 1852}{57.3}$ metres

= 258.6 metres.

∴ Bearing discrimination of this set at 4 miles range is 258.6 m. i.e., the two targets must be more than 258.6 metres apart for this radar to paint them separately in azimuth at a range of 4 miles.

Note: In actual practice, the scale size of the tracing spot would have to be added to the above calculated distance. As explained in the note under range discrimination, the scale size of a 0.5 mm tracing spot, on a 30 cm screen, would be 9.25 m when using the 1.5 M range scale, 18.5 m on the 3 M range scale, 37 m on the 6 M range scale, 74 m on the 12 M range scale, etc.

3. Minimum range

The minimum detection range of radar set depends on:

3.1. **The pulse length**: Since the same waveguide and scanner are used for transmission and for reception, a unit called the TR cell (transmission/receive switch), described later in chapter 7, is fitted. This unit blocks the receiver branch of the waveguide during transmission to prevent the transmitted energy from short circuiting into the receiver and damaging it. The TR cell, therefore, ensures that reception starts only after transmission is over. When transmission starts (i.e., when the leading edge of the pulse leaves the scanner) the tracing spot leaves the centre of the PPI on its radial path, as explained in chapter 2 under the heading of PL. By the time transmission is over (i.e., when the trailing edge of the pulse has left the scanner) and reception starts, the tracing spot would have travelled a radial distance of ½ PL in metres. Hence targets closer than ½ PL in metres cannot be shown on the PPI because their echoes would come back before reception starts. The theoretical minimum range of detection is therefore represented by ½ PL in metres. A PL of 0.2 μ would therefore have a theoretical minimum range of 30 metres.

3.2. **The de-ionisation delay**: A small delay occurs in the TR Cell between the completion of transmission and the commencement of reception (explained in chapter 7). This delay increases the minimum detection range. A delay of 0.05 μ (micro-second) would increase the minimum range by 7.5 metres.

3.3. **The VBW and the height of the scanner**: The VBW and the height of the scanner above sea level affect the minimum range as these two factors govern the distance off at which the lower edge of the radar beam would strike the sea surface. The VBW of a given scanner is fixed whereas its height above sea level depends on the ship's draft at that time. The higher the scanner above sea level, the greater the minimum range of detection of the radar set and vice versa.

However, the minimum range should not be calculated geometrically, using the height of scanner above sea level and its VBW - it is possible that targets closer than such a calculated distance may show up on the screen because:

3.3.1. The lower edge of the radar beam is taken to be the half-power point below the line of maximum power whereas, actually, some energy does get transmitted below this, which could cause response from nearby targets.

3.3.2. The height of a target may be such that its top intercepts the radar beam, even though the target's base is closer than such calculated minimum range.

3.4. **The wavelength**: As described in chapter 2, under the heading of 'wavelength', the minimum detection range of small targets is better when using 3 cm waves than when using 10 cm waves.

As per Performance Standards for Navigational Radar (IMO), the minimum detection range, with a scanner 15 m high, shall not exceed 50 m. Targets between 50 m & 1 M should be displayed without resetting any control other than range selector.

4. Maximum Range

The maximum range of a radar set depends on the following characteristics of the radar set:

4.1. **Height of scanner**: The greater the height of scanner above sea level, the greater the detection range. However, two major disadvantages may be experienced with a very high scanner - increased minimum detection range and also more clutter, as explained earlier in this chapter, under the heading of minimum range.

4.2. **Power of the set**: The greater the power of transmission, the greater the expected maximum range subject to the other factors mentioned here. This is because of attenuation in the atmosphere (loss of energy due to absorption, diffraction, scattering, etc., during the pulses' travel through the atmosphere). The peak power of transmission, of commercial marine radar sets, is around 25 to 60 kilowatts.

The electro-magnetic power generated for transmission is subject to attenuation within the set. The greater the length of the waveguide, or the greater the number of bends in it, the greater the attenuation within the waveguide. Water or dirt inside the waveguide, dust or particles of salt on the reflecting surface of the scanner, etc., can cause severe attenuation. The greater the attenuation within the set, the less the transmitted power and, consequently, the less the maximum range.

4.3. **Wavelength**: As explained earlier, in chapter 2, 10 cm waves have a greater maximum range than 3 cm waves due to less attenuation in the atmosphere and more diffraction.

4.4. **Pulse repetition frequency**: Each value of PRF has a maximum range to which it can measure. For example, if the PRF is 2000 it means one pulse is sent out every 1/2000 of a second, i.e., 500 μ. That means each pulse can travel 250 μ to and 250 μ fro (covering a range of 40 miles), before the next pulse leaves the scanner. The theoretical maximum range of PRF 2000 is therefore 40 miles.

In practice, however, each PRF would be allotted a much smaller range scale than its theoretical maximum range so as to ensure that echoes from one pulse do not get mixed up with echoes from the next pulse (see 'Second trace echoes', described later in this book). The manufacturers would have already pre-set the PRF for each range scale and the radar observer usually has no choice in this matter.

4.5. **Pulse length**: Long pulses ensure better maximum ranges than short pulses. This is because long pulses have more energy in them than short pulses and hence have a greater ability to suffer attenuation in the atmosphere, as explained in chapter 2.

4.6. **VBW and HBW**: The narrower the beam widths, the greater the directional concentration of the transmitted energy (see under VBW and HBW in chapter 2, and under 'Aerial gain' in chapter 6) and hence the greater the maximum range.

4.7. **Receiver sensitivity**: Every receiver generates some unwanted signals of its own, which are called noise. The greater the amplification factor, the more the level of noise. Sensitivity of a receiver is its ability to amplify a very weak signal sufficiently without losing the signal in receiver noise. Receiver sensitivity is one of the very important factors that determine the maximum detection range of a target by the radar set.

In addition to the characteristics of a radar set, the following external factors affect maximum detection range:

4.8. **Nature if target**: The height, horizontal size, nature of surface, shape and material of a target, and also its aspect, greatly affect the maximum detection range. These points are explained in detail in chapter 18.

4.9. **Weather effects**: Such as rain, snow, hail, fog, etc., cause attenuation, resulting in a decrease in detection range, as explained in detail in chapter 19.

4.10. **Anomalous propagation**: Super-refraction causes an increase in the maximum detection range whereas sub-refraction causes a decrease. Anomalous propagation is explained in detail in chapter 20.

4.11. **Sea and swell**: Rough sea and heavy swell cause rolling and pitching whereby the scanner goes well out of the vertical. Sea waves frequently obstruct the radar pulses and echoes, to and from far off objects, thereby reducing the maximum detection range.

In view of the foregoing points, targets at a range of 50 M do not generally return echoes strong enough to paint on the PPI of 3 cm radar. However, should severe super-refraction or ducting be present, the possibility increases.

5. Range accuracy

As per Performance Standards for Navigational Radar (IMO), the error in the range of an object, obtained by using the range rings or the variable range marker, should not exceed 1% of the maximum range of the scale in use, or 30 m, whichever is greater.

Range accuracy of radar depends on:-

5.1. **Correct synchronisation** between the transmission of the pulse and the commencement of the trace.

5.2. **Uniformity and rectilinearity of the time base.**

Uniformity of the time base means that the speed of the tracing spot must be very steady. *Rectilinearity* means that each trace created should be a perfect straight line. The speed of the spot, on the scale of the PPI, must be exactly half that of radio waves. Defects in uniformity and rectilinearity of the time base must be set right by technician.

5.3. **The scale of size of the tracing spot**. This is described in the note under range discrimination, earlier in this chapter. The inaccuracy caused by this would be half the scale size of the spot. For example, using a 30 cm display on the 3 M range scale, a tracing spot diameter of 0.5 mm would represent a distance of 18.5 m. Hence the range inaccuracy caused by the scale size of the spot, in this case, would be

9.25 m. On the same display, using the 12 M range scale, the scale size of the 0.5 mm spot would be 74 m and the range error caused by it would be 37 m and on the 48 M range scale, the error would be 148 m.

5.4. **Height of scanner**. When observing small targets very closeby, the radar measures the range from the scanner to the target whereas the correct range should be the distance along the surface of the earth.

Errors in radar ranges, and methods of determining them, are explained in detail in chapter 30.

6. Bearing accuracy

As per Performance Standards for Navigational Radar (IMO), the radar bearing of an object, whose echo appears on the edge of the display, should be capable of being measured with an accuracy equal to, or better than, ±1°.

The factors which govern bearing accuracy are:-

6.1. Correct alignment between the heading marker and the scanner.
6.2. Correct alignment between the heading marker and the bearing scale.
6.3. Gyro error, if any, when the display is gyro-stabilised.
6.4. Type of bearing marker used.
6.5. Rectilinearity of the trace.
6.6. Beam-width distortion.
6.7. Scale size of the spot.

Of the above, point 6.6 has been discussed in chapter 2 (under the heading of HBW), point 6.7 in this chapter under the heading of bearing discrimination, and the rest in chapter 29.

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CHAPTER 4

SOME WAVEFORMS

USED IN MARINE RADAR

Whilst discussing marine radar, terms such as spike waves, square waves, etc., are sometimes used and many mariners do not readily grasp the meanings of these terms.

If a graph was plotted, with time in microseconds along the X-axis and the current in amperes (or potential difference in volts) along the Y-axis, the shape of the curve so obtained differs for different units of the radar and each such waveform is given a name because of its distinct shape. Some of the waveforms used in marine radar are:

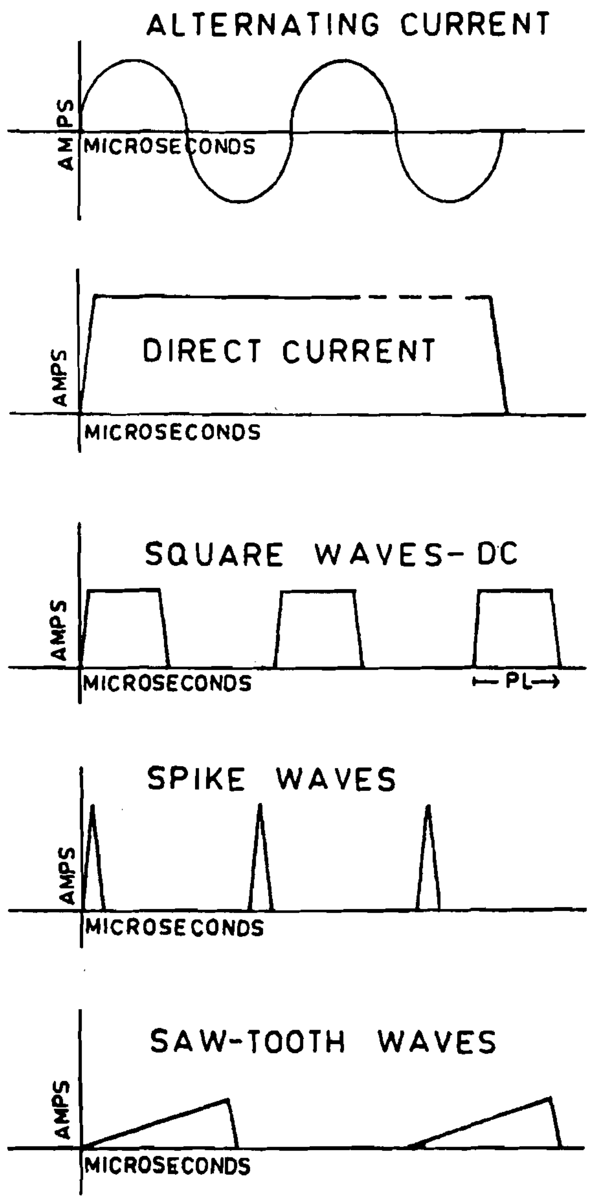
1. Alternating current waveform

If the alternating current flowing between two terminals A and B was plotted on a graph, flow A to B termed positive and that from B to A termed negative, the waveform obtained would be sinusoidal (like that of a sine curve). The number of waves per second is called the frequency, the unit of which is the Hertz (1 Hertz = 1 wave per second). The length of one full wave on the graph, converted from microseconds to metres at the rate of 300 m/μ, gives the wavelength of that current.

Velocity = frequency x wavelength
(m/sec) (Hertz) (metres)

2. Direct current waveform

Soon after the current is switched on, the current increases from zero to maximum in a very short while and then stays at that value. When the current is switched off, it quickly falls back to zero.


ALTERNATING CURRENT
AMPS
MICROSECONDS
DIRECT CURRENT
AMPS
MICROSECONDS
SQUARE WAVES- DC
AMPS
MICROSECONDS
PL
SPIKE WAVES
AMPS
MICROSECONDS
SAW-TOOTH WAVES
AMPS
MICROSECONDS

3. Square waveform (DC)

This is the waveform of an interrupted direct current. Each such wave is a pulse and the number of pulses per second is called the pulse repetition frequency (PRF) or pulse recurrence rate (PRR). The waveform is not exactly square or rectangular as the angles are not exactly 90°, but nearly so. This is because the current does require a small interval of time to go from zero to maximum and vice versa. The duration of each pulse is the PL.

4. Spike waveform

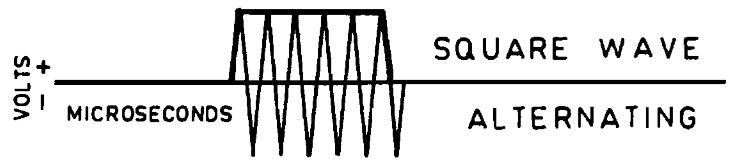
This also, is the waveform of an interrupted direct current but whose pulse length is extremely small. The current goes from zero to maximum in a very short while but falls back to zero equally fast without remaining at the maximum value. This spike is repeated at regular intervals, as required.

5. Saw-tooth waveform

Here the current goes from zero to maximum slowly but very steadily. On reaching the maximum value, it falls back to zero very quickly. The saw-tooth wave is repeated at regular intervals, as required.

6. Square waveform (alternating)

Short bursts of electrical or electromagnetic energy of very high frequency are also termed square waves if the line drawn from the origin, through the peaks of the waves and back to the baseline (the pulse envelope), appears like a square or a rectangle. The duration of each pulse, expressed in micro-seconds, is the PL.



CHAPTER 5

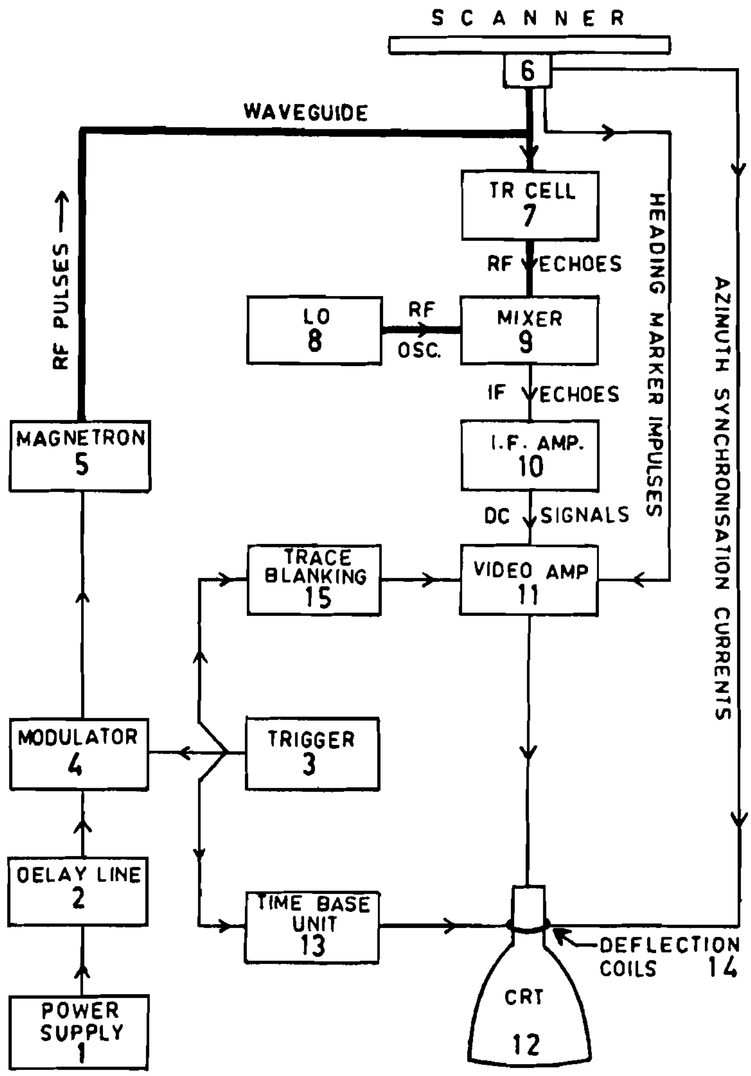
THE SIMPLE

BLOCK DIAGRAM

As explained in chapter 1, marine radar consists mainly of four parts - the transmitter (units 1 to 5 of the block diagram on the next page), the aerial or scanner (unit 6), the receiver (units 7 to 10) and the display (units 11 to 15).

1. **Power source**: The necessary AC input, depending on the make and model of the set, is usually provided:
   1.1. directly from the ship's mains, if suitable, or
   1.2. through a transformer, or
   1.3. through a motor alternator, or
   1.4. through an inverter if the ship's mains are D.C.
2. **Delay line**: Stores the energy received from the power source.
3. **Trigger unit**: Sends spike waves signals to the modulator (unit 4), the time base unit (unit 13) and the trace blanking unit (unit 15). The number of spikes per second equals to the PRF.
4. **Modulator**: Is a device which switches the magnetron on and off as required. In older sets this was done by a valve such as a thyratron or a trigatron but in modern sets solid state devices, such as a silicon controlled rectifier, are used. Each spike wave from the trigger causes the modulator to release one powerful DC pulse (square wave of 10,000 to 15,000 Volts) from the delay line to the magnetron. The duration of each pulse is the PL and the number of pulses per second is the PRF.

SIMPLE BLOCK DIAGRAM OF MARINE RADAR



5. **Magnetron**: Is a high power RF oscillator capable of being switched on and off, for short durations (equal to the PL) at the desired PRF, by the pulses from the modulator. The output of the magnetron consists of RF pulses of electromagnetic energy that are sent to the scanner through a hollow, metal tube called a waveguide.
6. **Scanner**: Sends the pulses out and receives the echoes, one direction at a time. Since it rotates at a constant speed, the entire area around it gets scanned regularly.
7. **TR Cell**: Is the abbreviated name for transmit/receive switch. It blocks the receiver branch of the waveguide during transmission so that the transmitted pulse does not directly enter the receiver and damage it. Soon after transmission is over, the TR cell allows the echoes that are received to pass into the receiver.
8. **Local oscillator**: Oscillates at a constant low power RF of about 30 to 60 MHz above or below (usually below) the magnetron frequency, the difference being called the intermediate frequency (IF). In many marine radar sets, the local oscillator uses a valve of special construction called the klystron.
9. **Mixer**: Mixes the echoes with the local oscillations and makes available, to the IF amplifier, the echoes reduced from RF to IF.
10. **IF amplifier**: Amplifies the IF signals several million times and passes them on to the video amplifier.
11. **Video amplifier**: Controls the amplification of signal voltages fed to the electron gun of the cathode ray tube.
12. **Cathode ray tube (CRT):** Provides a visual display of all targets in the vicinity. Because it gives a bird's eye view or plan, its screen is called the plan position indicator (PPI).
13. **Time base unit**: Generates the saw-tooth waves required by the deflection coils. Each spike-wave from the trigger unit releases one saw-tooth wave from this unit.
14. **Deflection coils**: Each saw-tooth wave received by the deflection coils causes the electron stream of the CRT to

move steadily across the PPI, in a radial direction, thereby creating a trace. One trace is created for every pulse transmitted. The deflection coils are made to rotate around the neck of the CRT, in synchronism with the scanner, thereby creating a rotating trace. In some radar sets, the trace is created and rotated by a rotating magnetic field in stationary deflection coils.

15. **Trace blanking unit**: Allows the electron stream, from the electron gun of the CRT, to hit the screen as soon as transmission takes place and cuts it off as soon as reception time is over (i.e., when the electron stream reaches the edge of the PPI). Being triggered by spike waves from the trigger unit, it sends one square wave to the electron gun of the CRT, for every spike wave received from the trigger. This unit is also called the brightening pulse circuit.

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CHAPTER 6

MORE ABOUT THE MAGNETRON, WAVEGUIDE & SCANNER

The magnetron

This is a resonant cavity oscillator that converts the electrical pulses received from the modulator into electromagnetic pulses. The input is electrical, through HT leads, while its output is electro-magnetic, through a waveguide. The frequency range of 3 cm radar is 9300 to 9500 MHz (also called the X band) and that of 10 cm radar is 2900 to 3100 MHz (also called the S band). The exact value of the frequency of each individual marine radar set is that of its magnetron. Each magnetron has its own fixed frequency. It oscillates only as and when it receives an EHT square wave. In between pulses the magnetron is idle.

The waveguide

This is a tube of uniform cross-sectional area, usually rectangular, which carries the RF pulses from the magnetron to the scanner and also the RF echoes from the scanner to the mixer (through the TR Cell). A small length of waveguide also connects the LO and the mixer. The waveguide is made of corrosion resistant material such as copper or suitable alloys. Its area of cross-section depends on the wavelength - the larger the wavelength, the greater the area of cross-section and vice versa. The length of the waveguide, the number of bends that it takes, damage to it, water or dirt inside it, all cause severe attenuation in the waveguide (considerable loss of transmitted power and also of echo strength) and consequent decrease in the range of first detection of all targets.

The scanner

This is a unidirectional aerial that beams the energy, and receives the echoes, one direction at a time. The size and type of scanner determine the HBW and VBW of the set and hence its aerial gain. *Aerial gain*: If an omni-directional aerial and an unidirectional aerial were to transmit signals of the same power, the former would send out the energy equally in all directions whereas the latter would concentrate it as a beam in one direction. It is, therefore, obvious that, at a given distance inside the beam, the field strength of an unidirectional aerial will be a number of times stronger than the field strength of an omni-directional aerial. This ratio, expressed in decibels*, is called the aerial gain of the scanner and it depends on the vertical size, horizontal size and type of scanner.

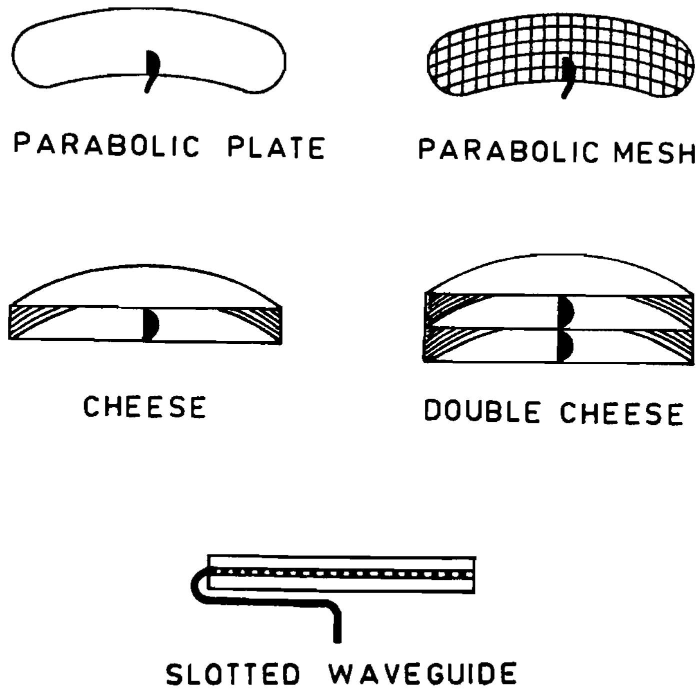
As per Performance Standards for Navigational Radar (IMO), the scanner must rotate at a constant RPM of not less than 20 (and also stop and start) in relative wind speeds up to 100 knots. The scanner motor situated just under the scanner is, therefore, very powerful. If the scanner is fouled by halyards or stays, or if prevented from rotating by icing, either the gears will get stripped or the motor would burn out in a few minutes. To prevent icing up of the scanner axle during periods of non-use in very cold weather, some manufacturers provide a heater which should be switched on whenever necessary. Some other manufacturers provide switching arrangements to enable the scanner to be kept rotating even when the set is switched off.

The surface of the scanner should be periodically cleaned of salt, dust, etc by brushing off with a soft paintbrush or wiping with a cloth. The scanner should never be painted, except under the supervision of the manufacturer's representatives, as ordinary paints would alter the surface characteristics and cause severe attenuation at the scanner.

In olden days, scanners of navigational radar used to be of four types - parabolic plate, parabolic mesh, cheese and double cheese. These are rarely seen on modern merchant ships.

*When comparing two powers X and Y, the number of decibels is [10Log_{10} X/Y]. Hence if X is twice Y, X is said to be 3db and if X is half of Y, x is said to be –3db.

TYPES OF SCANNERS



A parabolic reflector has the property that when parallel rays strike it, they will converge to a point called the focal point. When rays coming from the focal point hit the parabolic reflector, they will go out as a parallel beam. The upper end of the waveguide widens at its mouth and is called the horn or flare. The horn is situated at the focal length of the scanner, faces into it, and rotates along with it. The end of the horn is covered by a thin plate or plastic plug to prevent dirt and water from entering the waveguide, without itself causing much attenuation. The horn is situated a little lower than the actual focal point so that its body will not obstruct transmission and reception. Because of this and also to properly detect nearby objects, the scanner is tilted slightly towards the horn - hence the term *tilted parabolic.*

A parabolic mesh type of scanner is lighter an offers less wind resistance than the parabolic plate. Hence the scanner motor is of less weight and less power. The dimensions of each gap, and its position relative to the horn, have to be very precise and depend on the exact wavelength used.

The cheese scanner is parabolic but has two limitation plates at the top and bottom, to restrict losses of energy in the vertical direction, and thereby give better aerial gain. However, the horn lies directly in the path of the beam thereby causing a certain amount of obstruction and scattering.

The double cheese scanner has limiting plates at the top and bottom just like a cheese scanner but a third horizontal plate divides it into two halves - the upper half for transmission and the lower half for reception. Separate waveguides are used for transmission and for reception and so there is no need for a TR Cell. However, this type suffers from the same drawbacks as the cheese type.

The slotted waveguide type of scanner, as its name suggests, it is a horizontal length of waveguide with slots on one side. It is end fed (the transmitted pulse enters from one end) and the other end is permanently closed. The numerous slots are very specific in size and shape, and very precisely spaced, depending on the exact wavelength used and cause the energy to go out as parallel rays.

The slotted part of the waveguide has a weatherproof cover of corrosion resistant material, usually perspex or fibreglass, to keep out water, salt and dirt without itself causing much attenuation. This further reduces wind resistance. The advantages of this type of scanner over parabolic types of the same size are:

(i) It offers less wind resistance and hence needs a smaller scanner motor.

(ii) It has a smaller HBW.

(iii) It produces less side lobe effect (see chapter 23).

The slotted waveguide is thus the most popular type of scanner seen on modern ships of the merchant navy.

CHAPTER 7

MORE ABOUT

THE RECEIVER

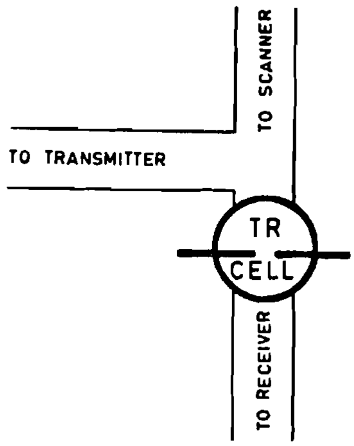
The TR Cell

The transmit/receive cell blocks the receiver branch of the waveguide during transmission so that the transmitted pulse, being of very high power (25 to 60 kW), cannot directly enter the mixer and damage it. It is necessary because we use the same waveguide and scanner for transmission and for reception. One type of scanner, called the double cheese scanner, described in chapter 6, does not require a TR Cell because separate waveguides are used for transmission and for reception. However, it was not found to be as efficient as the duplex system (same waveguide and scanner for transmission and reception) using a TR Cell.

Because the TR Cell has to shut off the receiver branch of the waveguide, without fail, during each and every transmission (500 to 4000 times every second, depending on PRF) it cannot be an electro-mechanical switch as the moving parts will give way due to fatigue. The TR Cell therefore has to be an electronic switch with no moving parts.

The TR Cell consists of a glass bulb with a low-pressure mixture of an inert gas and water vapour. It has two electrodes in it with a small gap between them.

A HT PD (high tension potential difference), of about 500 to 2000 Volts, is constantly maintained between these two electrodes but the current cannot flow between them because of the gap. When the transmitted pulse tries to pass through the TR Cell, its very high energy content (25 to 60 kW) ionises the gas (splits it up into protons and electrons) whereby the gas becomes a temporary conductor of electricity. The circuit now becoming complete, a spark jumps across the gap thereby preventing the transmitted pulse from passing through to the mixer. Soon after transmission is over, the gas de-ionises and, the circuit thus becoming broken, the sparking ceases. When an echo returns from a target, it passes through the TR Cell as it is too weak (only 2 x 10^{-12} to 2 x 10^{-4} Watt) to ionise the gas.



The Mixer and the LO

The echoes that are received are very weak and of radio frequency (RF). In commercial marine radar, it is not practicable, for reasons of economy, to amplify these RF echoes directly. The frequency of the echoes is considerably reduced to a value called the intermediate frequency (IF), before amplification is done. This is called the principle of the heterodyne.

The original RF of 3 cm radar is about 9300 to 9500 MHz and of 10 cm radar is about 2900 to 3100 MHz. The IF is around 30 to 60 MHz, in commercial marine radar.

The local oscillator (LO) produces continuous low power RF oscillations that differ from the magnetron frequency by a value equal to the IF. Both, the local oscillations and the echoes received, are fed to the crystal mixer. At the output end of the crystal, three frequencies are available – (i) the continuous oscillations of the LO at its RF (ii) the echo-signals at the magnetron frequency and (iii) the echo-signals at the IF. The IF amplifier selects and amplifies only the IF signals, ignoring the other two.

Due to temperature variation, voltage fluctuation, ageing of components, etc., the magnetron frequency and the LO frequency may each drift somewhat from their original frequency, thereby causing a change in the IF. The IF amplifier will accept variations only up to about ± 5MHz from the correct value of IF. If the IF varies by more than this, the LO can be adjusted (tuned) so that the IF returns to the correct value of that particular radar set. This tuning of the LO may be done manually (see under 'Manual tuning' in chapter 11) but may also be done, within certain limits, by an automatic frequency control (AFC) circuit.

The IF amplifier

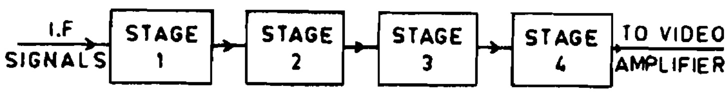
The echoes returning from a target are very weak and of greatly differing signal strengths. Furthermore, they lose some of their strength while being processed through the mixer. The strongest echo may be as much as 10^8 times as strong as the weakest one. The weakest one needs to be amplified about 10^9 times to be able to show up on the screen (the amount of amplification is controlled by the setting of the "gain" or "sensitivity" knob). If the stronger echoes are amplified so much, they would appear too bright and smudge severely on the screen (called blooming). The amplifier therefore has a limiting circuit so that the output signals do not exceed a predetermined ceiling value. The IF amplifier may be of the linear type or the logarithmic type as described below:

Linear amplification: The IF amplifier has several stages, each stage amplifying by a certain amount. The output of the first stage is the input of the second stage, and so on. The output signals of the final stage would all be of equal strength and hence all targets would appear equally bright on the PPI, regardless of whether it is a navigational buoy or a large ship.

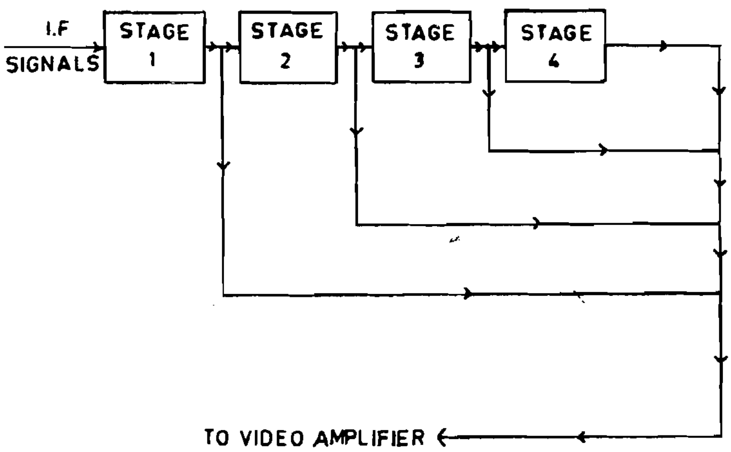
Logarithmic amplification: Here a parallel lead is taken after every stage of the IF amplifier. All these signals are joined together and then fed to the video amplifier. The advantage of this system is that contrast is available (i) between weak and strong echoes, (ii) possibly between two strong echoes of different strengths, (iii) between targets and sea-clutter and also (iv) between targets and rain echoes.

Some radar sets have a control knob with positions marked 'LINEAR' and 'LOG', thereby giving the observer a choice of the system of amplification, depending on the existing circumstances.

LINEAR AMPLIFICATION



LOGARITHMIC AMPLIFICATION



CHAPTER 8

THE CATHODE RAY TUBE

A cathode ray tube (CRT) is a funnel shaped, glass, vacuum container with an electron gun at its narrow end and a screen at its broader end. The electron gun gives off a stream of electrons that strikes the screen. The screen is coated on its inner side with a phosphor compound that glows when struck by electrons. A focusing and deflection system is provided which is either electromagnetic or electrostatic and hence the names 'Electromagnetic type' and 'Electrostatic type' of CRT.

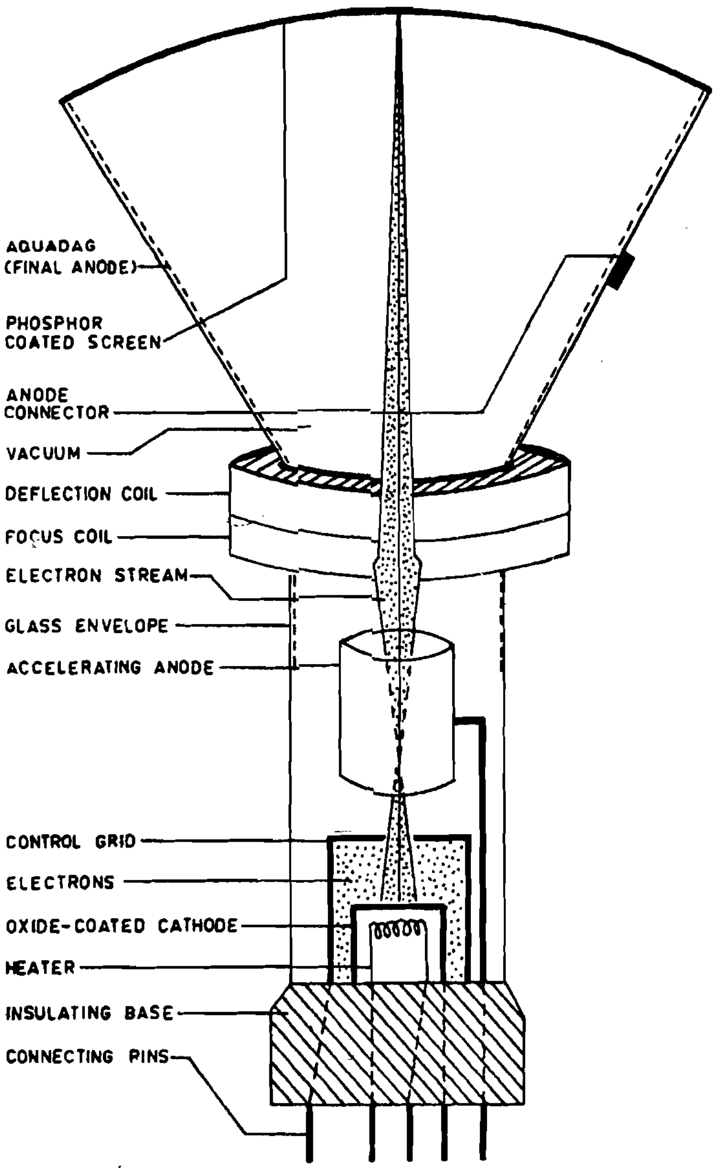
Because electrostatic deflection is not as strong as electromagnetic deflection, electrostatic tubes are much longer than electromagnetic tubes of same screen size. The former require lower voltages but are not as robust as the latter. Many instruments such as oscilloscopes, electrocardiographs, etc., use electrostatic tubes. Basic marine radar uses an electro-magnetic, long-persistence tube. Television sets use electro-magnetic tubes (as the neck is required to be very short) but of the short-persistence type. Television-type radar displays are described in chapter 17.

Electro-magnetic CRT

Referring to the sketch on the next page, a brief description of each part is given below:

Heater: A coil of high-resistance wire through which a current is passed so as to heat up the cathode.

Cathode: An oxide-coated cylinder that gives off electrons when heated (thermionic emission). In some types of CRT, the heater coil itself acts as the cathode.



THE CATHODE RAY TUBE

Control grid: Is a hollow cylinder covering the cathode. It has a small hole, on its axis, through which the electrons leave as a stream. It is given a negative potential with respect to the cathode. The value of this potential controls the number of electrons that are released towards the screen - the less negative this grid potential, the greater the number of electrons that pass through it and vice versa. The strength of the electronic stream is, therefore, controlled by varying the negative potential of the control grid by means of a knob marked 'Brilliance'.

If the grid potential is made sufficiently negative, with respect to the cathode (about -50 Volts), the electrons will not pass through the grid at all and hence the trace will get blanked off from the screen. This is how the trace-blanking unit works.

Each echo-signal is fed as a DC pulse to the control grid and causes a sudden brightening of the tracing spot on the screen thereby creating the blip or paint. Signal voltages to create range rings, the variable range marker, the heading marker and the electronic bearing line are fed to the control grid, as explained in chapter 10.

First anode: Is a hollow cylinder that is given a high positive voltage (about 800 Volts) with respect to the cathode. It attracts the electrons from the cathode and accelerates their movement towards the screen. It is also called the accelerating anode.

Focus coil: Is a coil of wire wound around the narrow part of the CRT. A direct current is passed through the coil and the magnetic lines of force, so formed, act on the electron beam. By altering the strength of this current, by means of a "Focus" knob, the electron beam can be made to converge to a point as it reaches the screen.

The screen: The underside of the screen is coated with a phosphor compound that glows when struck by electrons. This glow fades off slowly, in marine radar screens, so that all the echoes painted thereon, being visible for quite sometime, form a composite picture. This type of CRT is, therefore, also called a long-persistence tube.

The underside of the screen is fitted with a superfine mesh of very thin aluminium that is connected to the final anode. This is provided to prevent secondary emission - some electrons bounce off the screen and tend to hit the screen again. If allowed to do so, they would reduce the sharpness of the picture. The aluminium mesh collects these electrons, before they hit the screen again, and passes them on to the final anode.

Final anode: The inner side of the broad part of the glass envelope, right upto the screen, is coated with a chemical called aquadag which acts as the final anode. This is given a positive potential of 7,000 to 15,000 Volts with respect to the cathode and has the following uses:

1. It accelerates the flow of electrons towards the screen.
2. It shields the electron beam from external magnetic fields.
3. It collects the electrons from the screen and returns them to the cathode through an external electric cable thereby preventing a build up of a negative static charge at the screen.

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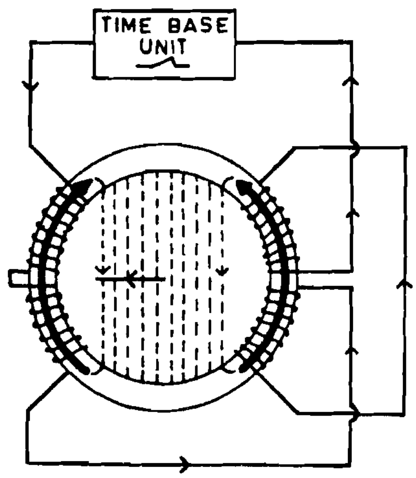
CHAPTER 9

CREATION, ROTATION AND SYNCHRONISATION OF THE TRACE

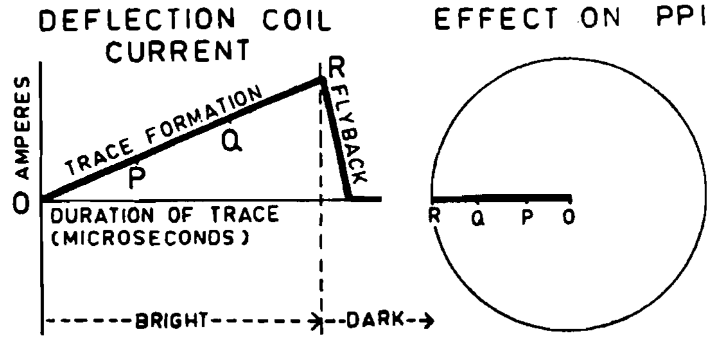
1. THE ROTATING COIL SYSTEM

Creation of the trace

Four deflection coils are wound around a soft iron ring and all four are fed with the same saw-tooth current supplied by the time base unit. The direction of the resultant magnetic field is shown in the following figure, where the deflection coils are viewed from the screen end of the CRT. Since the stream of electrons in the CRT is equivalent to a flow of current, its deflection is at right angles to that of the deflecting magnetic field.



As the strength of the saw-tooth current increases steadily from zero, the strength of the deflecting field also increases steadily. In the following figure, the value of the current and the corresponding position of the tracing spot are marked with identical letters:



The time taken for the saw-tooth current to increase from zero to its peak value is the duration of the trace and is made equal to the time taken for radio waves to travel twice the range scale in use, as explained in Chapter 1: 37μ for the 3-mile range scale, 74μ for 6-mile range scale, etc., One trace is made for every pulse transmitted by the radar set (about 500 to 4000 times per second which is the PRF).

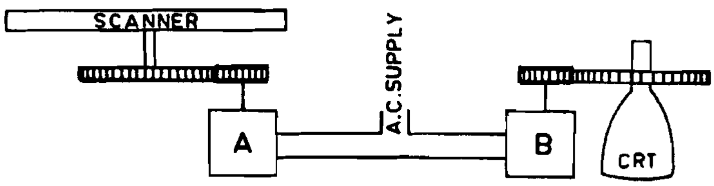
Rotation of the trace

The deflection coils are rotated around the neck of the CRT, in synchronism with the scanner, thereby creating a rotating trace. Since the number of traces created per second is between 500 and 4000 (equal to the PRF), whereas the RPM of rotation is only 20 to 30, the trace appears as a straight, radial, rotating line.

Azimuth synchronisation

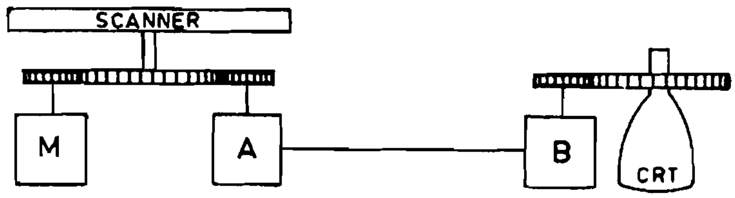
The rotation of the trace must be synchronised with the rotation of the scanner. Three popular systems are described here. The first two use conventional deflection coils to create the trace. The coils are then rotated around the neck of the CRT in order to rotate the trace. The third system, described in para 2 of this chapter, uses stationary coils with a magnetic field to **create and rotate** the trace.

1.1 TWO SYNCHRONOUS MOTORS



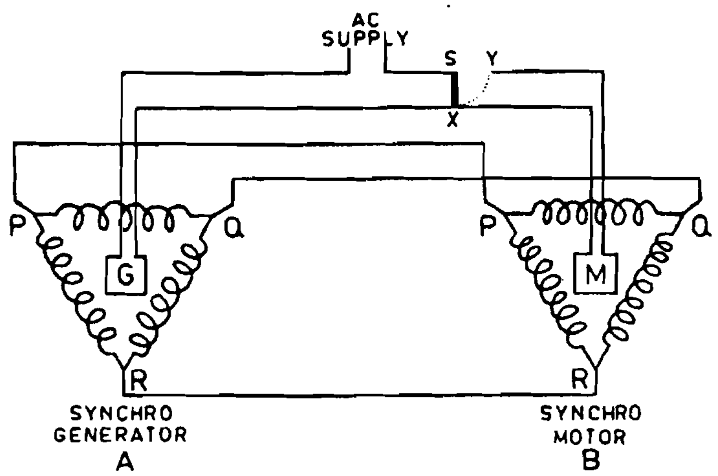
Synchronous motors are AC motors that will rotate at a very constant RPM, despite fluctuations in voltage, so long as the frequency of the AC supply is constant. Both A & B in the above figure are synchronous motors run off the same AC supply. 'A' rotates the scanner while 'B' rotates the deflection coils. The gear wheels are identical and hence synchronisation is achieved.

1.2 SYNCHRO SYSTEM



M is a motor that rotates the scanner.
A is a synchro generator (also called the transmitter) rotated by a gear driven off the scanner shaft.
B is a synchro motor (also called the receiver) that is rotated by the alternating current generated by A.
Since A and B are identical, B will rotate in synchronism with A.

SCHEMATIC EXPLANATION OF A SYNCHRO SYSTEM



The synchro generator and synchro motor are identical. Each has three coils (called stator coils) joined together, 120° apart, in the form of a triangle (delta winding) or a Y (star winding). Each has a rotor in the middle, perpendicular to the axis of the stator coils. The rotors are free to rotate and each has a single set of coil windings.

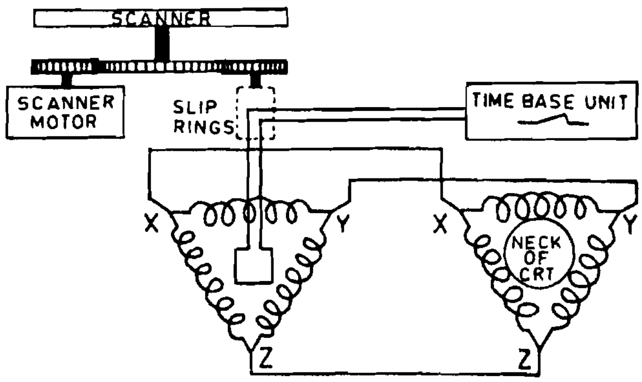
First imagine that switch S is in position X. The AC passing through G creates a magnetic field which induces currents to flow between the two sets of stator coils, resulting in a magnetic field around M also. The magnetic fields around G and M are, therefore, identical. If a soft iron bar was suspended in place of M, the magnetic field there would rotate the bar until it is aligned with the magnetic field. However, the torque (turning force) would be small and the soft iron bar can be in equilibrium in two directions, 180° apart.

If G is now held firmly and switch S is changed to position Y, the AC passing through M would make it behave like a powerful electro-magnet and cause it to align itself to G, with a strong torque. When G and M are aligned, with respect to their stator coils, a state of equilibrium is reached and no current flows between the stator coils. If rotor G is rotated through an arc, M also will rotate through a similar arc and align itself to G. Also, if M is rotated, G will follow. Switch S was useful in describing the synchro system but is not really fitted.

The scanner is rotated at a constant RPM by a separate motor. The synchro generator is rotated by a gear wheel off the scanner shaft. A similar gear wheel connects the deflection coils and the synchro motor so that the rotation of the scanner and the rotation of the deflection coils (and hence the trace) are synchronised.

2. THE ROTATING MAGNETIC FIELD SYSTEM

In this system, the creation of the trace and its rotation are both done by a magnetic field around stationary deflection coils and it is hence called the rotating magnetic field system. The deflection coils consist of three coils joined together, 120° apart in the form of a triangle (delta winding) or a Y (star winding), called stator coils, fixed around the neck of the CRT.



A rotor is driven off the scanner shaft by a gear wheel and this rotor has a single set of coil windings, around which another set of stator coils is fixed. The two sets of stator coils are identical and are connected as shown so that any magnetic field created in one of two sets is repeated exactly around the other.

The saw-tooth current from the time base unit is fed through the coils of the rotor so that, as it rotates, it creates a rotating magnetic field, whose strength has the same saw-tooth characteristics, in its stator coils. This peculiar magnetic field is repeated in the stator coils around the neck of the CRT so that it creates and rotates the trace.

This system having stationary deflection coils has the following advantages over systems that employ rotating coils:

1) Less parts required
2) No frictional loss around CRT (no rotating coils).
3) Less maintenance (no deflection coil bearings to be lubricated)
4) Less wear and tear (no deflection coil bearings to wear out).
5) No noise around PPI (as caused by slightly worn deflection coil bearings).

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CHAPTER 10

BASIC CONTROLS

(TIME-SYNCHRONISED)

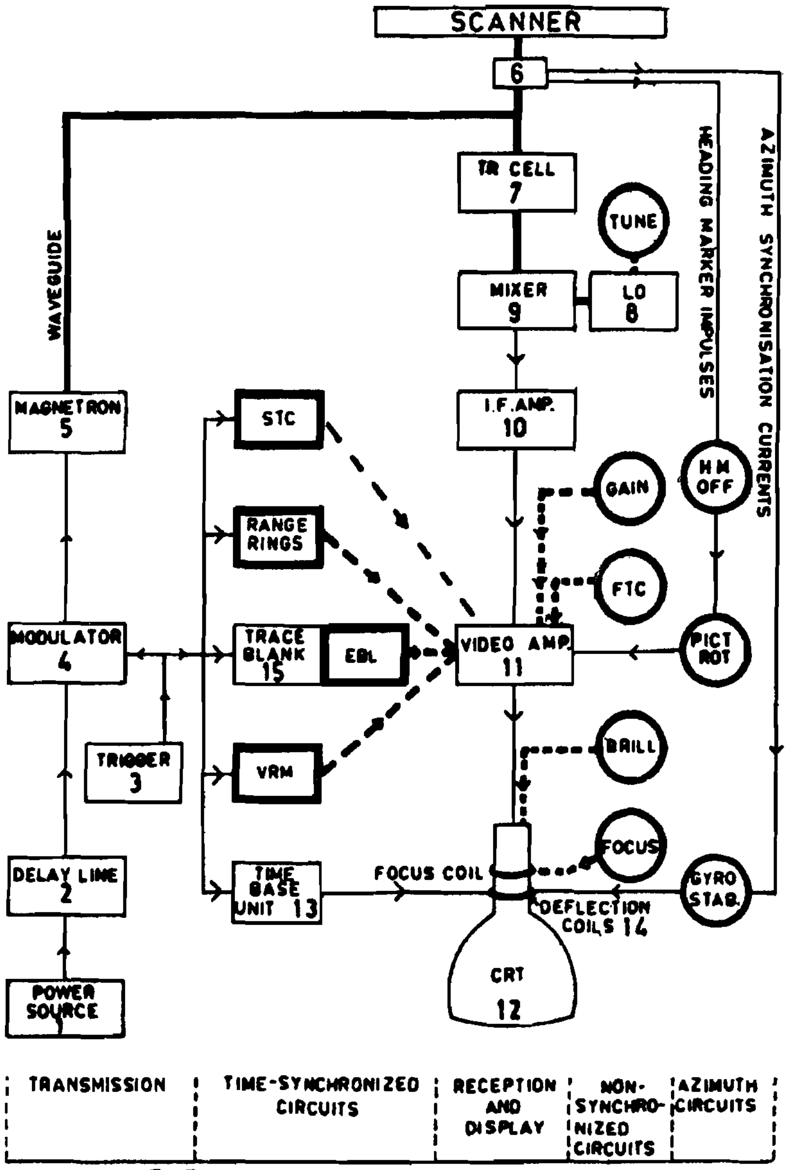
The following descriptions of the basic time-synchronised controls should be read in consultation with the advanced block diagram on the next page.

1. Anti-clutter

This is also called clutter suppression or swept gain control or STC (sensitivity-time control).

In a slight sea, there will be indications of sea-echoes on the PPI, around the centre spot, up to a range of about 3 to 4 miles. Paint on the PPI caused by sea-echoes is called clutter. The clutter area will be roughly oval in shape, symmetrical about the wind direction, with the greater part towards windward. This is because a wave presents, to the radar pulses, a near-vertical front profile (when approaching the ship) and a smooth and sloping rear profile (when going away).

The clutter echoes will change positions with every rotation of the scanner. As the sea gets more and more rough, the clutter echoes will increase in density. In a very rough sea, the clutter echoes may saturate the central part of the PPI (join together and form a bright patch around the centre spot, in which area even echoes of large targets cannot be distinguished). Even under moderate conditions, echoes of small targets such as buoys, boats, etc. tend to get 'drowned' or 'swamped' by clutter (become indistinguishable against so many clutter echoes). If the clutter echoes were suitably reduced in number and brightness, the smaller targets would become distinguishable on the PPI. This is the object of the anti-clutter circuit.



THE ADVANCED BLOCK DIAGRAM

Though echoes from sea-waves are very much weaker than echoes from small targets, they show up strongly because of the large amplification factor (controlled by the setting of 'gain') necessary to allow good detection ranges of all targets. If the setting of gain was reduced, many targets would cease to show up on the PPI, which situation is highly undesirable. Anti-clutter, therefore, works in opposition to gain - but whereas the setting of the gain control affects the whole PPI, the setting of the anti-clutter control works only within 3 miles range or so, on the PPI, i.e., within the first 37 microseconds or so after transmission.

Since the strength of the clutter echoes is maximum from nearby and decreases as range increases, control of clutter also is effected accordingly. The effect of anti-clutter is maximum soon after transmission and tapers off to zero at a range (up to a maximum of about 3 miles) depending on the setting of the anti-clutter control - the less the setting, the earlier its effect tapers to zero and vice-versa.

Anti-clutter should be so adjusted that targets within the clutter area appear just brighter than clutter. It should never be set so as to completely eliminate clutter. If the anti-clutter is set too high, echoes of small targets within a range of 3 miles or so may not be amplified enough to paint on the PPI. Another important fact to note is that whereas the effect of anti-clutter is equal in all directions, the clutter area may not be so - the clutter area is roughly oval in shape, greater part to windward. So a setting of anti-clutter in one direction may prove too high or the or too low in another. This may sometimes become noticeable by the appearance of dark patches on the PPI, near the outer edges of the clutter area. When in doubt, a lower setting should be preferred so that small targets will not be missed. The anti-clutter control should be frequently adjusted according to sea conditions and should never be left in some arbitrary position for long.

Modern radar sets are provided with automatic clutter control (ACC). This is based on the fact that clutter echoes from ***sea and rain*** are random echoes whereas target echoes are systematic. When the ACC is switched on, the echoes received from one pulse are compared with the echoes received from the earlier pulse. If they are inconsistent (do not agree in echo strength and time of arrival), they are not fed to the CRT. Hence most clutter echoes are rejected, without loss of target echoes. ACC is superior to manual clutter control because it provides the correct level of gain for nearby targets, regardless of the varying clutter density to windward and leeward. Furthermore, the ACC automatically adapts to changes in sea conditions unlike the manual clutter control which has to be frequently adjusted. ***When entering harbour or when sailing very close to land, it is advisable to switch over from ACC to manual clutter control*** as strong echoes from targets ashore may result in over-suppression and consequent loss of small targets.

2. Range rings

These are also called calibration rings. When required, a series of spike waves are sent to the control grid of the CRT at equal intervals, causing equidistant blips to appear on the trace. Since these blips occur on every trace, they join up in azimuth and appear as concentric equidistant circles, called range rings, each representing a definite value of range, depending on the range scale in use. The brightness of these rings depends on the peak value of the spike waves and this can be varied, as desired, by the observer. The rings are made to disappear by reducing the peak value of the spike waves to zero.

3. Variable range marker (VRM)

A single spike wave is sent to the control grid of the CRT resulting in a blip being painted on the trace. The blips of each successive trace join together in azimuth and form a circle. The radius of this circle can be varied, at will, by the observer. The value of the radius of the VRM, in nautical miles and decimal of a mile, is indicated by a digital display. The brightness of the VRM can be adjusted, at will, by the observer. In some sets, even when the VRM is switched off, its blip on the EBL is visible so that range along the EBL may be measured whenever desired, without actually switching on the VRM.

4. Electronic bearing line (EBL)

This is also called the electronic bearing marker (EBM) or electronic cursor. It consists of a radial line that is made to appear on the PPI when desired. The EBL does not flash, like the heading marker, when the rotating trace passes over it. The EBL can be rotated by a hand control and made to pass through any target on the PPI. The angle between the EBL and the heading marker (the relative bearing) can be read off a digital display. When the display is gyro-stabilised, the digital display of the EBL gives gyro bearings.

The EBL remains attached to the origin of the trace so that, even when using an off-centre display, its readout would be free of centring error. The EBL is also free of error of parallax. These errors are explained in chapter 29. Because of this, the EBL is a necessary feature of a true motion display (see chapter 27).

In most sets, the EBL control consists of three parts:

4.1. A brilliance control for the EBL.

4.2. A rotary knob to rotate the EBL, in azimuth, as desired

4.3. A digital readout which indicates the bearing - relative bearing in the case of an unstabilised display and gyro bearing in the case of a gyro-stabilised display.

5. Electronic range and bearing line (ERBL)

This is provided on most of the modern radar sets. It is a line whose direction and length correspond to the EBL and VRM. The ERBL is possible because of an innovation called 'Interscan techniques'. This is explained in Chapter 16.

The ERBL may be used in several modes:

5.1. **Attached-to-own-ship mode**: The ERBL remains attached to the position of the own ship on the PPI (the origin of the EBL and the origin of the trace remain coincident) even if and when latter is moved on the PPI.

5.2. **Detached-from-own-ship static mode**: The ERBL is detached from the own ship and may be moved to any part of the PPI and used to read off bearing and distance between any two points. It remains fixed there (static) until moved again by the observer.

5.3. **Detached-from-own-ship dynamic mode**: The origin of the ERBL is detached from the own ship and, once positioned anywhere on the PPI, maintains its bearing and range from the own ship, even if and when the latter is moved. This is very useful while using True Motion displays (explained in chapter 27).

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CHAPTER 11

BASIC CONTROLS

(NON-SYNCHRONISED)

The following descriptions of the non-synchronised basic controls should be read in consultation with the advanced block diagram in chapter 10. They are given below, in the order in which they appear in the block diagram.

1. Manual tuning

This control is provided to manually alter the frequency of the LO so as to bring the frequency of the IF signals to the correct value required by the IF amplifier (see under 'The mixer and the LO' in chapter 7). There are two controls for tuning - main and remote. The main or coarse tuning controls are fitted on the LO itself, on the power panel on the bulkhead, and are adjusted once for all. Main tuning requires re-adjustments rarely, such as when great changes of atmospheric temperature are experienced or when major components, specially the magnetron, have been changed. The remote or fine tuning control is fitted, on the display unit, for use by the radar observer as and when necessary. Where an AFC (automatic frequency control) circuit is provided, fine tuning by the observer would not be necessary. When carrying out main tuning, the AFC would have to be switched off.

A meter or a magic eye gives indication of correct tuning. If the tuning indicator is defective, tuning may be carried out while watching the PPI. Correct tuning is reached when maximum target echoes or clutter echoes are seen, or when the length of the performance monitor signal is greatest.

2. Gain

Gain controls the amplification of all echoes received. In most radar sets, this control works in the video amplifier whereas the IF amplifier is pre-set for optimum amplification - maximum possible without unacceptable levels of disturbance or distortion. If, after amplification, the strength of an echo is ***below*** a certain ***minimum*** level, the echo is not fed to the PPI. If, after amplification, the strength of an echo is ***above*** a certain ***maximum*** value, the excess is cut off before the signal is fed to the PPI.

If gain is set very low, no targets would show up on the PPI owing to insufficient amplification. If set slightly low, targets that return weak echoes (such as buoys 2 M away or a cluster of high rise buildings 30 to 40 M away) would not show up on the PPI.

If gain is set slightly high, 'receiver noise' (amplifier-created disturbances that resemble clutter) would be visible in all parts of the PPI, resulting in less contrast between targets and background. However, this is safer than setting gain low. If set too high, receiver noise would saturate the screen.

Correct setting of gain is achieved by increasing it until a speckled background of noise (resembling fine sandpaper) is just visible while on a medium or long range scale.

3. Differentiator

This is also called FTC (fast time constant) or anti-rain-clutter. Rainfall areas show up fairly well on the PPI. However, where the rainfall is heavy (intense), the rain echoes saturate part of the PPI such that targets tend to get 'drowned' or 'swamped'. This is because of two factors:-

3.1. The large amplification factor (controlled by the setting of the 'gain' control), necessary for good detection ranges of all targets, causes echoes from rain drops, which are very weak, to show up strongly on the PPI.

3.2. The PL, which causes all echoes to expand radially outwards on the PPI (by ½ PL in metres), causes the echo of each raindrop to overlap several million others on the PPI, causing a bright patch to appear.

In fact, tropical rainfall areas may easily be mistaken for land echoes because of their ***large size, bright appearance, clearly defined edges and regularity in painting***.

If either the setting of 'gain' or the PL of transmission was reduced, the rainfall area would appear less bright but this would result in many targets not showing up on the PPI, which effect is highly undesirable. The differentiator circuit reduces the PL of the incoming echoes in the video amplifier. Each echo painted on the PPI would thus have a much shorter length in the radial direction, resulting in the following advantages:-

(i) Less overlapping of rain echoes on the PPI, resulting in a considerable decrease in the brightness of the rainfall area. The edges of the rainfall area are still clearly depicted.
(ii) Very little such dimming effect takes place in the case of land targets, which can thus be distinguished from rainfall.
(iii) Ability to distinguish targets inside the rainfall area.
(iv) When navigating in restricted waters, this improves range discrimination thereby increasing the clarity of the picture.
(v) Possibly eliminate interference from Racons at close range.
(vi) Better range discrimination on all range scales.

FTC should never be left on indefinitely as targets, especially small ones, tend to get missed out on the PPI. The use of a logarithmic amplifier (discussed in chapter 7 under 'IF amplifier') may achieve a somewhat similar effect, without the danger of losing small, weak targets.

Automatic clutter control (ACC) is very effective is reducing both rain-clutter and sea-clutter. This is described under 'Anti-clutter' in chapter 10.

4. Brilliance

This is also called 'brightness'. As explained under 'control grid' in chapter 8, this controls the strength of the electron stream in the CRT. If set very low, no electrons would be released - hence no picture. If set slightly low, the picture would be dim and fade off quickly such that a complete picture may not be visible all the time. If set very high, the screen would get saturated - no targets can be distinguished against the bright background of the screen - and the life of the phosphor coating of the screen would be drastically reduced. If set slightly high, the following disadvantages would be experienced:

4.1. Decrease in the life of the phosphor coating of the screen.
4.2. Less contrast between paint and the background of the PPI.
4.3. The heading marker (and targets after gain has also been set) would be unnecessarily bright and distracting.
4.4. Night vision of the observer would be adversely affected - it would take unduly long for the observer's eyes to recover from the glare of the screen at night.
4.5. Secondary emission may take place resulting in blooming. The number of electrons that may strike one square mm of the screen at one instant is limited. Any electrons in excess of that bounce off and hit the screen nearby. This is called secondary emission. This causes the targets to expand in size (bloom) and their outlines to become blurred. The result is similar to that caused by de-focussing.

The setting of brilliance depends on the amount of external light falling on the PPI. For correct setting, ensure that the gain, sea-clutter & rain-clutter controls are at zero (anti-clockwise). Turn up the brilliance until the rotating trace just appears. Then turn down the brilliance until the rotating trace just disappears.

5. Focus

This control ensures that the electron stream converges to a point, as it reaches the screen, by suitably altering the current passing through the focus coil (see chapter 8). To focus correctly, switch on the range rings and adjust till they appear as thin as possible. In most sets, focussing is pre-set internally by a technician and no control knob is provided on the display.

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CHAPTER 12

BASIC CONTROLS

(AZIMUTH)

1. Heading marker on/off

For measurement of bearings, the heading marker, also called the heading flash, is the reference line provided. It is always visible on the PPI. It may sometimes be necessary to switch it off temporarily to search for small targets ahead. For this purpose, a spring-loaded switch is provided. As soon as finger pressure is released, the heading marker becomes visible again.

2. Picture rotate

This is also called heading marker alignment. Rotation of this knob in either direction causes the entire picture, including the heading marker, to rotate accordingly. This control is necessary to:-

2.1. Align the heading marker to the zero of the scale, in the case of an unstabilised display.

2.2. Align the heading marker to the course of the vessel, in the case of a gyro-stabilised display.

3. Electronic bearing line (EBL)

The EBL, also being a time-synchronised control, has already been described in chapter 10.

4. Electronic range and bearing line (ERBL)

The ERBL, also being a time-synchronised control, has already been described in chapter 10.

5. Mechanical cursor

A perspex sheet, centred over the PPI, with a diametric line etched on it, can be rotated as desired by the observer. The diametric line is made to pass over a target and the reading where the line intersects the outer fixed scale is the bearing of the target - relative bearing for an unstabilised display and gyro bearing for a gyro-stabilised display.

6. Gyro-stabilisation switch

An unstabilised display becomes gyro-stabilised by the operation of this switch. This is also called the presentation mode switch.

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CHAPTER 13

BASIC CONTROLS

(OTHERS)

The following basic controls are grouped together as they are not shown on the advanced block diagram in 10.

1. On/off

This is the main power switch of the radar set and is situated on the display unit. Any additional main switch, which may be provided externally on the bulkhead, etc., must always be left on, except during radar maintenance or repair.

2. Standby

Is a switch that cuts off the EHT to the transmitter and the CRT, when desired by the observer. It may be a separate two-position switch marked 'Standby/transmit' or it may be incorporated with the main power switch with three positions marked 'off/standby/on'. The switch is then referred to as the main function switch.

When the radar observer desires to switch off the set temporarily in order to prolong its working life, and yet have the facility of obtaining a picture at an instant's notice, he may put the set on standby, leaving all the basic controls in their correct settings. When a picture is required, the standby switch is put 'on' (or to 'transmit', as the case may be) and a picture appears instantaneously, already adjusted and ready for use. If manual control of anti-clutter is in use, it may be necessary to re-adjust its setting, in case the weather situation has altered during period that the set was on standby.

If the set is switched off, it would require about two to three minutes, sometimes as much as four minutes, for the set to warm up and, thereafter, for the observer to adjust the controls. Where such a delay can be afforded, the set may be switched off and where such a delay cannot be afforded, the set may be put on standby.

When on standby, the transmitter is off and the PPI is blank. In some sets, the scanner may stop rotating when on standby. All components of the set are warmed up and ready to function at an instant's notice, when the set is on standby.

3. Pulse length selector

Is a switch marked 'short/long' and gives the observer a choice of pulse length. Longer pulses mean greater detection ranges of all targets and it is especially useful when making landfall after a long ocean passage. However, when using longer pulses, the following adverse effects may be experienced:-

3.1. Minimum detection range becomes more.
3.2. All targets appear larger in a radial direction.
3.3. Clutter area becomes larger and brighter.
3.4. Range discrimination becomes less.

All the foregoing points are described in detail under 'Pulse length' in chapter 2. For normal operation, short pulses should be used.

In some modern sets, the PL selector switch is incorporated in the function switch that is marked 'Off/Standby/Short pulse/Long pulse'.

4. Range selector

This switch gives the observer the choice of range scale. The range scales to be available are 24, 12, 6, 3, 1.5, 0.75, 0.50 & 0.25 M.

5. Centre shift

It may happen that, due to change of earth's magnetic field from place to place, external magnetic influences, vibration, etc., the centre spot shifts out of the geometric centre of the PPI. Two controls are provided to bring the spot back to the centre - one for shifting it in the X-axis and the other for shifting it in the Y-axis. It may sometimes be necessary to shift the centre spot out of the centre, intentionally. This also is done by the centre shift controls. The reason for wanting an off-centre display could be:-

5.1. The coating at the centre of the screen may be burnt and hence objects very nearby may be missed. By purposely shifting the centre spot off to one side, targets very nearby will show up as usual.

5.2. The observer may want to see more in one direction, without changing the range scale, in which case he would shift the centre spot off in the opposite direction.

When the display is off-centred, bearings taken with the mechanical cursor would be subject to centring error. Hence the EBL should be used. It is possible to allow for centring error with the mechanical cursor. This is described later in chapter 29.

6. Performance monitor

This switch is provided to check the overall efficiency of the set, as described in detail in chapter 14. When this switch is put on, a plume or a sun pattern appears on the screen. While on the 1.5 M range scale, or other small range scale specified by the manufacturer, the length of the plume (or the radius of the sun pattern) is measured, with gain set normal and both anti-clutter and differentiator controls set at minimum. The present length of the plume, expressed as a percentage of the maximum length in the past, gives the present ***relative efficiency*** of the set.

7. Scale illumination

The brightness of all readouts such as range scale in use, distance between consecutive range rings, bearing scale, digital displays of VRM, EBL, ERBL, names of various controls, etc., are all controlled by this switch.

8. Scanner on/off

This starts or stops the scanner. It may be necessary to stop the scanner, when the set is working, for maintenance, alignment of heading marker, etc. Alternatively, in some radar sets, the scanner may be kept rotating, whilst the rest of the equipment is off, to prevent icing up of the scanner shaft in very cold weather. This is not necessary if a low power heater circuit is provided.

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CHAPTER 14

EFFICIENCY OF A RADAR SET

As per Performance Standards for Navigational Radar (IMO), the radar set must have means of ascertaining the level of its overall performance. It is understood that such means shall be available to the radar observer at all times and not rely on the existence of targets in the vicinity.

A simple oscillator, in the form of an echo box, is mounted at some suitable point on the ship where the transmitted pulse would enter it, oscillate for some time, come back as a long echo and show up as plume (feather) on the display. The length of the plume is an indication of the performance of the set - the longer the plume, the better the performance.

The length of the plume is usually measured on the 1.5 M range scale, unless otherwise indicated by the manufacturer, using the variable range marker. The error, if any, of the variable range marker must, of course, be found and allowed for. In most radar sets, the length of the plume is between 1000 m and 2000 m. The present length of the plume, expressed as a percentage of the maximum length obtained in the past, gives the present ***relative efficiency*** of the set.

$$\frac{\text{Present length of plume}}{\text{Maximum length in the past}} \times 100 = \text{Efficiency \%}$$

The working of the echo box is similar to the striking of a bell. Though the time of contact between the striker and the bell is very short, the ringing sound is heard for considerable time.

The duration of the ringing sound depends on several factors such at the quality of the bell metal, the power exerted by the striker, the material of the striker, damping factors such as objects in contact with the bell surface, cracks or defects on the body of the bell, etc. The duration of the ringing sound is, therefore, a good indication of the overall performance of the bell.

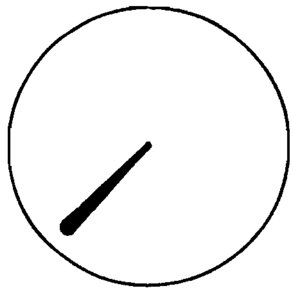
Similarly, the length of the plume indicates the overall performance of the radar set and depends on several factors such as the power of transmission, proper tuning to obtain the correct IF, the efficiency of the receiver, etc. Attenuating factors such as water or dirt inside the waveguide, damage to the waveguide, salt or dirt accumulation on the reflecting surface of the scanner, etc., also will decrease the length of the plume, thereby indicating a decrease in the overall efficiency of the radar set.

Where it is not possible to fix the echo box at a convenient spot, it may be fitted behind the scanner and fed through a small piece of waveguide which is opened by a magnetic relay only when the performance monitor switch is operated. In this case, a cartwheel or sun pattern appears on the PPI because the echo box rotates along with the scanner. The maximum radius of this pattern, just like the length of the plume, is an indication of the overall performance of the set.

If a radar set is working with 80% efficiency, it may be approximated that the maximum detection ranges of targets may be 80% of what they were at 100% efficiency (when the plume was at its maximum length). This is one of the reasons why the regular filling up of the radar logbook (described in chapter 31) is very important. However, the detection ranges of targets are also greatly influenced by various external factors that are discussed in detail in the 'Interpretation' part of this book. The exact procedure to check the performance of the set is described later in chapter 28. Where the efficiency of a radar set falls below 80%, an investigation must be made and the cause rectified.

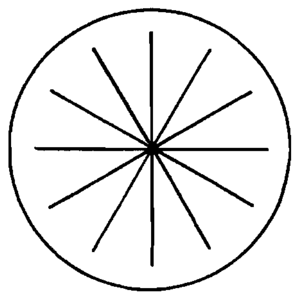
If the plume (or any radial line of the sun pattern) shows any discontinuity (appears broken up instead of being a continuous radial line), it should not be used to ascertain the efficiency of the set as it means that the echo box is not functioning properly.

A rough idea of the quality of performance may then be obtained by the detection ranges of targets, if any, that appear on the PPI. The presence of clutter (echoes from sea waves) is proof that the sea is working reasonably well.



Plume

Cartwheel pattern



The real benefit of the performance monitor is felt when, in open sea, no targets show up on the PPI, especially when in fog or when making landfall after a long ocean passage. The absence of paint on the screen may be due to the fact that there is no target within its detection range or due to malfunction of components of the radar set. This can only be ascertained by the use of the performance monitor.

CHAPTER 15

SITING OF

COMPONENTS

1. Scanner

The problem of siting a radar scanner on a ship may be discussed under four headings - vertical positioning, transverse positioning, longitudinal positioning and other factors.

1.1. Vertical positioning

This refers to height of the scanner above sea level and also height of scanner with respect to other shipboard objects. Experience has shown that a scanner height between 12 m and 18 m above sea level gives best all-round radar performance.

A very high scanner would give good detection ranges of all targets but would have three disadvantages:

1.1.1. The increased length of waveguide would create greater attenuation inside it resulting in loss of power of both, the transmitted pulse and the received echo.

1.1.2. The vertical beam width of a given scanner being fixed, increase in height would cause an increase in the minimum detection range i.e., the lower edge of the radar beam would strike the sea surface further away such that targets closer than this point may not be detected by the radar set.

1.1.3. The amplitude and extent of sea clutter would increase, causing echoes of small targets within the clutter area to become less conspicuous.

A low radar scanner would give good minimum detection range but will also have two disadvantages:

1.1.4. Decrease in maximum detection ranges of all targets.
1.1.5. Blind and shadow sectors caused by shipboard obstructions.

Bearing in mind the variation in height above sea level due to change of mean draft and the optimum height above sea level suggested by the manufacturer, the height of the scanner above the upper deck should be decided so that a reasonably good picture is obtained whether the ship is loaded fully, partly or in ballast.

The scanner should preferably be fitted above the funnel and below the cross-trees in order to avoid blind sectors caused by them. The cross-trees subtend a large angle at the scanner but by fitting the scanner below them, the blind sector lies up in space whereas at sea level, only the shadow sector of the mast will be experienced. If for any reason, the scanner has to be fitted at a greater height than the cross-trees, it should be sufficiently high up to ensure that the blind sector, caused by the cross-trees, falls well within the minimum range of the radar set.

1.2. Transverse positioning

The scanner and the transceiver unit (transmitter-cum-receiver unit) should be as vertically aligned as possible to keep the length of the waveguide, and the number of bends in it, down to a minimum. Otherwise, increased attenuation in the waveguide would result.

On ships with centre-line masts, the scanner should be slightly off-centred, to avoid a shadow sector right ahead. The distance off the centre-line should be kept to a minimum. Otherwise, the radar may show a target to be fine on one bow whereas, to an officer standing at the centre of the wheelhouse, the target may visually appear to be fine on the other bow - a very serious ambiguity.

Where the shadow sector on each bow is inevitable, such as when having bipod masts or goal posts, it is preferable to have the scanner on the centre-line so that the shadow sectors on either bow are symmetrical.

1.3. Longitudinal positioning

The scanner should preferably be in a vertical line with the transceiver so as to keep the length of the waveguide, and the number of bends in it, to a minimum.

On very long ships subject to unusually great trim by the stern, the forecastle may tend to obstruct the radar beam, especially during pitching. In such cases, it may be advisable to fit the scanner on top of the foremast. Since the waveguide then cannot come to the bridge, the transceiver is also fitted on the foremast, inside the sheltered crow's nest or inside a separate watertight box. The length of the waveguide is then only a metre or so. The leads from the transceiver to the bridge are then only electrical wires. However, this poses one problem - maintenance personnel have to climb the mast when required and this is not always practicable in bad weather, very cold weather or rain.

One important point to bear in mind is that, if the scanner is situated on the foremast, visual beam bearings and radar beam bearings of objects closeby may differ. Though this will not appreciably affect navigation, it is well worth remembering, especially when in restricted waters in poor visibility.

1.4. Other factors

1.4.1. The scanner should be so situated that the observer can easily ensure that the scanner is clear before switching on the set.

1.4.2. The scanner should be sufficiently far away from all halyards, stays, etc., which may foul the scanner if they get slack, collapse or part.

1.4.3. The scanner should be well away from all other aerials such as those belonging to Satcom, VHF, Loran, GPS, domestic receivers, etc.

1.4.4. The scanner should be sufficiently far away from magnetic compasses. Every scanner has a 'safe compass distance' marked on it.

1.4.5. The scanner should be suitably isolated or fenced off so that nobody doing any job, other than scanner maintenance, can go near the scanner by mistake. If not, the person will not only be injured by the rotating scanner but also fall down from such a height and suffer further injury.

Extensive research has been done on the effects of radiation from pulses transmitted by radar. It has been said that exposure to continuous, powerful electro-magnetic energy (500 kiloWatts or more, as used in military radars) may cause some ill-effects to human health but pulses transmitted by commercial marine radar are very short and are relatively weak (25 to 60 kiloWatts only) and present no danger at distances beyond about one metre from the scanner. However, going near a scanner whilst radar is being worked should be discouraged, as a matter of routine. The energy inside a wave-guide is much more concentrated. Should a wave-guide be open, whilst the radar is being operated for repairs, etc., one should avoid standing in front of, specially avoid looking into, the open wave-guide.

2. Display

When selecting a site for the display unit, the following points should be considered:

2.1. **Magnetic safe distances**: The safe distance from magnetic compasses, as stated by the manufacturer, should be maintained.

2.2. **Lighting**: The amount of light ensuing from the display unit, though small, may interfere with the keeping of an efficient visual lookout from the wheelhouse at night. An additional light may also be required at the display unit for carrying out running repairs at night. During daytime, the opposite happens. The wheelhouse becomes too bright for proper viewing of the radar screen. The provision of thick curtains, around the display unit, for screening whenever required, will be a great advantage. Some radar sets have 'daylight viewing displays' that give a very bright radar picture (see chapter 16) whereby the use of curtains during daytime is eliminated. In such cases, the curtains may still be an asset at night.

2.3. **Viewing ability from site**: The display unit should be so sited that the master, pilot or navigator can view the radar screen and the visual scene, quickly and easily. To facilitate this, the display unit should preferably be in line with a large porthole, but sufficiently away from it so as to be clear of direct sunlight. To protect the display unit from getting wet, inadvertently due to rain or spray, the porthole in front of it should preferably be of the non-opening type.

2.4. **Facilities for viewing radar screen**: It should be possible for at least two officers to view the display simultaneously. As it may be necessary for one officer to observe radar for long periods, a seat should be made available and the height and angle of the display should be suitable for a seated observer as well as for a standing observer.

2.5. **Facilities for plotting**: Suitable facilities for plotting should be provided and kept readily accessible to the radar observer at all times.

2.6. **Comparison with chart**: The radar observer may want to compare his radar observation with the chart and with the position fixing information obtained from other navigational aids. Where the display unit is in the chartroom, this is no problem at all. However, in most ships, the display unit is located in the wheelhouse. In such cases, the provision of a small chart-table with a suitably screened light would be desirable. In many modern ships, the chartroom is a part of the wheelhouse itself whereby access to the chart-table is quickly and easily available from the display unit in the wheelhouse.

2.7. **Safe distance**: The display unit should be sufficiently far away from equipment such as the clear-view screen, electric telegraph, fans etc., whose sparking could cause interference.

2.8. **Access for repairs**: Suitable space should be available all round the display unit, for maintenance, repairs, etc.

3. Transceiver

In most radar sets, the transceiver consists of bulk-head mounted panels which should be sited so as to:

3.1. Be at eye level, for easy maintenance.

3.2. Preferably be in the chart-room so that lights may be used, for running repairs at night, without disturbing the night vision of the navigating officer and the lookout man.

3.3. Be as directly below the scanner as possible so as to keep the waveguide as short and straight as possible.

3.4. Be at safe distances from magnetic compasses, as specified by the manufacturer.

3.5. Be away from sources of heat or cold (heaters and air-conditioning ducts) or fumes (as from batteries, etc.).

3.6. Be free of excessive vibration.

3.7. Be safe from spray, rain, dust, etc.

3.8. Have adequate space around it so that repairs and maintenance may be carried out without interfering with the navigation of the ship.

3.9. Where the transceiver is mounted remotely, such as on the foremast, etc., a communication link between its site and the site of the display unit is desirable.

4. Motor alternators or inverters

These should be so located that they are protected from weather, well-ventilated and not subjected to undue vibration, dampness, fumes or excessive changes of temperature. Motor alternators are liable to cause vibration and noise and hence should be so located that they do not disturb the crew whether on or off duty.

5. Spare parts

Certain spare parts, particularly spare magnetrons, may seriously affect magnetic compasses. They should be stored in a specially designed box, in accordance with the safe compass distance marked on it. Where the manufacturer has not specified a safe compass distance for the spare-parts box, it should be stored at least 10 metres away from magnetic compasses.

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CHAPTER 16

DEVELOPMENTS

IN BASIC RADAR

Over the years, many developments have taken place in radar while still using conventional CRTs. Some of them are:

1. Interscan techniques

During the time interval between the completion of a trace and the commencement of the next one, the transmitter and the receiver are both idle. This period is utilised to carry out various additional functions. For example, when using the three-mile range scale, the tracing spot takes 37 μ to create one trace. If the allotted PRF for that range scale is 2000, one pulse leaves the scanner every 1/2000 of a second or 500 μ. So after every 37 μ, the tracing spot is idle for the next 463 μ. During this interval between traces (or scans), the tracing spot is used to create several other effects - hence the name 'Interscan techniques'.

Some of the facilities made available by interscan techniques are:

1.1. Electronic bearing line (EBL).
1.2. Electronic range and bearing line (ERBL).
1.3. Electronic map drawing facility.
1.4. Electronic parallel index lines.
1.5. Various symbols and markers for Semi-automatic and Automatic Radar Plotting Aids (ARPA).

2. Video processed displays

These are also called synthetic displays because the raw video signals are not fed directly to the display unit like conventional radar. The radio frequency echoes received from targets are of various shapes ranging from small spike waves to irregular quadrilaterals. These signals are then:

2.1. Passed through a logarithmic amplifier (see chapter 7). Suitable minimum and maximum threshold limiting values (min-TLV & max-TLV) are applied throughout. The min-TLV ensures that very weak signals are eliminated. On the radar screen, most of the sea and rain clutter thus gets eliminated. The max-TLV ensures that, after amplification, the signal strength shall not be too high. Logarithmic amplification ensures that, at the final output stage, a fair amount of discrimination is available between weak and strong echoes.

2.2. Digitally converted into square waves.

Video processing of signals allows a clear radar picture with little or no sea clutter and a fair amount of visible difference between weak and strong echoes. Very bright displays, also called daylight viewing displays, are thus possible using conventional CRTs without the danger of burning out the phosphor coating of the screen.

3. Collision avoidance markers (CAMs)

These were invented by Decca Radar Ltd. They are one of the simplest and most effective semi-automatic plotting aids invented for basic radar.

Description: Each marker looks like a matchstick – a head and tail that are always attached to each other. Hence they are also referred to, by navigators, as matchstick markers. The tail always points to the electronic centre. Once positioned on the PPI, the head of the matchstick maintains its position from the electronic centre – it moves if the electronic centre is moved manually (during RM) or automatically (during TM).

Use: The use is the same whether using RM or TM displays!

Place the matchstick head exactly on a target. Thereafter, if the target:

(a) Moves along the tail, it means that the target is on a collision course with the own ship.

(b) Moves nearly along the tail, it means a small CPA range.

(c) Moves well away from the tail, it means a large CPA range.

(d) Remains on the head, it means that the target has the same course and speed as own ship.

A line drawn from the matchstick head, through the position of the target at any subsequent time, is the line of approach from which the value of CPA can be measured off. This holds good whether using RM or TM displays!

Explanation using RM display: When the matchstick head is placed on a target, it represents 'O'. At any subsequent time, the position of the matchstick head again represents 'O' (since it has not moved during this interval) while the position of the target at that time represents 'A'. OA produced gives the line of approach from which the CPA range can be measured off.

Explanation using TM display: When the matchstick head is placed on a target, it represents 'W'. At any subsequent time, the position of the matchstick head represents 'O' (since it moves along the course and speed of the ship) while the position of the target at that time represents 'A'. OA produced gives the line of approach from which the CPA range can be measured off.

The use of these markers is most effective when using a TM display wherein the course, speed and aspect of a target are readily available. These markers make up for the only thing not readily available on a TM display – relative line of approach and CPA.

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CHAPTER 17

THE RASTER

SCAN DISPLAY

Most of the modern radar sets use raster scan displays instead of conventional cathode ray tubes (CRTs). Raster means lattice or mesh or graticule.

Pixels

The raster screen consists of tiny picture elements called *pixels.* Just like facsimile is abbreviated to *fax*, and in airline parlance, passenger is *pax*, the word *picture* is abbreviated to *pix* and *elements* to *els* resulting in the name *pixels*. The word *pixels,* therefore, is the short form of the words *picture elements*.

Each pixel is very tiny and square in shape. The pixels are coated with a fluorescent (not phosphorescent) compound that glows when struck by a stream of electrons but, unlike conventional CRTs, the glow fades off immediately - there is no after glow. However, since the picture is repeatedly painted about 60 times a second, the human eye sees a continuous picture. There are two types of raster screens used in marine radar – TV-type and high resolution (HR) type.

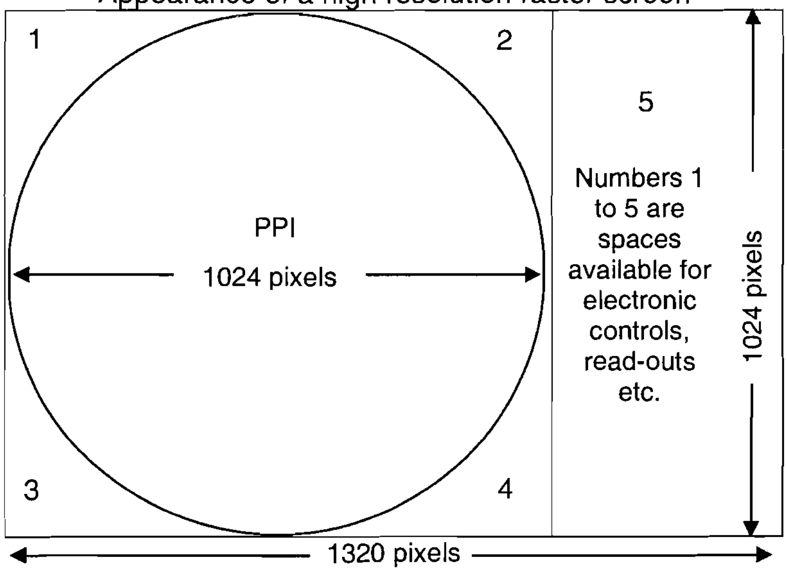
The TV-type raster screen

The TV-type raster screen is rectangular in shape with a height-to-width ratio of about 2:3. In other words, its width is about 1.5 times its height. The screen has about 625 lines (rows) of pixels in the Y-axis and about 940 pixels in each line along the X-axis. The total number of pixels is about 600,000 (i.e., 625 x 940). TV screens are classified by the value of the diagonal, in centimetres or inches, of the effective viewing area. A 69 cm (27-inch) screen will have a vertical dimension of about 38 cm (15 inches) and a horizontal dimension of about 57 cm (22.5 inches). [Numbers here have been rounded off.] This is suitable for ship's radar and comparable to a conventional 36-cm (14-inch) diameter CRT. Since this type of raster screen is commercially available, its cost is considerably low.

High resolution raster screens

Most of the modern radars use high resolution raster screens. These screens also are rectangular in shape but have a height-to-width ratio of about 3:4. They have about 1024 lines (rows) of pixels in the Y-axis and about 1320 pixels per line in the X-axis. They give much sharper pictures, and are hence costlier, than standard TV-type raster screens described earlier.

Appearance of a high resolution raster screen



More about the raster screen

The electron stream sweeps the screen horizontally. It commences at the top left of the screen and descends line by line. One sweep from the top left corner of the screen to the bottom right corner forms one picture. This is repeated at about 60 Hz (times a second).

Basic radar - Rθ

Basic radar pictures are based on two polar coordinates – range and bearing abbreviated here to R and θ respectively. The origin of the trace is the electronic centre (EC) of the PPI. All targets are painted on their R and θ from the EC. The radar screen is necessarily circular and the PPI occupies it fully.

Raster screens - XY

Raster screens are based on Cartesian coordinates - X and Y - from a fixed point on the screen. For the sake of convenience, to avoid negative numbers, we will assume this fixed point to be the bottom left of the screen and indicated by the letter S (source or origin of the raster screen). Everything shown on the raster screen is painted with reference to its X and Y values from S.

Difference between radar screen and PPI

On a raster scan display, the radar screen is the entire rectangular area within which a circular area depicts the PPI. Everything seen on the radar screen is created by the brightening of pixels when struck by the electron stream. On radar using a conventional CRT, the radar screen and the PPI are the same and necessarily circular in shape.

Digital scan conversion

Imagine a graph paper with 1024 lines on the Y-axis, marked L1, L2, etc., upwards from S, the bottom left corner of the graph. The graph also has 1320 lines along the X-axis, numbered from 0 to 1320 from left to right from S. Imagine that every indicator or marker shown on the PPI, such as the outer limit of the PPI, the EC, HM, Range Rings, VRM, EBL, ERBL, the degree markings on the periphery of the PPI, etc., is plotted thereon and the locations (X and Y values from S) of *each and every point* (pixel) over which these lines pass, noted.

Imagine that a blank raster screen replaced the graph paper. As and when the stream of electrons comes over a pixel whose location has been noted earlier, the intensity of the electron stream is momentarily increased so that the pixel glows. At the end of one sweep of the screen, all the markers, including the outer limit of the PPI, the EC, etc., would appear clearly. The sweeps of the screen are repeated at about 60 Hz (times per second).

This is called digital scan conversion. The polar coordinates (Rθ values) of echoes received from targets are also converted to Cartesian coordinates (X & Y values) and shown on the PPI accordingly.

Staggered sweeps

Some manufacturers cause the first sweep of the raster screen to be painted using only odd number of lines in the Y-axis – L1023, L1021, L1019, and so on. The next sweep is made using the even number of lines – L1024, L1022, L1020, and so on. This is called *Staggered* or *Interlaced sweeps.* This goes on every alternate sweep of the screen. This prevents smudging when the size of the tracing spot becomes slightly enlarged. The picture is then refreshed about 30 times per second as against 60 times per second where the full sweep system is used.

Picture updated only once per scanner rotation

It must be remembered that information (range and bearing) of a target is received only when the scanner points to the target. If the scanner RPM is 20, then target information is updated only once every three seconds. Thereafter:

On conventional CRT displays, the afterglow of the target remains visible on the old position of the target, due to the persistence of the screen, until the scanner points to the target again and receives fresh information.

On raster scan displays, the last known information of a target is repeated about 30 (or 60) times per second until the scanner points to the target again and receives fresh information.

Display of other information

The sweep of the electron stream covers the entire radar screen and is not restricted only to the PPI. Hence the remaining space is used to display all other controls and information necessary for radar operation such as the display mode in use, the course steered, the range scale in use, the range-ring interval, the range indicated by the VRM, the bearing indicated by the EBL, the direction and range indicated by the ERBL, the PL (short or long) in use, the anti-clutter setting, the differentiator (anti-rain-clutter) setting, etc.

User comparison between CRT and Raster scan displays

	Conventional CRT display	*Raster scan display*
1.	PPI fills the radar screen	PPI is only part of the screen
2.	High setting of brightness can damage the screen especially at the EC - burnt out patches may occur.	Screen cannot be damaged by improper setting of any controls whatsoever. Hence very bright displays possible.
3.	Echoes received are fed directly to PPI.	Echoes are processed, stored and then fed to PPI.
4.	Targets on the PPI tend to fade between scans because the target is painted once every 3 seconds (assuming RPM of scanner to be 20).	No fading between scans – in 3 seconds, the entire radar screen is refreshed about 180 times using full sweep and about 90 times if using the staggered sweep system.
5.	Only two colours possible - one for background of PPI and other for markers and targets.	Many colour variations possible. Background (sea) can be one colour (say light blue), markers another colour and targets can be assigned different colours depending on echo strength.

6.	Outlines of targets are correctly shown.	Since picture is composed of tiny, square pixels, outlines of targets are shown as a series of connected squares. This very apparent on small range scales.
7.	Trails behind targets are always there with no control over them.	Trails behind targets are normally absent but by use of stored memory, they can be created as desired: stipulated intervals and duration, TM/RM trails, etc.
8.	Touch-screen controls not possible.	Touch-screen controls easily possible.
9.	Reflection plotters may be fitted for manual plotting.	Reflection plotters cannot be fitted but manual plotting is possible using EBL/ERBL.
10.	Fitting of manual cursor possible as the radar screen is circular.	Fitting of manual cursor not possible as screen is rectangular. However, electronic degree markings along periphery of PPI perform the same function.
11.	Fitting repeater (slave) displays quite cumbersome.	Fitting repeater (slave) displays very easy.
12.	Photographic results not very good because parts of the screen just swept by the trace are bright whereas the rest of the screen is darker.	Photographic results very good because all parts of the screen are equally bright at all times.
13.	Controls are necessarily fitted on to the display unit.	The control panel can be separate and connected by only a plug-in cable.

14.	Wireless remote controls not possible.	Infrared remote controls are possible as optional extras.
15.	Wall mounting above eye level not possible - controls would not be reachable.	Wall mounting above eye level possible in view of the foregoing two points.
16.	Lots of electro-magnetic parts and controls. Frequent maintenance required.	No moving parts. Parts are mostly electronic plug-in boards. Simple to replace. Maintenance not frequently required.
17.	CRT has to be tailor-made for each type and model.	Commercial types of screens used are easily available.

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Notes

Part II
INTERPRETATION

CHAPTER 18

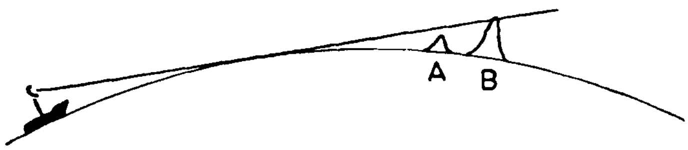
CHARACTERISTICS

OF A TARGET

The important characteristics of a target that influence its range of first detection are as follows:-

1. Height above sea level

Other things being equal, higher objects are detected further away than lower objects.



Target B is higher than target A and hence has greater detection range, other characteristics being assumed equal.

2. Horizontal size

The larger the horizontal size of the target, the greater the echoing surface and the better the detection range, other things being equal.

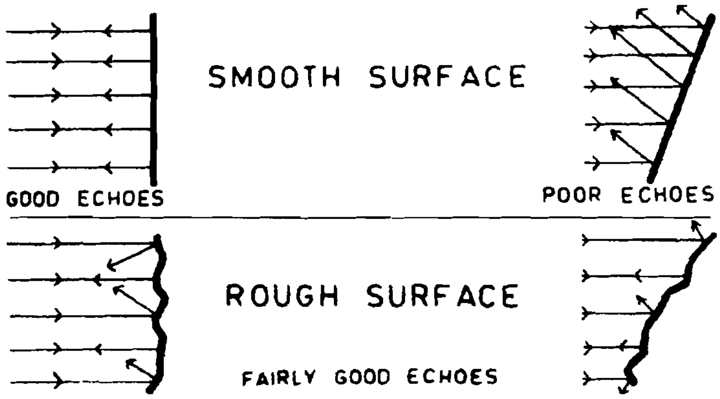
Target C has greater size in azimuth than target D and hence has a greater detection range. A faint line on the PPI is easier to spot than an isolated, faint blip.

3. Composition

The material of the surface of the target is a very important factor. Hard substances are better reflectors of radar waves than soft substances. Other factors being same, the radar reflectivity of the following substances are given in ascending order: wood, concrete, rock and best of all, metal.

4. Nature of surface

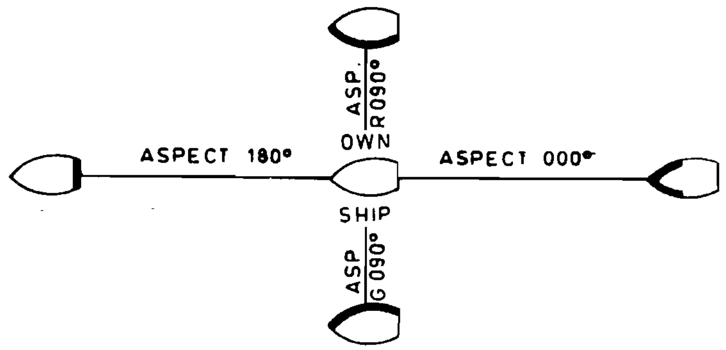
Smooth surfaces return good echoes to the scanner only if they are perpendicular to the radar pulses; otherwise, they are poor radar targets. Rough surfaces return echoes of medium strength from all angles of view.



If the amplitude of the ups and downs of the surface is negligible compared to the wavelength, the surface is considered smooth. If the amplitude is considerable, compared to the wavelength, the surface is considered rough. Therefore, what is considered smooth for radar is not necessarily considered smooth for light waves whose wavelength is measured in microns (millionths of a metre).

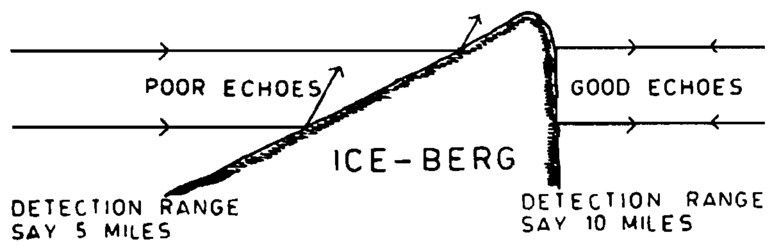
5. Aspect

The aspect is the angle from which an object is viewed. For plotting purposes, it is the angle between the target ship's head and the theoretical line of sight, expressed from 0° to 180° Red or Green i.e., own ship's relative bearing as seen from the target, expressed Red or Green from 0° to 180°



When the aspect is 90° R or G, there is greater echoing surface on the target's hull (and hence greater detection range) than when the aspect is 000° or 180° as shown in the above figure where the echoing surface in each case is shown in bold lines. Superstructure also plays an important part for ship-targets.

For land targets, the word aspect is used in its literal sense i.e., angle of view. A land target may be steep on one side and gently sloping on the other. When the steep side is viewed by radar, good detection range is obtained but if the aspect changes and the other side is now viewed, the detection range is considerably less.



It is probably this factor (change of aspect) which causes some icebergs to suddenly disappear from the PPI even though range has not increased. An iceberg of glacier origin has peculiar shapes. It may happen that one side is steep and has a detection range of say 10 miles, whereas another side is sloping and has a detection range of say 5 miles only. Initially the steep side may be towards the scanner and the iceberg shows up on the PPI at 10 miles range. As the ship passes by, when the range is say 7 miles, the change of aspect or capsizing of the iceberg may cause the sloping side to be presented to the scanner. The detection range of this side being only 5 miles whereas the range is 7 miles, the iceberg suddenly disappears from the PPI and reappears when the range is 5 miles.

Icebergs of ice-shelf origin have steep near-vertical sides and are generally good radar targets from all angles of view. A large passenger liner is a very good target because of its large size, great amount of superstructure and high freeboard. Buildings are very good reflectors, especially if two of them at right angles to each other act like a large corner reflector.

Based on the foregoing factors, the following approximate detection ranges may be expected, under normal propagation conditions, using a scanner 15 m above sea level:

Hills and mountains	15 to 40 M
Coastline 60 m high	20 M*
Coastline 6 m high	7 M*
Piers and breakwaters	5 to 10 M
Low sandy coastline	1 to 5 M
Large passenger liner	about 18 M
General cargo ship 5000 GT	7 M*
Small vessels 10 m long	3 M*
Small wooden boats	1 to 4 M
Navigational buoy (without radar reflector)	2 M*
Navigational buoy (with radar reflector)	5 M
Icebergs	3 to 15 M
Growlers (pieces of ice-bergs 1 m high)	4 M

*Minimum requirement as per Performance Standards for Navigational Radar (IMO).

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CHAPTER 19

WEATHER EFFECTS

ON RADAR PERFORMANCE

When radio waves pass through the atmosphere, some of their energy is lost due to absorption, scattering, diffraction, etc. Such loss of energy is termed attenuation in the atmosphere. Weather phenomena such as drizzle, rain, hail, snow, fog etc., cause varying amounts of attenuation and are discussed below. Attenuation due to these weather effects causes loss of echo strength and consequent decrease in detection ranges of targets.

1. Drizzle

Drizzle means small droplets of water, less than 0.5 mm diameter, which fall towards the ground. The drizzle area appears on the PPI as if seen through ground glass and has indistinct edges - filmy areas with soft edges. Detection ranges of targets within or beyond the drizzle area are not much affected. Targets within the drizzle area generally show up clearly.

2. Rain

Drops of falling water, larger than 0.5 mm diameter, is called rain. Rainfall areas show up clearly on the PPI. Targets inside the rainfall area may be distinguishable by use of the differentiator (explained in chapter 11).

In a heavy tropical downpour, the rainfall area appears as a bright solid block inside which targets cannot be distinguished, despite adjustment of controls. They may easily be mistaken for land echoes because of their ***large size, bright appearance, clearly defined edges and regularity in painting***. Detection ranges of targets beyond such a rain area are severely reduced. If rain is falling on the observing vessel, detection ranges in all directions will be adversely affected due to attenuation. Tropical rain-bearing clouds have been known to produce echoes strong enough to be mistaken for land echoes, even though no rain was actually falling at that time.

3. Hail

Hail stones give echoes on the PPI, similar to rain drops. Small hail stones give weaker echoes and large hail stones (larger than about 6 mm diameter) give stronger echoes than rainfall. The rate of precipitation with hail usually being less than with rain, attenuation due to hail is generally much less than with rain.

4. Snow

If snow falls in single crystals, as is common in cold climates, echoes from snow are not troublesome, unless snowfall is extremely heavy. If, however, several snow crystals join together and fall as large flakes, as is common in temperate latitudes, their echoes show up on the PPI like rain. The rate of precipitation with snowfall usually being much less than with rainfall, attenuation due to snowfall is generally much less than with rain.

5. Fog

Echoes from fog particles themselves are negligible, but attenuation may be severe. In colder climates, dense fog will appreciably decrease the detection ranges of all targets. In warm climates, however, the detection ranges are not much affected, unless fog is so thick that visibility is practically nil.

6. Sand storms

These are common in the Red Sea, Persian Gulf, etc. Though they greatly reduce optical visibility, no adverse effect on radar performance has been noticed.

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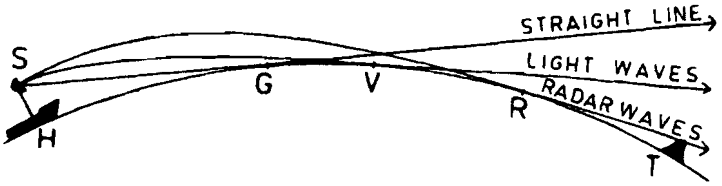
CHAPTER 20

ANOMALOUS PROPAGATION

Anomalous (or non-standard) propagation is the changing of the distance of the radar horizon, due to changes in atmospheric conditions. The point where a ray of energy reaching the observer's eye or scanner, just grazes the earth's surface as a tangent, is called the geometric horizon. Because of their greater wavelength, radar waves are refracted more than light waves and hence the radar horizon is further away than the visible horizon.



GH	= Distance of geometric horizon from ship	$= 1.93\sqrt{h}$
VH	= Distance of visible horizon from ship	$= 2.07\sqrt{h}$
RH	= Distance of radar horizon from ship	$= 2.20\sqrt{h}$
RT	= Distance of target from radar horizon	$= 2.20\sqrt{x}$
HT	= Theoretical detection range of target	= RH+RT

In the foregoing figure and table, 'h' is height of scanner (or eye) above sea level in metres, 'x' is the height of target above sea level in metres and distances are in nautical miles along the curved surface of the earth.

From the foregoing figure and formulae, it is clear that the theoretical detection range of a target is the sum of RH and RT and, under normal circumstances, is given by the formula:

$$d = 2.20\sqrt{h} + 2.20\sqrt{x}.$$

$2.20\sqrt{h}$ represents the distance of the radar horizon under certain assumed conditions of the atmosphere.

These values are the estimated mean values over land, throughout the year:
Atmospheric pressure: 1013.2 mb at sea level decreasing, as height increases, at the rate of 11.8 mb per 100 m.
Air temperature: 15°C at sea level decreasing, as height increases, at the rate of 0.65°C per 100 m.
Relative humidity: 60% assumed constant at all heights.

Any change in the above conditions, especially lapse rate of temperature and change of relative humidity with height, will cause a change in the distance of the radar horizon. Anomalous propagation may be expected whenever there is a considerable difference between the temperatures of air and sea.

There are three forms of anomalous propagation:

1. Sub-refraction

If the radar rays bend less than usual, they will touch the earth's surface, as a tangent, at some point closer than the standard radar horizon of $2.20\sqrt{h}$ (see figure at the end of this chapter). Because this decreases the detection ranges of surface targets, this kind of anomalous propagation is called sub-refraction. Sub-refraction occurs when temperature falls at a greater rate than the assumed standard lapse rate of 0.65° C/100 m or if relative humidity increases with height. If sub-refraction is severe, the rays may bend upwards, causing the radar horizon to be closer than the geometric horizon. Sub-refraction will be found whenever a cold breeze blows over a relatively warm sea, as in the following cases:

1.1. In the lee of an iceberg.
1.2. On the leeward side of very cold land masses.
1.3. Land breezes in coastal regions (they blow at night).

2. Super-refraction

If the radar rays bend more than usual, they will touch the earth's surface, as a tangent, at some point beyond the standard radar horizon of $2.20\sqrt{h}$ (see figure at the end of this chapter). Because this increases the detection ranges of surface targets, this form of anomalous propagation is called super-refraction.

Super-refraction can occur either if temperature falls at a slower rate than the assumed standard lapse rate of 0.65°C/100 m or if relative humidity falls height (relative humidity was considered to be constant, at all heights, under standard conditions).

Super-refraction is thus experienced whenever a warm breeze blows over a relatively cold sea, as in the following cases:

2.1. In areas of high pressure (in the centres of anti-cyclones) warm dry air is descending, as a result of which temperature may fall less than 0.65°C/100 m height (causing super-refraction), or remain constant with height (called an isothermal layer, causing strong super-refraction), or even increase with height (called temperature inversion, causing severe super-refraction).

2.2. Sea breezes in coastal waters are warm compared to the sea. (They blow during daytime).

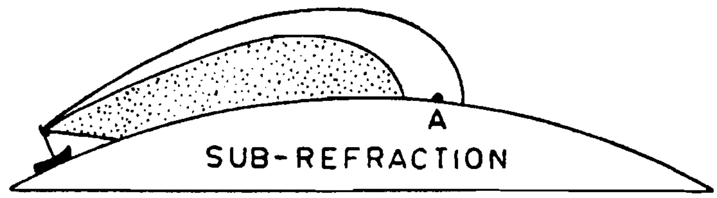
2.3. Day-time winds blowing over land-locked seas such as Red Sea, Mediterranean Sea, Persian Gulf, etc.

3. Ducting

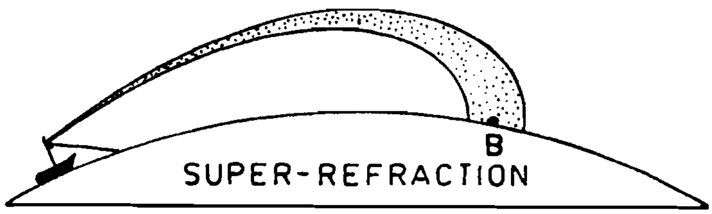
If the rays leaving the scanner are refracted downwards very sharply, strike the sea surface, are reflected upwards, are refracted downwards again, strike the sea at some further point, and so on continuously, they effectively follow the curvature of the earth and carry the energy to great distances, without much loss (see figure at the end of this chapter). The echoes returning along the same path will be strong though coming from very great distances. As the energy is virtually trapped within a narrow belt or 'duct', this form of severe super-refraction is called 'ducting'.

Ducting will be caused where there is a sharp decrease of relative humidity with height accompanied by a temperature inversion. (Temperature inversion is a condition where the temperature of air rises with height instead of falling).

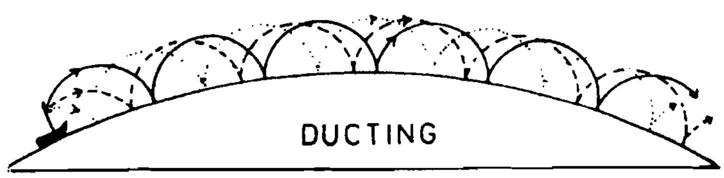
Note: In the following figures illustrating sub-refraction and super-refraction, vertical coverage diagrams of the **radar lobe** are shown. A lobe represents the boundaries inside which the transmitted radar energy is of significant power (usually 50% or more of the peak power). Targets within the lobe are expected to show up on the PPI, provided they are sufficiently radar conspicuous. Targets outside the lobe are not expected show up on the PPI, even if they are ideal radar targets. A lobe may be illustrated by means of a vertical diagram, as shown in these figures, or by means of a polar diagram as shown under 'Side lobe effect' in chapter 23.



Shaded portion shows reduced size of lobe due to sub-refraction. Target A, which was detected under normal circumstances, is now not detected.



Shaded portion shows increase in size of lobe due to super-refraction. Target B, which was not detected under normal circumstances, is now detected.



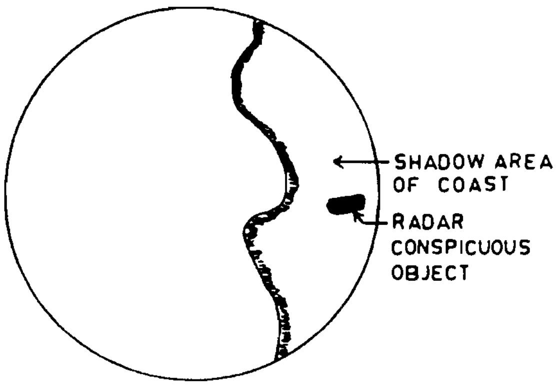
The transmitted energy is virtually trapped within a narrow duct.

CHAPTER 21

SHADOW AREAS, SHADOW SECTORS & BLIND SECTORS

1. Shadow areas

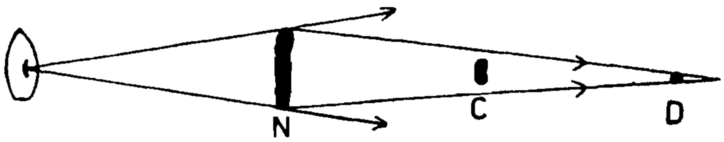
When the transmitted radar pulses strike a large target, they are reflected - some of the energy comes back to the scanner; most of it gets reflected elsewhere. A very limited amount of energy may go directly beyond the large target, because of diffraction. Targets lying in such areas, directly beyond large targets, are said to lie in 'shadow areas'. Only very radar-conspicuous targets, in shadow areas, show up on the PPI, that too with very reduced echo strength.



One very good example of a shadow area is the radar picture of a coast - the hinterland appears to extend only 2 to 3 miles beyond the coast. The rest of the hinterland, further beyond, lies in the shadow area of the coast wherein only very radar conspicuous targets show up.

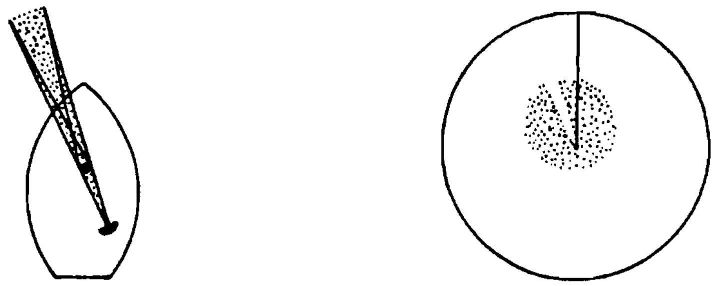
The foregoing figure is a side elevation showing the vertical extent of a shadow area. Target A is higher and closer than target B. Target B is painted on the PPI whereas A is not, because A lies in the shadow area of M. Had A been even higher, its top would have shown up on the PPI, as it would then have extended above the shadow area of M.

The following figure is a plan showing the horizontal extent of a shadow area. N is a high island. Target D is smaller and further away then target C. Target D is painted while target C is not because C lies in the shadow area of N. If target C had been much longer in the north-south direction, its ends would have painted as two separate echoes, because its central part would have been in the shadow area of N.



2. Shadow sectors

Shipboard structures such as masts, Samson posts, etc., partly obstruct the radar beam. Because of diffraction, targets

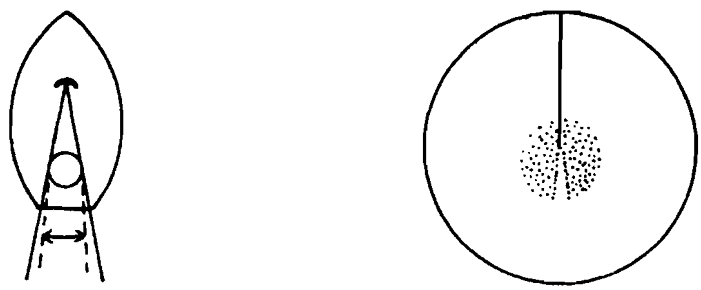


directly beyond them do appear on the PPI, but their detection ranges are considerably reduced. Such spaces are hence known as 'shadow sectors' and they are recorded, in the radar log, by the relative bearings of their extremities, as seen on the PPI. Measurement of the limits of shadow sectors is described later in this chapter.

3. Blind sectors

Sometimes, shipboard structures such as the funnel completely obstruct the radar beam such that targets beyond them are not detected at all. Such targets are said to be in the 'blind sector' of the scanner because no echoes are received from them. Bad siting of the scanner causes this.

Because of diffraction, a shadow sector exists on either side of a blind sector, enclosed by the geometrical tangent, as shown in the following figure.



In modern ships, the scanner is mounted on top of a special mast so that the scanner is well above, and/or far off from, all major obstructions and hence have no blind sectors.

Measurement of limits of shadow and blind sectors

Shadow and blind sectors can be measured in two ways:

1. When there is a fair amount of wind, if the gain is reduced such that clutter echoes are only just visible, shadow sectors (and blind sectors) will be conspicuous by the total absence of clutter in them. If the gain is

increased, clutter will appear in shadow sectors also, but not in blind sectors. In this case, anti-clutter control may be gradually applied instead of decreasing gain.

2. By observing a small target such as a buoy, using very little gain, while swinging the ship around. The paint will disappear when it enters a shadow sector (also a blind sector) and reappear when it leaves such a sector. If the gain is kept normal, the target would show up in shadow sectors also but not in blind sectors.

The extremities of shadow and blind sectors cannot be geometrically calculated because of two reasons:

1. The radar beam does not emanate from a spot, but from a scanner whose dimensions may be about 1.5 metres or more.
2. The amount of diffraction cannot be calculated with sufficient accuracy, as it depends on various factors.

The radar logbook should contain the relative bearings of the extremities of all shadow and blind sectors.

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CHAPTER 22

THE RADAR PICTURE

AND THE CHART

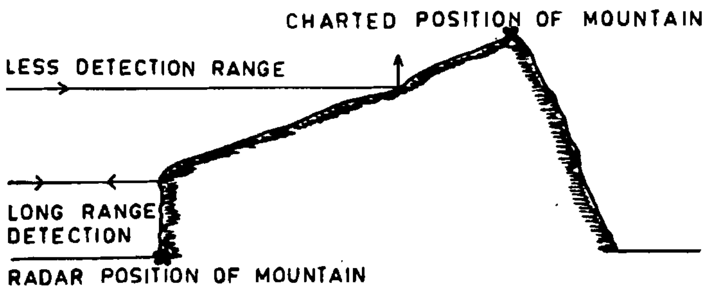
A radar picture of a coast may be somewhat different from a charted outline of the same area for several reasons as outlined below:

1. Radar reflectivity of coast

Height of coastal features, their composition, nature of surface and aspect are very important for a radar picture, as described in chapter 18. For the reasons described therein, the coast, as seen on the PPI, may appear to have gaps in it because the detection range of some parts may be less than the actual present range from the ship. A charted outline of the same area is continuous and complete, being unaffected by the characteristics of coastal features.

2. Positions of mountains

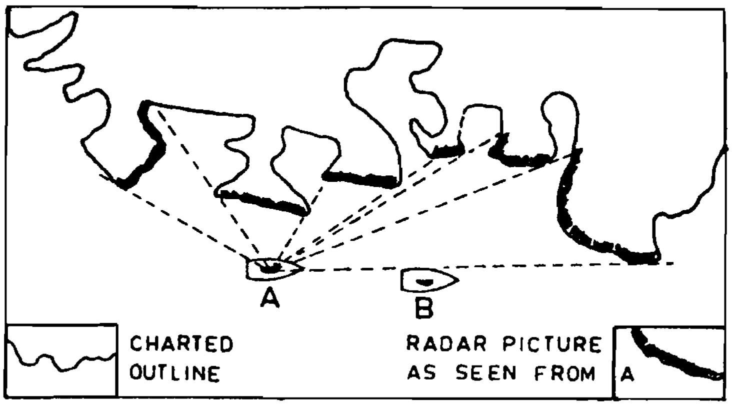
The chart gives importance to the highest point of a mountain and depicts its position with a 'spot height'.



The position of the mountain, as seen on the PPI, may not be correct - a cliff well below the top of the mountain may return good echoes at longer ranges than the mountaintop, which is smooth and sloping. Also, the shape and position of a mountain, as seen on the PPI, may change owing to change of aspect. This does not happen on a chart.

3. Shadow areas

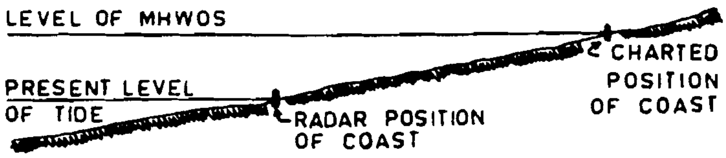
The radar picture gives a bird's eye view, compiled by information obtained by horizontal travel of radar waves. The radar picture is, therefore, subject to shadow areas - spaces behind large targets where smaller targets do not show up, as described in chapter 21. These shadow areas change with aspect. In the following figure, the coastline is assumed to be high and of constant height throughout. Wherever the radar pulses strike directly, the coast will show up but the areas behind may not show up, they being in shadow areas. The charted outline remains the same, despite change of aspect, being free of shadow areas. The following figure illustrates one of the reasons why a radar picture and a charted outline may not be exactly the same.



The radar picture as seen from A is shown above. It is left as an exercise to the reader to fill in the radar picture obtainable from B, using a colour pencil, and seeing for himself how change of aspect causes a change in the radar picture.

4. Height of tide

The charted outline of a coast is drawn for the level of water at MHWOS (mean high water ordinary springs). Radar shows the coastline as it is, at the present state of tide, which, most probably, will not be MHWOS. A gently sloping, sandy coastline may not change much in shape but may change considerably in position, due to a small change in height of tide.



The radar picture of a rocky coast may change considerably in position and shape, due to tide, because some rocks may cover at high water and uncover at low water.

5. Shapes and sizes of targets

The chart shows the correct shapes and sizes of all targets whereas the radar screen does not. Targets shown on the PPI are subject to distortion in azimuth due to HBW and the scale size of the spot. The radar pulses are reflected back to the scanner by the nearer edge of each target. The pulses cannot explore the farther side of a target. The reflecting edge of each target appears, on the PPI, to have a radial depth of [½ PL + the scale size of the spot], regardless of whether it is a buoy or a building. A stepped target, however, has many reflecting surfaces at different ranges and hence its paint would have greater radial depth than the paint of a target with a single vertical edge.

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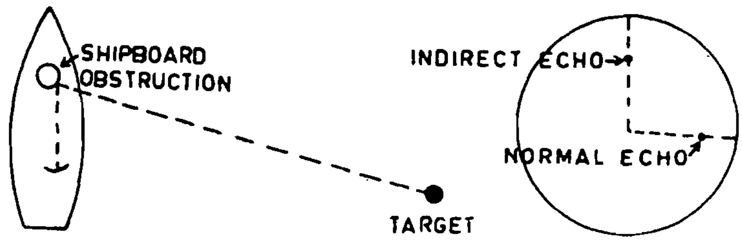
CHAPTER 23

SPURIOUS ECHOES

1. Indirect echoes

Sometimes, shipboard obstructions such as masts, funnels, cross trees, etc., may reflect the radar energy on to a target in some other direction. The echo returns along the same path and paints in the direction of the obstruction, at practically the correct range of the target. Such echoes are called indirect or false echoes. The normal (direct) echo of the target will also paint on its correct range and bearing. Where a shipboard obstruction is the cause of frequent appearance of indirect echoes, the situation can be remedied by fitting corrugated sheets of asbestos or metal on the obstruction so that the energy which hits the corrugated sheets scatters in various directions instead of reflecting off as a beam. Indirect echoes are not common on modern ships where the radar scanner has been properly sited.



The characteristics of indirect echoes are given below:

1.1. Indirect echoes, caused by shipboard obstructions, only appear inside shadow sectors or blind sectors. This is because, if the shipboard obstruction is large enough to reflect the radar waves in some other direction as a beam, it must be large enough to cause a shadow sector or a blind sector.

1.2. When caused by shipboard obstructions, they always show up on the same relative bearing (inside a shadow sector or blind sector).

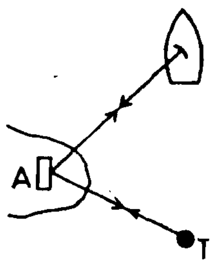
1.3. A slight alteration of course will most probably cause an indirect echo to disappear, but a fresh one, from another target, may now possibly appear on the same relative bearing.

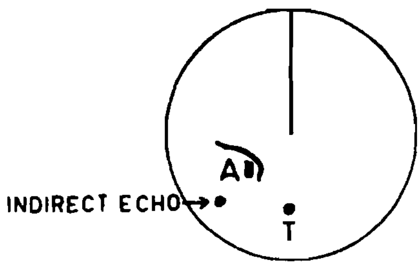
1.4. They are generally caused by large targets such as land, rarely by relatively small targets such as ships. This is because, if the observing ship yaws even by a slight amount, the indirect energy leaving the observing ship will change direction by twice the amount yawed and will most probably miss the target ship, whereas it will not miss a large land target.

1.5. If the VRM is passed through an indirect echo on the PPI, it would also pass nearly through the normal echo which would be much brighter, but on its correct bearing.

1.6. Plotting may give improbable, sometimes absurd, results.

Indirect echoes can, in some cases, be caused by good radar reflecting targets such as buildings, etc., at very close range.

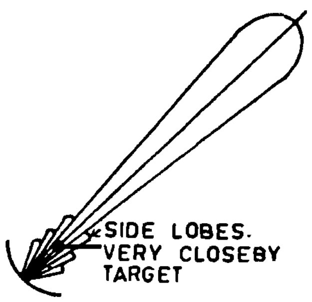


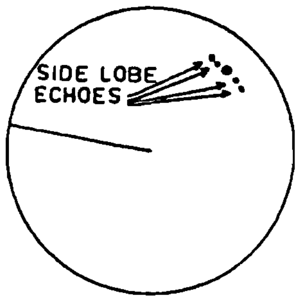


Here the range of the indirect echo will be the sum of the distance between the scanner and the reflecting surface and the distance between the reflecting surface and the target. A slight reduction of gain or a slight application of anti-clutter may cause the indirect echo to disappear.

2. Side lobe echoes

In commercial marine radar sets, because of cost and size limitations, the scanner cannot be perfected to the extent of sending all the available energy in a single narrow beam.

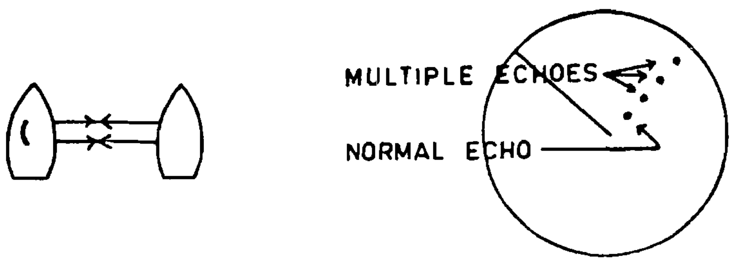




As a result, some of the energy is radiated as weak beams at various angles on either side of the main beam. These weak beams are known as side lobes and the energy content of these is extremely small. Only very close-by objects give strong enough response to side lobes. As each side lobe sweeps over the target, an echo is painted in the direction in which the trace (and also the main lobe) is pointing at that time. When the main lobe sweeps over the target, a very much stronger echo is produced. The overall effect of the side lobes is to produce a series of smaller echoes on either side of the main echo, all at the same range. The effect can be eliminated by a suitable reduction of gain or a slight application of anti-clutter. Side lobe echoes are considerably reduced when using a slotted waveguide type of scanner.

3. Multiple echoes

When two ships are passing beam to beam on parallel courses at close range, say less than a mile, a second echo may sometimes appear on the bearing of the other ship and at double the range. Occasional there may be a series of such echoes, all on the same bearing, but at equal intervals of range. The closest echo represents the correct position of the target. The other such echoes are known as multiple echoes and they are caused by the transmitted energy being reflected back and forth between the hulls of the two ships and painting on each successive return to the scanner. Multiple echoes only occur on the beam bearing, i.e., when the hulls of the two vessels are parallel to each other.



4. Second trace echoes

Echoes sent back from targets just outside the range scale in use are not registered on the PPI because, by the time they arrive, the spot has returned to the centre of the screen and is awaiting transmission of the next pulse. If, however, the target is sufficiently far away and super-refraction is present, a strong echo may arrive after the next trace has started. It will then be painted on the PPI on its correct bearing but at a wrong range. Such an echo is called a second trace echo because the echo of the first pulse paints on the second trace. It is necessary that, for a second trace echo be registered on the PPI, the echo of the first pulse should arrive during the second trace i.e., after the centre spot has left the centre, on its second run, but before it has reached the edge of the screen. For the formation of second trace echoes, the following points are important:

4.1. PRF of the range scale in use.
4.2. The presence of a radar conspicuous target at the appropriate range, depending on the PRF in use.
4.3. The presence of super-refraction.

The correct range of a second trace echo can be calculated, knowing the PRF in use. If the PRF is 2000, one pulse leaves the scanner every 1/2000 second or every 500 μ. If the first pulse must arrive as an echo, just when the next pulse is leaving, it must have travelled for a total time of 500 μ (250 μ to and 250 μ fro). At the rate of 6.173 μ per nautical mile, the pulse would have covered a range of 40.49 miles (squared off to 40 miles for the sake of convenience), in that time interval. The echo of a target 40 miles off would come back just when the next pulse is leaving the scanner. If the target is 41 miles off, it would paint at 1 mile on the second trace; if 42 miles off, then at 2 miles range; if 43 miles off, then at 3 miles range, and so on. 40 miles is, therefore, referred to as the critical range of PRF 2000. The possibilities of second trace echoes, on a typical radar set, when using a PRF of 2000, are given below:

Range Scale (miles)	Second trace echoes possible between the ranges of*
0.75	40 and 40.75
1.5	40 and 41.5
3	40 and 43.0

Similarly, the critical range of PRF 1000 is 81 miles. The possibilities of second trace echoes, on a typical radar set, when using a PRF of 1000, are given below:

Range Scale (miles)	Second trace echoes possible between the ranges of*
6	81 and 87
12	81 and 93
24	81 and 105
48	81 and 129

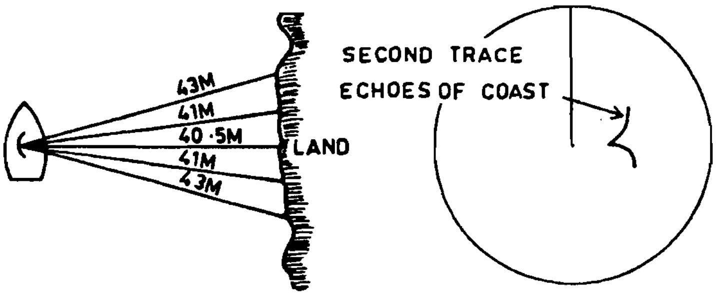
**Limiting ranges for second trace echoes are the critical range and critical range + range scale in use.*

However, under normal meteorological conditions, using a 3 cm marine radar set, targets at a range of 50 miles do not return echoes strong enough to paint on the PPI but should severe super-refraction or ducting be present, the possibility increases.

In the typical radar set discussed earlier, a target 42 miles off could paint as a second trace echo0 at 2 miles range on the PPI, while using the 3 mile range scale. If switched on to the 6, 12 or 24 miles range scales, the target 42 miles off does not show up as a second trace echo, on the PPI. So if an echo is suspected to be second trace, change over to a longer-range scale *having a different PRF*. If it disappears, it was second trace, but if it still paints, its range is correct.

The possibility of receiving second trace echoes increases as PRF increases but, by careful matching of PRF and range scale, the manufacturers reduce the possibility as much as practicable.

It is because of second trace echoes that a peculiar effect sometimes appears on the PPI, as shown in the figure below:



Assuming that the radar set is switched on to the 3 mile range scale and has a PRF of 2000, the second trace echoes from the coast may show up on the PPI as shown above.

In the typical radar set discussed earlier, the 6-mile range scale has a different PRF from the 3-mile range scale. So if the range scale was now changed over to 6 miles, the second trace echoes of the coast, as shown in the above figure, would disappear.

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CHAPTER 24

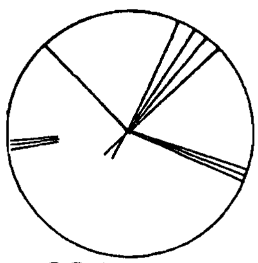
RADAR

INTERFERENCE

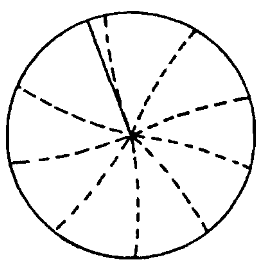
1. Spoking

This is the name given to unwanted radial lines that sometimes appear on the screen. These 'spokes' may occur all round the screen or may be confined to certain arcs only. They may appear on every rotation of the trace or they may appear intermittently. They may be complete or incomplete radial lines.

The presence of faults such as dirty contacts, either of the heading marker circuit at the scanner or of the slip rings of the rotating deflection coils, are common causes of spoking. Spoking can also be caused by heavy sparking of motors, etc., of other instruments nearby, such as those of clear-view screens, echo sounders, etc.



SPOKING



STARRING

2. Starring

Echoes sometimes appear on the screen in the form of curves or spirals of dotted lines, as shown in the above figure, which change position with every rotation of the scanner. This effect is called starring and is caused by another ship's radar, whose transmitting frequency is within the bandwidth of the own ship's radar, operating in the vicinity. If the other ship now puts her set on stand-by, starring will disappear from own ship's radar screen. It is therefore a good idea, when using radar *for navigation purposes only*, to put the set on stand-by in between fixes, when radar is not actually required, so that it will not only prolong the life of the radar set but also not cause starring on the screens of other ships. However, in poor visibility, this is not practicable or reasonable.

It may sometimes happen that starring is experienced by own ship, when only one other ship's presence is detected on the PPI. It should not be assumed that this other ship is operating her radar. It may happen that this other ship is not operating her radar (either switched off or defective) but that the starring is caused by the radar of a third ship which is too far away to show up on the own ship's screen but close enough to cause starring.

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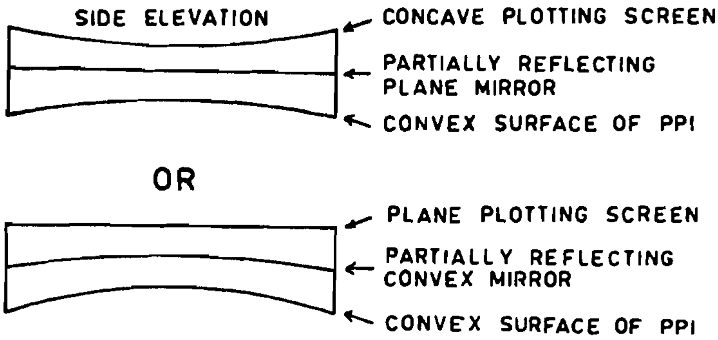
CHAPTER 25

ACCESSORIES

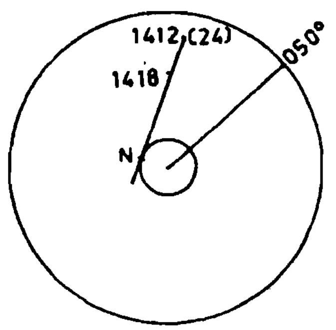
AND AIDS TO RADAR

1. Reflection plotter

This is portable, plotting device which is clamped on top of the radar screen. A metal frame holds a transparent, perspex, plotting screen a few centimetres above the PPI. Plotting is done on this plotting screen using wax pencils. In tropical climates, wax pencils tend to become too soft and hence omnichrome pencils (available in yellow only) are preferable. The marks thus made can be erased by using a flannelite duster or a soft cloth.



As soon as a target is detected, the following markings are made on the plotting screen: a mark to denote its position on the plotting screen, the time of observation and the range scale in use at that time, thus: X 1412 (24). After a suitable interval of time, the position of the target and the time are again marked thus: X 1418. The line joining these two positions is drawn in, using a flexible, plastic ruler.



Whilst using a relative motion (RM) display, this line represents the direction and rate of approach. This line is produced past the centre of the PPI, the variable range marker (VRM) adjusted until this line is a tangent to the VRM circle, and the distance off at the closest point of approach (CPA) is read off the digital display of the VRM.

Whilst using a true motion (TM) display, the line joining the two positions represents the true course and speed of the target.

All necessary plotting can be done, with reasonable accuracy, on the plotting screen itself.

The surface of the PPI is necessarily convex because all parts of it must be the same distance from the electron gun. Since the plotting screen is fitted a few centimetres above the PPI surface, distortion and error of parallax are both likely to result, unless allowed for.

Both these are prevented by fitting a partially reflecting mirror between the PPI surface and the plotting screen. This mirror is made of high-density glass, and is not silvered, so that part of the light falling on it is reflected while the remainder passes through. In some makes, the plotting screen is made concave, with the same radius of curvature as the PPI surface, while the partially reflecting mirror is plane (flat). In other makes, the plotting screen is plane (flat) while the partially reflecting mirror is convex, having a radius of curvature equal to twice that of the PPI surface.

Independent lighting is provided between the PPI and the plotting screen. A potentiometer control allows the intensity of this light to be varied as desired by the observer. When this light is switched on, the marks made on the plotting screen appear on the PPI surface, as if drawn on the PPI surface itself. It may be necessary, in some sets, to use only white colour wax or omnichrome pencils to achieve this effect. Error of parallax and optical distortion are both prevented by this method. When this light is switched off, the marks on the plotting screen will cease to be visible, thereby allowing a clear view of the PPI, unobstructed by plotting marks made by the observer.

The advantages of using the reflection plotter are:

1.1. Saves time - no reading off bearings, ranges etc., and no plotting separately on paper.
1.2. Less chances of error - less reading off and no transferring information to paper.
1.3. Can, at anytime, ascertain if other vessel is maintaining course and speed - its echo should move steadily along the line joining its first and second observed positions on the plotting screen.
1.4. Several targets can be plotted simultaneously.
1.5. Ease of plotting allows observer to keep bridge watch also (when not in congested waters).
1.6. Record of movements of selected targets is maintained.
1.7. Very inexpensive accessory to radar, requiring no maintenance.
1.8. Easy erasure of marks after use.

2. Radar reflectors

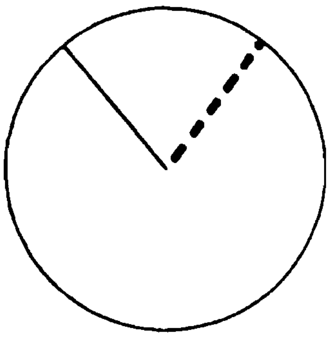
A simple radar reflector consists of three triangular plates mutually at right angles to one another. Any ray of energy that hits the inside face of any one of the three plates must, after reflecting off, return in the opposite direction.

A group of such corner reflectors, placed around in a circle, would considerably increase the detection ranges of poor radar targets, from all directions. Sometimes, tiers of such circles are place one above the other. The detection range of a conical buoy may be increased from 2 miles to 5 miles by fitting a radar reflector. Though most of the transmitted energy misses the buoy, what little does hit the reflector returns a good echo that not only appears much stronger than surrounding clutter, but also increases the detection range considerably.

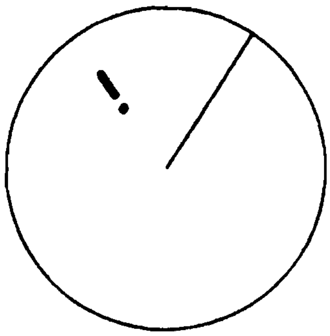
There are more complicated designs of radar reflectors but their details are outside the scope of this book.

3. Ramark

A Ramark is a radar beacon that may be regarded as a 'Radar lighthouse' because it works continuously, whether any ship is nearby or not. Its name is derived from Radar marker. It transmits signals in all directions, covering the entire marine radar band (9300 to 9500 MHz if the Ramark is of the X band and 2900 to 3100 MHz if of the S band). When the own ship's radar scanner points to the Ramark beacon, signals of the Ramark are received and painted as a series of dots. Since these signals show up continuously during the entire formation of a trace, they extend, from the centre, all the way up to the edge of the screen, regardless of whether the Ramark beacon lies inside or outside the range scale in use at that time. Since it is not possible to determine which of these dots is the normal echo of the structure of the Ramark beacon, Ramark gives only the bearing of the beacon, but not its range. Because of this, and also the fact that Ramark signals clutter up the PPI along the bearing of the beacon, Ramarks are practically obsolete, being replaced by Racons.



RAMARK



RACON

4. Racon

A Racon is a radar responder beacon. Its name is derived from Radar beacon. When the ship's pulse arrives at the Racon, the Racon amplifies and returns the pulse to the scanner as a fairly strong signal of the same frequency. This signal creates a short, bright line on the PPI. Because of a slight, pre-set, time delay, the signal of the Racon arrives after the normal echo of the structure of the beacon. The result is an exclamation mark whose dot is the correct position of the Racon. Bearing and range of the Racon are, therefore, available. At longer ranges, the normal echo of the structure of the beacon may not paint on the screen. The closer edge of the line may then be taken to be the position of the beacon and the resulting error in range will be very small.

Once a Racon responds to a particular frequency, it will not respond to that frequency again for a few minutes. This not only conserves energy, but also does not distract the radar observer by showing up brightly on every rotation of the scanner.

In order that a Racon will not unnecessarily respond to ships that are too far away to use the Racon signals, the Racon is adjusted such that it will not respond unless the ship's pulse that arrives is above a predetermined signal-strength. Because of this, the effective range of a Racon is only about 30 miles or so.

Where several buoys, etc., in the same locality have Racons fitted on them, the Racon signal of each object is so designed as to appear as a different Morse letter, for identification purposes.

A Racon is useful in identifying light-vessels or buoys in poor visibility especially in areas of high traffic density and in crowded anchorages.

The Ramarks and Racons referred to so far are said to be of the 'in band' type because they operate within the frequency range of marine radar. Another type, called the 'cross band' Racon, gets interrogated by normal radar frequency pulses but responds on a fixed frequency on the fringes of the marine radar band. Such response does not show up on the PPI normally. If and when the observer desires to receive such a Racon signal, he has to re-tune the LO of the radar set, as a result of which only the Racon signal shows up on the PPI. When tuning is returned to normal, targets shows up on the PPI as usual but, because of the persistence of the screen, the Racon signal is visible for identification. The 'cross band' type of Racon does not distract the observer's attention during normal use and does not cause interference at close ranges like the 'in band' Racon.

Comparison between Ramark and Racon:

1. Both are excellent for making landfall when identification of land features is difficult.
2. Both yield better results at longer ranges because interference from other targets is less.
3. Ramark gives bearing only while Racon gives bearing and range.
4. Ramark signals clutter up the PPI in the direction of the beacon, thus obscuring echoes of nearby objects in that direction. This is a serious disadvantage. Racon leaves the PPI clear from the centre to the echo of the beacon.
5. Ramark is simple, sturdy and less expensive. Racon is complex and hence more expensive. Maintenance of Racon requires more highly skilled personnel.
6. Ramark signals are detected even when the actual beacon may be outside the range scale in use at that time. Racon signals only show up if the beacon is within the range scale in use.
7. Ramark signals have been reported to have been picked up even when its range was over 50 miles. Racon signals, being triggered by the ship's pulse, have a detection range around 30 miles or so.
8. For fitting on light-vessels, buoys, etc., Racon is suitable because it gives bearing and range whereas Ramark is unsuitable as it gives only bearing.
9. Fitting of a Ramark on a convenient, conspicuous spot inland is ideal and effective, as its operation is continuous and does not depend on a ship's pulse. A

Racon would be unsuitable on such locations because, for a ship's pulse to trigger it, the ship would have to come reasonably close to the Racon beacon, by which time it may be too late for the safety of the ship.

10. On a chart, Ramarks and Racons are each indicated by a magenta circle with the appropriate name 'Ramark' or 'Racon' next to it.

5. Search and Rescue Transponder (SART)

SART enables search and rescue (SAR) units to locate ships or their survival craft when in distress. It is a portable device to be taken to the lifeboat or liferaft when abandoning ship. As its name implies, it ***trans***mits as a res***ponder*** - responds to radar signals, like a Racon, but is otherwise quiescent (passive).

When interrogated by radar waves of the X band (also known as the 3cm band or 9 GHz band), a SART gets triggered into transmitting a series of twelve 400 milliWatt (mW) pulses. These signals appear as a distinctive line of 12 blips on the PPI of the X band radar. The signals extend outwards from the position of the SART, along the line of bearing, for distance of 8 nautical miles on the PPI. The gap between successive blips is 0.6 nautical mile.

As the SAR unit nears the SART, the blips change to wide arcs. These arcs eventually turn to concentric circles when the SAR unit is within about one nautical mile from the SART.

The blips can be made more prominent, when several other targets, sea or rain clutter are present, by de-tuning the radar. De-turning will reduce the brightness of the echoes of other targets, sea or rain clutter, or even eliminate them, but it will not affect the brightness of the blips on the PPI because the SART emits a broad band signal.

A SART responds to X band radar signals:

a) From ships, with a scanner height of 15 metres or more, at a range of at least 5 nautical miles;
b) From SAR aircraft, flying at a height of 900 metres (about 3000 feet), at a range of about 30 nautical miles.

The SART has a thermoplastic body of highly visible orange or yellow colour. It should be protected against inadvertent activation and should be capable of the following:

- manual activation and de-activation;
- frequency range from 9.2 GHz to 9.5 GHz;
- horizontal polarisation;
- a response of 12 sweeps upon interrogation;
- output power of not less than 400 mW;
- withstanding without damage a drop into the water from a height of 20 metres;
- being water-tight when submerged at a depth of 10 metres for 5 minutes;
- not being unduly affected by sea water or oil;
- operating in ambient temperatures of –20° C to +55°C;
- working for at least 96 hours in standby condition;
- working for at least 8 hours when being continuously interrogated with a PRF of 1000.

Note: The last two points refer to battery capacity. The battery is usually of 6 lithium manganese dioxide cells connected in series totalling to 18V. Lithium cells have a long shelf life, can operate over a wide range of temperature and are highly reliable. These batteries need replacement at intervals stipulated by the manufacturer. This may be between 3 and 5 years.

Testing procedure and practical demonstration of the SART is included in GMDSS courses.

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Notes

Part III
PRACTICALS

CHAPTER 26

THE RELATIVE MOTION DISPLAY

A relative motion (RM) display is one in which a stationary spot (called the origin or electronic centre) represents the position of the own vessel, while all targets move relatively across the radar screen. The relative movement (apparent course and speed) of each target, on the radar screen, is the resultant of its actual course and speed and the reversed course and speed of the own vessel such that even stationary targets move, on the radar screen, with a course and speed opposite to that of the own vessel.

The origin is normally centred over the radar screen but may be shifted off-centre, if desired by the observer, and this is discussed at the end of this chapter. There are two types of RM displays - Head Up (or unstabilised) display and North Up (or gyro-stabilised) display - and each is described below:

The Head Up Display

Here the 12 o'clock position of the PPI always represents own ship's course and hence the heading marker remains at the zero of the fixed, graduated ring around the PPI. All bearings are relative. The right side of the radar screen is the starboard side of the ship and the left, the port side. At the instant of measuring the bearing of a target, the ship's heading must be noted exactly. The sum of relative bearing and the true course at that instant gives the true bearing of the target, if all are expressed in the three-figure notation. If the sum exceeds 360, then 360 must be subtracted from it. A lot of time gets wasted by doing this for each target, and the chances of error are fairly high.

As the course is changed, the heading marker remains fixed while all the targets swing around to their new relative bearings. During this process, the picture gets smudged. No bearings can be obtained accurately during the alteration and for some time thereafter, until the smudged picture fades off and the new picture gets painted clearly. When the own ship is yawing in bad weather, plotting becomes practically impossible as the targets keep painting on different relative bearings with every rotation of the scanner.

The North Up Display

Here, the zero of the fixed scale of the PPI represents true North and the heading marker represents the true course of the own ship. All bearings of targets are true. As the own ship alters course, the heading marker swings around to the new course on the PPI, but all targets remain on their true bearings. Hence smudging of targets does not take place during alterations of course or yaw, however fast the change of heading may take place.

How gyro-stabilisation is achieved

Consider an unstabilised display with a target showing up 5° on the starboard bow. If the vessel now alters 10° to starboard (clockwise), the target on the radar screen moves over to its new relative bearing of 5° on the port bow (anti-clockwise). So a clockwise alteration of course causes an anti-clockwise rotation of the picture on the radar screen, by an equal angle. Hence gyro-stabilization is achieved by rotating the picture in the direction of alteration (clockwise for a clockwise alteration of course, and vice versa) by an equal angle. The gyrocompass sends a few thousand updating signals per minute to the radar so that all targets remain on their true bearings, without any smudging in azimuth, however fast the change of heading may take place.

Comparison between unstabilised and gyro-stabilised displays

	Head Up Display	North Up Display
1.	Picture smudges in azimuth during alterations of course.	Picture does not smudge during alterations of course.
2.	Because of smudging, accurate bearings cannot be taken during large course alterations.	Bearings can be taken accurately, even during large alterations of course.
3.	Plotting becomes highly inaccurate during yaw in bad weather, as ship's head keeps changing several degrees per second, resulting in severe smudging.	Plotting accuracy unaffected by yaw.
4.	All bearings are relative.	All bearings are true.
5.	Time wasted in conversion of relative bearings into true bearings.	No such time lost as true bearings are directly obtained.
6.	Chances of clerical error in conversion from relative to true bearings.	No such chances of clerical error as true bearings are directly obtained.
7.	Radar picture is head-up whereas the chart is North up.	Both being North up, easier comparison with the chart.
8.	After large alterations of course, observer tends to get disoriented with plotting as all targets have shifted to their new relative bearings on the radar screen.	No such disorientation as all targets remain on their true bearings on the radar screen, despite large alterations of course.
9.	No indication, on PPI, of gyro course steered. Temporary alterations or wandering off course can remain forgotten/undetected unless the compass repeater or course recorder is inspected.	Heading marker indicates, at all times, the gyro course steered. Every time the observer inspects the radar screen, the course steered gets checked by him.
10.	Automatic or semi-automatic plotting aids cannot be used.	Automatic or semi-automatic plotting aids can be used.

Although the unstabilised display is most certainly inferior to the gyro-stabilised display, the radar observer must be familiar with it also, in case of failure of the gyrocompass.

The Head-Up Display has two very minor advantages:

(i) The left side of the radar screen is the port side of the ship and its right side, the starboard side. However, if a navigator steering a course of 180° on a chart experiences no difficulty in remembering which parts of the chart are the ship's port and starboard sides, why should any difficulty exist for a North-up radar screen? No navigator ever consults a chart ship's-head-up! A few hours of clear weather practice will ensure a lifetime of efficiency and ease!

(ii) Blind sectors and shadow sectors remain constant on the unstabilised radar screen. Here again, this is a very minor point. On modern ships, radar scanners are well sited and hence blind sectors are practically non-existent. Shadow sectors do not cause any appreciable difficulty in radar observation and hence their change of position with a gyro-stabilised display is not important.

The Course Up Display

This is a gyro-stabilised head up display. It is available on some modern sets especially on those where the manufacturer has made identical radar sets with and without ARPA (Automatic Radar Plotting Aid) because most ARPAs have this facility. Its use is easier illustrated by an example. Imagine that a ship is steering 120°(T) with the radar set on a North Up RM Display. The heading marker would be at the 4 o'clock position of the PPI. If the Course Up mode is switched on, the entire picture, HM and azimuth ring (see following note) would immediately rotate anti-clockwise by 120° so that the HM would now be at the 12 o'clock position of the PPI. All bearings would be true. If the ship now alters to 150°(T), the HM would move to the 1 o'clock position of the PPI while the picture remains steady. The picture is now not exactly course up but nearly so. If subsequent course alterations cause the heading marker to move too far away from the 12 o'clock position of the PPI, pressing of a Course Up Reset button would again rotate the entire picture, HM and azimuth ring until the heading marker appears at the 12 o'clock position.

Note: Physical rotation of the azimuth ring is undesirable, as it would involve moving parts, motor, and contacts, etc., making it cumbersome. Hence, in some cases, the azimuth ring is fixed but the degree values such as 000°, 090°, etc., are digitally displayed by L.E.Ds. The displayed values are made to change as necessary giving the same effect as rotation of the azimuth ring. In some other cases, the azimuth ring and its degree markings are electronically created inside the CRT itself and hence its rotation does not involve any moving parts.

In the Course Up Display, all bearings are true. The right side of the PPI is the starboard side of the ship and the left, the port side. No smudging of the picture takes place during course alterations or during yaw. Blind sectors and shadow sectors would remain nearly on the same parts of the PPI. The only drawback is that the picture is Course Up while the chart is North Up. Hence comparison with the chart is not as easy as it is with the North Up Display.

Off-centre RM displays

Displays are sometimes intentionally off-centred by the observer. This may be done for one or more of the following reasons:

(i) By shifting the origin to one side of the radar screen, the displayed area increases on the other side, without change of scale. For example, by shifting the origin 6 miles astern, while using a 12-mile range scale, the range displayed becomes 18 miles ahead and 6 miles astern. The origin may be shifted in any direction, as desired by the observer.

(ii) Sometimes, in older sets using conventional CRTs, the centre of the radar screen 'burns out' i.e., the chemical coating on the underside of the screen loses the quality of glowing when struck by the electron stream. The centre of the radar screen, therefore, appears as a black patch. This can happen after several years of normal use but may happen earlier if the brilliance was set unnecessarily high.

Targets will not show up inside this burnt-out central area and, until such time that the CRT can be changed, the temporary remedy is to shift the origin away from the centre of the screen so that targets close to the own ship may show up.

(iii) Off-centre display is a necessity when using a TM display, as explained in the next chapter.

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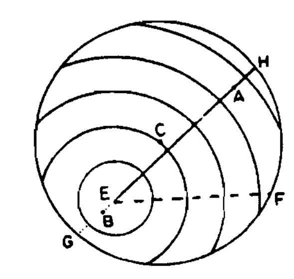
CHAPTER 27

THE TRUE MOTION DISPLAY

A true motion display is one in which the origin (or electronic centre) moves across the radar screen at the course and speed of the own ship. The course is fed in directly from the gyrocompass whereas the speed is normally fed in by log but may be fed in manually, when desired. The picture is necessarily gyro-stabilised - usually North Up. It could possibly be Course Up if such a facility has been provided on the set, as described in the previous chapter.

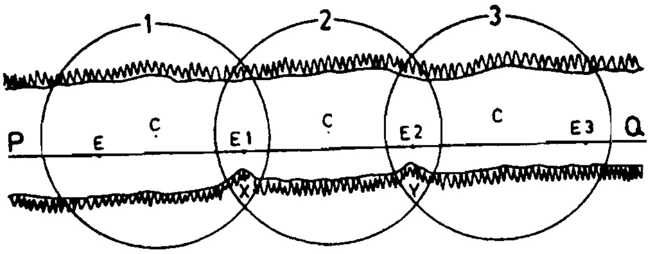
The movements of all targets on the radar screen are true - stationary targets remain stationary whereas moving targets move on the screen on their actual courses and speeds. The origin may be shifted at any time to any convenient part of the radar screen, as desired by the observer, within about 75% (may be between 66% and 80%, depending on the manufacturer) of the radius of the screen. In the course of its run, when the origin reaches its limiting point (A in the next figure) it jumps back, automatically and instantaneously, to a similar point on the other side (B in the next figure) and resumes its run. The HM, EBL, range rings and the VRM move along with the origin.

It will be noticed that maximum movement of the origin is possible only when it passes through the centre of the PPI and, at that time, its run is about one and a half times the radius of the PPI (assuming 25% restriction from edge of PPI). For example, using the 12-mile range scale, the origin can move a maximum distance of about 18 miles on a steady course before jumping back, if it passes through the centre of the PPI.



C:	Centre of PPI
E:	Electronic centre
EH:	Heading marker
EF:	Electronic Bearing Line
A:	Limiting point of run of E
B:	Jump back point of this run
CA:	= CB = 75% of PPI radius
Circles around E are range rings	

Illustration of the principle of true motion (TM):



In the foregoing figure, the charted outline of a river and the course line (PQ) of the own ship are shown, the own ship's position at present being E. The picture seen on the own ship's TM display corresponds to picture 1 of the figure. As the own ship moves along its course line, the origin E moves across the PPI but the land remains stationary on the radar screen. When the origin reaches the limit of its run on the radar screen (E1 in the figure), the origin jumps back to the other side, automatically and instantaneously, and the picture now seen on the own ship's TM display is picture 2 of the figure. Point X, which happened to be on the starboard beam just before the origin jumped back, is still on the starboard beam soon after the jump. Again the land remains stationary on the screen while the origin moves across the PPI. When the origin reaches the limit of its run again (position E2), it jumps back and picture 3 is now seen on the PPI, and so on. The observer may, at any time, move the origin (and hence the picture) to any part of the PPI, within the limits mentioned earlier.

Sea stabilisation: Here the movement of the origin (electronic centre) is the ship's ***movement through the water*** - gyro course and log speed. If the influence of current causes the course and speed made good (movement over ground) to be somewhat different from the gyro course and log speed, it may be seen, when coasting, that land and other fixed objects on the PPI appear to have a course and speed equal to the reversed set and rate of current. This poses no problems for collision avoidance or for navigation because the bearings and ranges of all objects are unaffected by this and are hence correct. Furthermore, the rate of current is usually in the region of 1 or 2 knots and the apparent movement of fixed targets during small plotting intervals such as 3 or 6 minutes, is barely noticeable. Out in open sea, it may be reasonably assumed that current equally affects the own ship and all other ships within the range scale in use. Such an assumption is made in relative motion also. To put it briefly, on a sea-stabilised display, all movement - own ship, fixed objects and moving objects - is their movement through the water.

Ground stabilisation: Here, input of set and rate of current is fed in whereby the movement of the origin on the PPI is the course and speed made good (***movement over ground***). Now, fixed objects remain stationary on the PPI and the movement of all moving objects is their movement over ground.

More about sea and ground stabilisation:

Imagine a ship using a sea-stabilised TM display. There is a land target, right ahead 18 miles off, showing up on the PPI. Speed input by log is 15 knots whereas the speed made good is 14 knots. After one hour, the origin has moved ahead by a distance corresponding to 15 miles on the PPI whereas the ship has moved only 14 miles. Since the target now paints on the screen at its correct range of 4 miles from origin, its paint appears to have moved away by 1 mile from its original position one hour ago. Since this apparent movement on the screen is gradual, the paint of the target smudges and appears to move away steadily at a speed of 1 knot. If the speed input is less than the speed made good, the paint of the stationary target ahead would smudge and move towards the origin.

Similarly, if the course made good is to starboard of the course steered, land on the starboard side will appear to smudge and move closer to the heading marker and land on the port side will appear to smudge and move away from it. The converse will happen if the course made good is to port of the course steered.

However, one point must be clearly stressed here. Even if the inputs of course and speed are incorrect, ***ranges and bearings of targets are unaffected – they are correct.***

Note: When ground-stabilised, the origin moves at the course and speed made good but the ***heading marker always indicates gyro course steered.***

Manual controls provided for ground-stabilisation may be:

(i) Two controls, one for input of true set of current in degrees and the other for actual rate of current in knots or

(ii) One control to correct the course steered into course made good, graduated in degrees up to 25, such that clockwise rotation of this knob applies a starboard correction and vice versa. Speed correction has to be applied, in this case, by changing over from log input to the desired manual speed input.

The set and rate of current may be obtained by radar plotting (reversed movement of a fixed object) and fed in by the controls described in (i) above. If controls described in (ii) above are provided, they may be adjusted until the paint of a fixed object leaves no appreciable trail on the radar screen.

In addition to the basic controls found on a radar set, the following additional controls may be expected on a TM display:

(1) A three-position presentation-mode switch marked 'RM head-up/RM north-up/TM'. The first position gives an unstabilised picture whereas the second and third positions give gyro-stabilised north-up displays, RM or TM as desired.

(2) A compass alignment control, which is used to align the gyro-repeater of the radar set with the master gyrocompass, to ensure correct input of gyro course.

(3) Origin-shift controls for TM presentation. The position of the origin on the PPI is controlled by this set of controls when in TM, but by the basic centre-shift set of controls when in RM. So when the presentation switch is changed over from RM to TM, or vice versa, the position of the origin on the PPI will change, depending on the settings of the appropriate controls.

(4) A speed input switch with three positions marked 'LOG/ZERO/MANUAL'. In the first position, the speed input is by log. In the third position, the speed input is manual. A knob nearby, graduated in knots from 0 to about 35, is used to enter the desired speed of the origin, by hand. In the second position, the movement of the origin is taken off and the picture then becomes an off-centred RM display. The advantage of this switch is the ability to change over from TM to RM, or vice versa, without changing the position of the origin (and hence, targets on the PPI) during the process. This ability is necessary when using a reflection plotter. Instead of the 'Zero' position of the speed input switch, some radar sets may have an additional position of the presentation mode switch marked 'RM off-centre' to achieve the same result.

(5) Set and drift controls as described earlier in this chapter under the heading of 'Ground-stabilisation'.

(6) Reset warning lamp that lights up a few minutes before the origin reaches the limit of its run on the PPI.

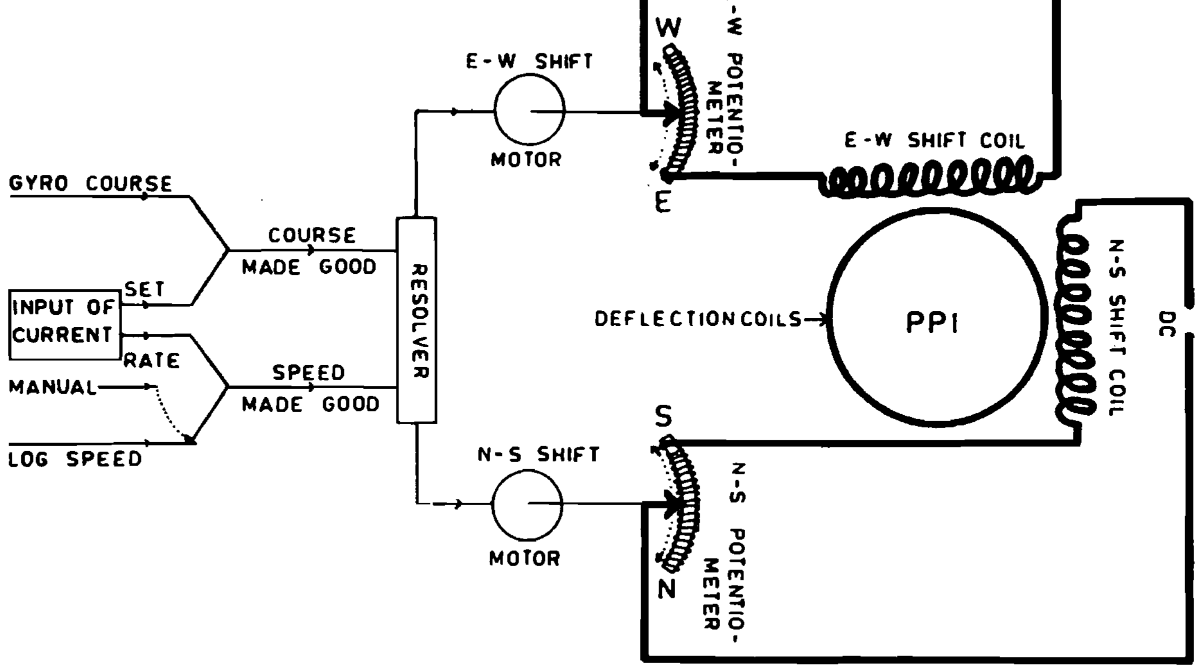
(7) Illuminated presentation-mode indicator, which keeps the observer informed of the type of presentation in use.

The foregoing list of controls is intended only to give the reader an idea of the controls that may be found on a TM radar set. Various makes of radar may have different types of controls to carry out the same functions.

Automatic ground-stabilisation:

This described in detail under para 7 under 'ARPA facilities' in chapter 42. Though its principle is very simple, it is a feature of ARPA and not of basic radar.

BLOCK DIAGRAM OF TM UNIT



Basic radar is RM and is a necessary requirement on all ships. TM is an additional facility that is available and is purely optional. It is a necessary requirement that every TM display must be able to be converted into a RM display, at the mere flick of a switch.

TM may not be available on the very small (say less than 1.5 miles) or very large (over 24 miles) range scales. The manufacturer's operating manual should be consulted for details regarding any particular set.

TM can be understood better by referring to the block diagram on the previous page. The resolver converts the inputs (course, speed, set of current and its rate) into N-S and E-W components and passes them on to the respective shift motors.

Each shift motor causes a sliding contact to move across a potentiometer thereby varying the current through the shift coil. The resulting change in the magnetic field around the neck of the CRT causes the electron stream to get deflected. The electronic centre, therefore, moves along the radar screen, at the course and speed made good.

If, at anytime, the speed input is made zero, the picture would become an off-centre RM display. If the currents through the shift coils are cut off, the picture would become a centred RM display, the centring then becoming dependant on the RM 'X and Y' shift controls.

Advantages and disadvantages of RM & TM.

	Relative motion	True motion
1.	All objects move relatively on the PPI. Stationary targets move on the screen with own ship's reversed course and speed. Hence all objects produce relative trails on the screen, whether actually moving or not.	Objects move on the PPI on their actual courses and speeds. Stationary targets remain stationary on the screen. Hence moving targets create trails on the screen whereas stationary targets do not.

2.	Course, speed & aspect of any target only available after plotting of triangle of relative velocities.	Course, speed and aspect of any target directly obtained.
3.	CPA range and time directly obtained.	CPA range and time obtained only after plotting triangle of relative velocities.
4.	The lines of approach of various targets can be drawn on the reflection plotter, once and for all, and their dangers assessed according to the value of CPA range. At any future time, if the target is not on this line, alteration of course and/or speed is indicated, provided own ship has maintained course and speed. However, the type of action, taken by a target, its magnitude and direction are not readily available. Any course and/or speed alteration by own ship would cause the line of approach of each and every target to change.	The line of approach of a target cannot be drawn on the reflection plotter, once and for all, but has to be drawn as and when CPA range has to be checked. Course and/or speed alterations by targets can easily be detected, regardless of any course and/or speed alteration by own ship. Furthermore, the type of action taken by a target, its magnitude and direction, is directly available at all times.
5.	Targets on collision course are easily identified and so further manual plotting is confined to only such targets. Hence semi-	Automatic or semi-automatic plotting aids are a great help in overcoming the only draw-back of TM - obtaining CPA range and time. Once such an aid is provided, TM is very

	automatic or automatic plotting aids have less use in RM for collision avoidance than in TM.	comfortable to use and more efficient than RM.
6.	Easier to use, for collision avoidance, in open sea as CPA range is directly available. Own ship would not be frequently altering course for navigational reasons.	Easier to use in coastal navigation because the target's alterations of course for navigational reasons can be anticipated and appreciated easily. Own ship maybe frequently altering course for navigational reasons.
7.	Cost of RM radar less than TM radar, as TM is really an additional facility provided on basic (RM) radar.	Cost of TM radar more than RM radar. This difference added to cost of automatic or semi-automatic plotting aids makes it much costlier than RM radar. However, considering utility value, greater safety and efficiency may easily offset cost.

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CHAPTER 28

THE GENERAL PROCEDURE

FOR RADAR OPERATION

The general procedure to switch on a radar set

1. Make sure that the scanner is clear.
2. Set the four critical adjustment controls - gain, brilliance, anti-clutter and differentiator - to off or minimum.
3. Set the main function switch (OFF/STANDBY/ TRANSMIT) to standby. The radar set will then begin to warm up. Even if the set is solid state, certain parts will require time for warming up. During this time, steps 4 to 8 may be carried out.
4. Set range elector switch to desired range scale.
5. Set PL selector switch to desired position (short pulses for normal use). In some radar sets, the main function switch is marked OFF/STANDBY/SHORT PULSE/ LONG PULSE, whereby the radar observer has to choose the PL, automatically, every time he switches on the set. In such a case, omit this step as it is covered by step 9 below.
6. Ensure that the EBL, ERBL, VRM & range rings are all off, by turning down their respective brightness controls.
7. Set the presentation mode switch (RM unstabilised/RM stabilised/TM) to the RM stabilised mode.
8. Adjust panel lights to the desired intensity.
9. When the set has warmed up (about two to three minutes after switching to standby), set the main function switch to TRANSMIT. In some sets, instead of TRANSMIT,

the main function switch is marked SHORT PULSE/ LONG PULSE so that PL has to be selected at the same time as switching on from standby (see step 5). In such a case set main function switch to short pulse.

10. Gradually increase the brilliance until the rotating trace becomes visible. Then gradually decrease the brilliance until the rotating trace just disappears. The brilliance has now been set correctly and should not normally require re-adjustment if and when the range scale is altered. Brilliance must be set only when the three other critical adjustment controls - gain, anti-clutter and differentiator - are all off or at minimum.
11. If a brilliance control is provided separately for the heading marker, turn it down. Unnecessary brightness of the heading marker will (i) cause the heading marker to be broader than necessary (ii) distract the observer's attention from targets when the picture is obtained later on and (iii) reduce the life of the CRT. This control will not, and must not, blank out the heading marker completely however low the control may be set.
12. Ensure that the electronic centre coincides with the geometric centre of the display. The latter is indicated by a mark on the centre of the mechanical cursor. If a mechanical cursor is not fitted, centring could be checked by switching on the range rings and verifying that the outermost ring is completely visible. It would also coincide with the circumference of the PPI. If not centred properly, part of that range ring would not be visible. If necessary, centre the picture by rotating the centre-shift controls as required - one knob moves the electronic centre along the X axis and the other, along the Y axis.
13. Check that the heading marker is properly aligned. When gyro-stabilised, it should indicate the correct gyro course. When unstabilised, it should coincide with the zero of the bearing scale. If not, align it as per

manufacturer's instructions. Usually, a spring-loaded knob is to be pulled out (or pushed in), rotated as necessary and then released.

14. If a focus control is provided, make the range rings appear, adjust the focus control until those range rings that are half way between the centre and the edge of the screen appear as thin as possible and then turn off the range rings. In most of the modern sets, the focus is usually pre-set and no control is provided for general use.
15. Gradually increase the gain until the receiver noise is just visible as a speckled background. The setting of gain would have to be reduced when using short-range scales.
16. Tune the set, as per manufacturer's instructions. Where an AFC (automatic frequency control) circuit is provided, tuning by the observer would not normally be necessary each time (see chapter 11).
17. Test the efficiency of the set, as described later this chapter.
18. Adjust other controls as necessary.

Notes concerning switching on a radar set

(1) The power supply to the radar set may have a main switch on a bulkhead or other place nearby. Such a switch must always be left on, except during specific periods of maintenance.

(2) No harm to the set would normally occur if the standby position of the main function switch is by-passed i.e., if the switch is set directly from off to transmit. The picture will be available only when the necessary parts have warmed up.

(3) For more information regarding each control, especially clutter suppression and differentiator, refer to the relevant chapters in Part I of this book.

(4) When using the range rings, VRM, EBL, or ERBL keep their respective brilliances down to the barest minimum required for

comfortable operation. If such brilliance is set high, not only will the corresponding lines appear blurred or broad, but also the life of the CRT will be shortened. When not required, remember to turn off these markers.

(5) The foregoing procedure for switching on is intended as a general guideline only. The radar observer must study the operating manual of the manufacturer and follow it implicitly.

If TM is desired, the following additional steps are required

1. Set the speed-input switch marked LOG/MANUAL to the desired position. If manual, also set the adjacent switch to the desired speed input.
2. If a sea-stabilised TM display is desired, ensure that no information regarding current is fed in. If a ground-stabilised TM display is desired, feed in the necessary information regarding the set and rate of current.
3. Set the presentation mode switch marked 'RM unstabilised/RM stabilised/TM' to TM.
4. Shift the electronic centre to a suitable position of the display, by means of the controls provided.

Notes concerning TM

(1) Before attempting to put the radar set on TM, chapters 26 and 27 should be read and understood thoroughly.

(2) The TM controls provided by different manufacturers may vary considerably. Hence only a general idea is given here.

(3) TM may not be available on very small (less than 1.5 M) or very large (over 24 M) range scales. The manufacturer's operating manual should be consulted. If the presentation mode switch is in TM, and a very large or very small range scale is switched on, for which TM has not been provided, the picture would become an off-centre RM display and an illuminated sign to that effect would come on.

The procedure to check the efficiency

1. Switch on the radar set and get a picture.
2. Tune the set (not necessary if AFC is provided).
3. Change over to the range scale specified by the manufacturer (usually the 1.5 M range scale).
4. See that the PL selector switch is in the 'short pulse' position.
5. Set the clutter suppression and differentiator controls to minimum or off positions.
6. Set gain as usual.
7. Operate spring-loaded 'performance monitor' switch and a feather or a cartwheel-pattern will appear on the screen.
8. Measure off the maximum length of the feather (or the maximum radius of the cartwheel) with the help of the VRM. Any error of the VRM must be allowed for.
9. Relative efficiency % = $\dfrac{\text{Present length of feather}}{\text{Max. length in the past}}$ x 100.

Notes concerning efficiency if the set:

(1) The maximum length of the feather (or radius of cartwheel) obtained in the past, and its date, must be entered conspicuously in the radar logbook.

(2) The length of the feather may change due to age or when major components have been renewed. If the length of the feather changes due to renewal of components, a new set of observations must be commenced for future reference and the entry in the radar log amended accordingly.

(3) The efficiency so obtained is not an absolute value, but only relative, as explained in chapter 14.

(4) If, at any time, the relative efficiency drops below 80%, an investigation of the causes must be made. Some of the very simple causes could be water or dirt in the waveguide, salt or dust on the scanner, improper tuning, etc. If the cause is not as

simple as that, the help of a technician may have to be sought. Meanwhile, a record of the length of the feather, and the maximum detection ranges of targets obtained, should be kept.

(5) If there is considerable clutter present on the screen, it may be difficult to distinguish the end of the feather or cartwheel. A little bit of clutter suppression may be used, in such a case, but it should be borne in mind that use of clutter suppression tends to shorten the length of the feather.

(6) It would be a good idea to attach a dymo-tape strip to a conspicuous part of the display unit indicating the maximum length of the feather (or radius of cartwheel) and the date that it was obtained, for quick reference during regular use.

The procedure for switching off

1. Change over to a medium range scale (12M is suitable).
2. Set the four critical adjustment controls - gain, brilliance, anti-clutter and differentiator - to off or minimum.
3. If a separate PL selector switch is provided, set it to 'short pulse'.
4. Set the main function switch to 'off'.

Notes concerning switching off

(1) Switching over to a medium range scale is recommended in order to save time, in case it is necessary to switch on the set in a hurry in an emergency.

(2) No harm to the set will occur even if the four critical adjustment controls are not set to minimum while switching off. The reason for setting them to off or minimum is only to prepare the set for the next switching on.

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CHAPTER 29

ERRORS IN

RADAR BEARINGS

Bearings obtained by radar are subject to errors caused by various factors. Some of the main sources of such errors are elaborated below:

1. Angle of squint

The heading marker should appear when the pulse leaves the scanner in the ahead direction. If it does not, all radar bearings would be in error, whether obtained by the EBL or by the mechanical cursor, whether the display is gyro-stabilised or not. This is called squint.

To check for this, choose an isolated target near the edge of the radar screen. Alter course so as to bring the target right ahead visually and then see if the heading marker passes through its paint on the radar screen. If it does not, squint exists and the heading marker contact in the scanner unit must be adjusted, as per manufacturer's instructions. In most cases, inside the watertight box under the scanner, a knurled wheel has to be rotated - clockwise rotation would cause clockwise shift of heading marker and vice versa; a specific amount of rotation would cause 1° shift of heading marker.

When the scanner is of the slotted wave-guide type, a change of transmission frequency, caused by a change of magnetron, can cause squint. This is because the slots in this type of scanner are arranged for a particular frequency and if this frequency changes, even slightly, the transmitted energy would change direction resulting in squint. Squint must be checked for and corrected, as soon as possible, in the manner described earlier.

Until such time that the heading marker contact can be adjusted, the error caused by its misalignment can be found and applied to radar bearings. For example, if the heading marker lies two degrees to the left of the paint of the target that is visually right ahead, the error is computed as follows:

Relative bearing by radar	: 002°
Visual relative bearing	: 000°
Error of heading marker	: 2° high or minus 2°

So, in this case, all radar bearings, whether observed by the mechanical cursor or by the EBL, must be reduced by 2° to obtain correct bearings. As mentioned earlier, this error would be applicable even if the display is gyro-stabilised.

The target chosen for this check should be distinct and isolated, to avoid mistaken identity, and sufficiently far away to avoid error of parallax - the distance of displacement of the scanner from the centre line of the ship should not subtend a finite angle at the target.

2. Misalignment between heading marker & bearing scale

The direction indicated by the HM must always be correct with respect to the bearing scale fixed around the PPI. On an unstabilised, centred display, the HM should indicate zero on the bearing scale and on a gyro-stabilised, centred display, the heading marker should indicate the gyro course steered. If not, radar bearings would be in error. If the display is off-centred, the direction of the HM should be checked as explained later in this chapter, under 'centring error'.

While using an unstabilised display, if the HM shows 357° instead of 000°, its error is 3°. So radar bearings read off the bearing scale must be increased by 3° to obtain correct bearings. However, it is possible that the bearing indicated by the digital readout of the EBL may be free of this error, as it is independent of the fixed bearing scale around display when in the unstabilised mode.

While using a gyro-stabilised display, if the HM indicates 126° when the Master gyro and/or other repeaters on the ship show 125°, the error of the HM is 1° high or minus 1°. So all radar bearings, whether observed by the mechanical cursor or by the EBL, will have to be reduced by 1° to obtain correct bearings, in this case.

Misalignment between the HM and the bearing scale is very simple to eliminate. A spring-loaded knob is usually provided which has to be pulled out (or pushed in), rotated until the heading marker is aligned correctly and then let go.

3. Error of parallax

Because the mechanical cursor is a few centimetres above the surface of the CRT, it is important to ensure that the observer's eye is held correctly over the PPI, whilst measuring bearings with it. If not, error of parallax would result. To assist the observer in this regard, the mechanical cursor is usually etched on both, the top and bottom, faces of the perspex sheet. The observer has only to ensure that, whilst measuring bearings, the etched lines on both faces coincide. The use of the hood (visor), if and when convenient, would eliminate error of parallax. This is because the opening is so small that the observer's eye is correctly positioned over the centre of the PPI.

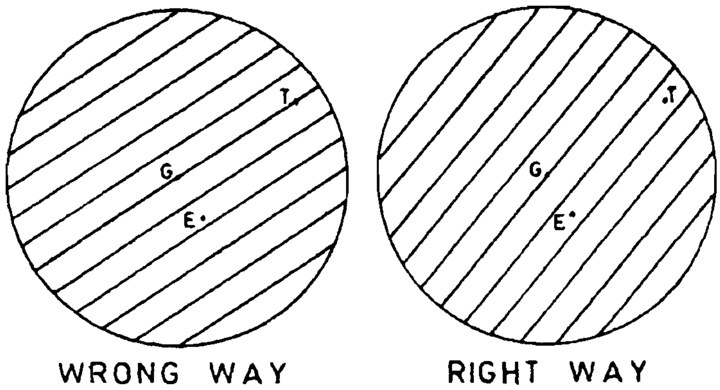
The EBL is free of this error because it is on the radar screen itself and not a few centimetres above it.

4. Centring error

When using an off-centred display (when the electronic centre and the geometric centre of the display are not coincident), bearings observed by *using the mechanical cursor* in the normal manner will be in error, as shown in the following figure. This is because the geometric centre is the centre of the bearing scale and also of the mechanical cursor whereas the electronic centre is the point from which the picture has been displayed on the screen.

The following figure shows an off-centre display. G is the geometric centre and E, the electronic centre. The HM originates from E but, for illustration purposes, is not shown here. T is the paint of a target on the screen.

OFF-CENTRE BEARING BY MECHANICAL CURSOR



Since ET is the correct bearing, the mechanical cursor is rotated until it is parallel to ET and the correct bearing is read off the bearing scale. Since line ET is not actually visible, the parallel is obtained by seeing that the perpendicular distances of E and T, from the mechanical cursor, or any of the parallel index lines, are equal.

The foregoing procedure is similar to chart work where the bearing of T from E is required. The parallel ruler would be placed along ET and then shifted to G, the centre of the compass rose!

Centring error will be nil in the direction of displacement and maximum in a direction perpendicular to it. In other words, if a target was situated on the line passing through G and E, centring error will be nil. If a target was situated in a direction perpendicular to GE, as shown in the figure, centring error will be maximum.

Centering error is not applicable when using the EBL because the origin of the EBL is always the electronic centre. The EBL is hence independent of the geometric centre of the radar screen.

If it is desired to check the direction of the HM, while using an off-centre display, rotate the mechanical cursor until it is parallel to the HM and then read off the direction, of the mechanical cursor, from the bearing scale.

5. Digital error of EBL

It may sometimes happen that the digital readout of the EBL may not show the correct reading. This can be checked easily in many ways and the error computed.

One way of checking for this error is to properly centre the picture, ensure that the scanner, HM and the zero of the bearing scale are aligned properly and then compare the reading where the EBL meets the bearing scale, with the digital readout of the EBL. They should be the same. If not, the error of the digital readout can be computed as follows:

Correct bearing as per bearing scale 130°
Digital read out 132°
Digital error of the EBL: minus 2° or 2° high.

This error would have to be applied to all bearings obtained from the digital readout.

Another way to check for this error, regardless of whether the display is centred or not, is to align the EBL with the HM. The digital readout should indicate zero if the display is unstabilised, or the gyro course of the ship if gyro-stabilised. If not, digital error of the EBL exists and should be computed as explained earlier.

In some radar sets, the mechanical cursor and the EBL are rotated by a single control and hence they would remain parallel always. In such a case, the direction of the EBL is obtained by noting the reading of the mechanical cursor on the bearing scale. Since, in such a case, no digital readout is provided, the question of its error does not arise!

6. Some other sources of errors

When an accurate bearing of a target is desired, reduce the range scale suitably so as to cause the paint of the target to be as far away from the electronic centre as practicable. For example, using a radar screen of 15cm radius, a target two miles off would be (i) 1.25 cm away from the electronic centre when using the 24 M range scale and (ii) 10 cm away from the electronic centre when using the 3 M range scale. Since the accuracy of the direction of a line joining two points increases as the distance between the points increases, it is obvious that the bearing of the target is more accurate when measured on a smaller range scale than on a larger one.

When observing the bearing of an end of land, the inaccuracy caused by beam-width distortion (explained under HBW in chapter 2) should be borne in mind.

Because some gyro-repeaters can be aligned to only plus or minus half a degree of the master gyro, true bearings obtained through radar may be in error by this amount, due to this cause. The gyro error, if any, would also be present.

Non-rectilinearity of the time base (the trace not being a perfect straight line) can also cause errors in radar bearings. This is a malfunction of the set and must be set right by a technician.

When using the EBL, its brightness must be reduced to the barest minimum necessary for comfortable use. Unnecessary brightness of the EBL will cause it to be broader than necessary, thereby reducing the accuracy of its measurements and also shortening the life of the CRT.

Human error is another factor that may cause errors in bearings.

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CHAPTER 30

ERRORS IN

RADAR RANGES

Radar ranges have fewer causes for error than radar bearings. Of the two methods provided for measuring range, the range rings are more reliable than the variable range marker (VRM). Since the latter is a moving control, and constantly varied during use, there is a possibility for its accuracy to 'drift' somewhat.

The range rings and the VRM always remain centred over the electronic centre and hence their accuracy remains unaffected even if the picture is off-centred.

Where brightness controls are provided for the range rings and the VRM, reduce their brightness to the barest minimum necessary for comfortable use. Unnecessary brightness will cause the markers to be broader than necessary (thereby reducing the accuracy of the measurements) and also reduce the life of the CRT.

When measuring range, it is important to remember that the ***closer edge*** of the paint on the PPI ***represents the correct range*** of the target (see under 'Pulse length' in chapter 2).

The use of coastlines, for checking the accuracy of radar range, should be avoided because the positions of coastlines change with height of tide (see chapter 22).

Error of range rings

Error of range rings is quite rare. Once checked and corrected, it should normally last indefinitely.

To check the accuracy of the range rings, first ensure that the correct number of range rings are visible and that they are equal distances apart. Six rings are to be provided on range scales of 1.5 M and above.

It must be mentioned here that it is sometimes possible, owing to defects or internal maladjustment, that the number of rings may be one more or one less or that the rings may be unequal distances apart and yet they may show correct ranges. This is an unsatisfactory state of affairs and must be rectified by a technician as soon as possible.

The position of the ship, whilst stationary in port, should be fixed accurately. The radar ranges of suitable objects should be measured off the PPI by using the range rings and then compared with their ranges as per chart. The difference between the radar range of an object and its charted range is the error of the range rings.

By this method, there is a possibility that any error in the position of the ship would be wrongly attributed to inaccuracy in radar range. Therefore, the error of the range rings, if found unacceptable, should be verified on several occasions, using different targets, before a technician is called in to correct it. Correction should preferably be done while the ship is in a position to re-check soon after.

The error of the range rings should not exceed 1% of the maximum range of the scale in use, or 30 metres, whichever is greater.

Error of the VRM

To find the error, if any, of the VRM, make it coincide with a range ring. Then compare the reading of the VRM with the range indicated by the range ring. The difference, if any, is the error of the VRM. For example:

Range indicated by range ring	4.0 M
Range indicated by VRM	3.9 M
Error of VRM: plus 0.1 M or	0.1 M low.

The error of the VRM should not exceed 1% of the maximum range of the scale in use, or 30 metres, whichever is greater.

On a given range scale, the error of the VRM may be constant or it may be a percentage of the range being measured (decrease as range decreases and vice versa). The error, if any, may also vary from range scale to range scale and it may also change from time to time. In view of this, checks for error of the VRM should be made at least once a watch and the error, if any, applied to all ranges measured by it. Appropriate entry in the radar logbook should also be made.

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CHAPTER 31

THE RADAR LOG BOOK

The radar logbook is a very important record that should be kept up-to-date regularly, preferably at the end of each watch, for efficient use of the ship's radar set. It is maintained in order to assist the radar observer and the maintenance technician to:

(a) Review the past performance of the set.
(b) Assess the present quality of performance by comparing it with its earlier performance.
(c) Assist in deciding what maintenance is to be carried out.
(d) Keep a record of the detection ranges of various targets encountered, especially those of navigational importance, for reference if the vessel returns to the same area at a future date. A carbon copy is usually sent to the head office of the shipping company for their record. Where two radar sets are provided, a separate logbook should be maintained for each.

The contents of the radar logbook may be divided into four sections: (1) Technical details (2) Operational record (3) Log of targets and (4) Maintenance record.

1. Technical details

The first few pages of the radar logbook usually contain technical details and important information for quick reference by the radar observer. The details should include:

1.1. Name of the ship.
1.2. Date of installation of radar set.
1.3. Name of manufacturer.
1.4. Model and serial number of the set.
1.5. The size, type and RPM of scanner; its HBW and VBW.
1.6. For each range scale, the PRF and available PL, the limits of possible second trace echoes.
1.7. The relative bearings of the extremities of all shadow sectors and also blind sectors, if any.
1.8. The maximum observed length of the performance monitor signal and the date of its observation (see chapter 14 titled 'Efficiency of a radar set').
1.9. A table showing the height of the scanner above sea level for various drafts of the ship.

Since the layout of the radar logbook has not been internationally standardised, it is possible that specific columns may not be provided, in the first few pages of the radar logbook, for all the foregoing information. In such cases, the information may be entered in any convenient place, within the first few pages, such as the inside part of the front cover, an additional page stuck on, etc.

2. Operational record

This part of the radar logbook generally deals with duration of actual use. The entries include the date, time switched on, time switched off, number of hours actually used, number of hours on standby, locality where used, reasons for use (collision avoidance, landfall, pilotage, practice, etc.), the observed errors, if any, of the VRM and EBL, any faults noticed during operation and any other remarks that the officer of the watch may think fit to record (such as the occurrence of starring, false echoes, second trace echoes, performance of Ramarks and Racons, etc.). This part of the radar logbook should be filled up ***after every navigational watch***.

3. Log of targets

This part of the radar logbook is a record of the observed detection ranges of various targets. The entries usually include the date, approximate ship's time, height of scanner above sea level, general locality, weather conditions and visibility, the observed length of the performance monitor signal, brief description of each target and its observed maximum detection range.

The record of the length of the performance monitor signal and the corresponding maximum detection ranges of various targets, as observed at various times in the past, assists in anticipating the detecton ranges of targets at future times, for any particular length of performance monitor signal.

This part of the radar logbook is very useful on subsequent voyages to the same locality as the maximum observed detection ranges of various navigational marks and features would then be available.

4. Maintenance record

This part of the radar logbook is a record of all fault-rectification, maintenance and repairs carried out on the radar set. The entries include the date, place, brief details of work done, important spare parts used up and their balance stock, the name of the firm or organisation (and the port) that carried out the work, etc. An entry specifying the total amount spent on each occasion would also be useful.

In the olden days, these entries used to be made by the Radio Officer. Since most of the ships of today do not have a Radio Officer on board, the entries may be made by the Electronics Officer (if such a person is on board) failing which, by the Second Officer, in consultation with the person who carried out the work.

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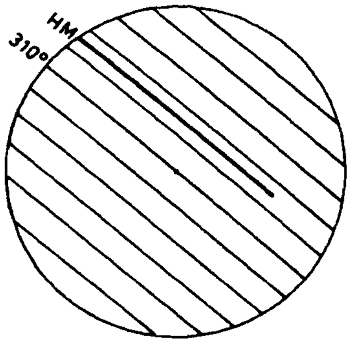
CHAPTER 32

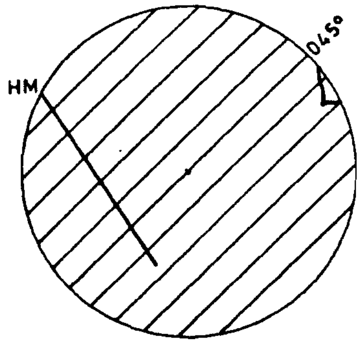
THE PARALLEL INDEX

Uses of the Parallel Index

1. *To check the direction of the HM using an off-centre display:*
Rotate the parallel index until the lines are parallel to the heading marker. The reading of the mechanical cursor is then the direction of the heading marker (310° in the left hand side figure below).



Direction of HM

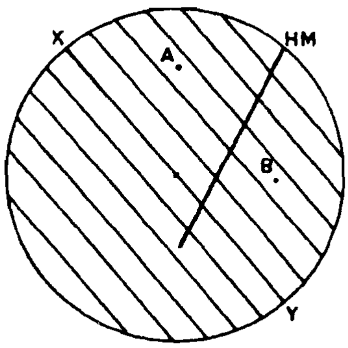


Off-centre bearing

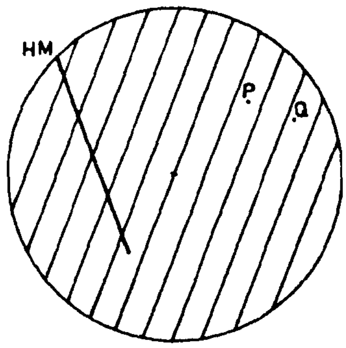
2. *To obtain the bearing of a target using an off-centre display:*
This has been explained in detail under 'Centring error' in chapter 29. The figure above (right) may serve as a reminder. The bearing in this case is 045° (T).

3. *To obtain the bearing between two targets*:

Rotate the parallel index until the lines are parallel to the line joining the two targets (AB in the following figure, left). Reading X of the mechanical cursor is the bearing of A from B and reading Y, the bearing of B from A. The lower the range scale in use, the further apart A and B would be on the screen and the greater the accuracy of this measurement. This method may be used for both, centred and off-centred displays.



Bearing between targets



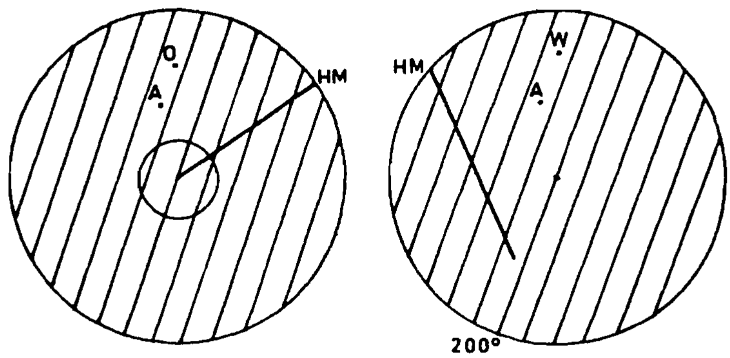
Range between targets

4. *To obtain the approximate distance between two targets*:

Rotate the parallel index until the lines are perpendicular to the line joining the two targets (PQ in the foregoing figure, right). Estimate the distance between the targets, bearing in mind that the distance between consecutive index lines is one-sixth the range scale in use. The lower the range scale in use, the greater the accuracy of this measurement. This method may be used or both, centred and off-centred displays.

5. *To obtain the CPA range quickly (RM display only)*:

Rotate the parallel index until the lines are parallel to the movement of the target on the RM display (OA in the following figure, left) and read off the CPA range using the VRM. The marks O and A may be made on the reflection plotter. This method may be used for both, centred and off-centred displays.



6. *To obtain the course & speed of a target quickly (TM only)*:
Rotate the parallel index until the lines are parallel to the movement of the target on the TM display (WA in the foregoing figure, right) and the reading of the mechanical cursor is the course of the target (200° in this case). The marks W and A may be made on the reflection plotter. The distance moved by the target during the plotting interval, may be obtained, as explained earlier in para 4 of his chapter, and the approximate speed of the target deduced.

Parallel Index Techniques

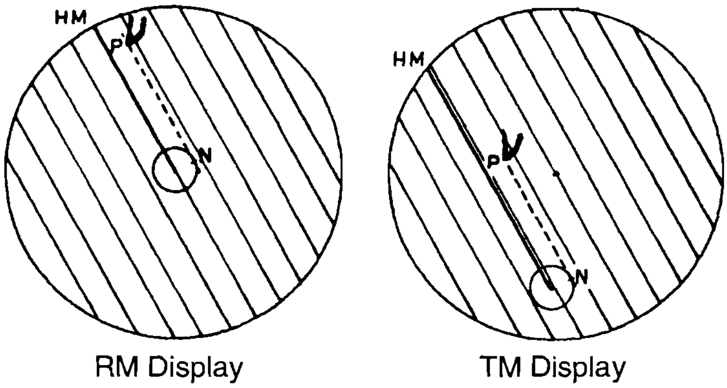
Parallel index technique is the art of manoeuvring a ship to a desired position, or along a desired track, in such a manner that the entire manoeuvre is carried out while using the PPI only. The chart is consulted before hand and a little pre-computation may be done, but no fixes are plotted on the chart because continuous monitoring is done on the PPI with the help of the parallel index. Allowances for current and wind are made, as and when necessary, during the manoeuvre, by inspection of the ship's progress on the PPI. Three such techniques are illustrated here.

Instead of the parallel index, it is possible to use the ERBL, in the 'Detached-from-own-ship static mode' (see para 5.2 of chapter 10).

1. *To steer a course to pass a given distance off a point:*
Set the VRM to the desired distance to pass off the point of land. On the reflection plotter, draw the tangent PN from the present position P of the point of land to the VRM circle. Rotate the parallel index until the lines are parallel to the tangent. The reading of the mechanical cursor is the initial course to steer. Inspect the chart to see that such a course is safe. Set course.

1.1. *On a gyro-stabilised RM display,* while on the above course, the paint of the point of land should move along the tangent PN (see the following figure, left). If, due to current or wind, the paint tends to move to starboard of the tangent, alter course slightly to starboard, and vice versa. In other words, con the ship to keep the paint, of the point of land, on the tangent.

PASSING DISTANCE TECHNIQUE



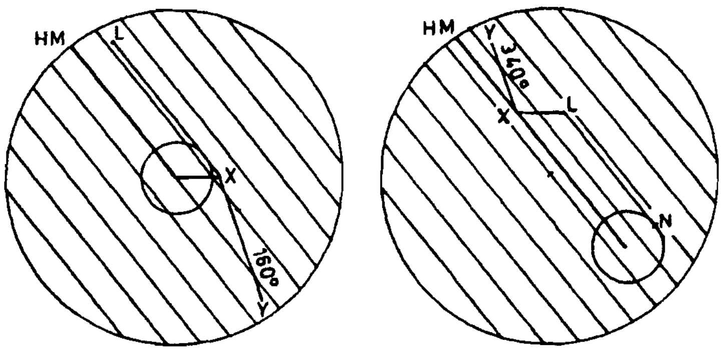
1.2. *On a TM display,* the paint of the point of land should remain stationary at P, while the origin moves along the display. Con the ship such that the VRM circle is always tangential to line PN on the reflection plotter. In the figure, above right, if the circumference of the VRM overlaps the tangent, a port alteration of course is to be made; if it falls short, a starboard alteration. If at any time during the manoeuvre, due to sea-stabilisation or due to improper ground-stabilisation, the paint of the point of land moves on the PPI, it is ***very important*** that it be brought back to P by shifting the entire picture with the help of the TM N-S and E-W shift controls, and the manoeuvre continued without a break.

2. *To alter course off a navigational mark or point of land*:

It is desired that when a certain light-vessel bears 090°(T) 3M off, course should be altered to 340°(T).

2.1. *On a gyro-stabilised RM display*, lay off a point X on the reflection plotter, 090°(T) 3M off the electronic centre. Join the present position L, of the light-vessel, to X. Rotate the parallel index until the lines are parallel to LX and the reading of the mechanical cursor is the initial course to steer. Adjust the VRM such that it is tangential to LX and its read out is the distance that the ship will pass off the light-vessel. Inspector the chart and ensure that the intended course is safe. From X, draw a line XY in the direction 160° (reverse of final intended course of 340°) on the reflection plotter, using the parallel index lines - see following figure, left.

COURSE ALTERATION TECHNIQUE



RM Display TM Display

While on the initial course, the paint of the light-vessel should move along LX. If the paint tends to move to port of LX, a slight alteration of course to port should be made, and vice versa, to ensure that the paint of the light-vessel moves along LX. Just as the paint of the light-vessel is very nearly under X, course should be altered to 340°(T) and, thereafter, the paint of the light-vessel should move along line XY. Suitable adjustments of course steered should be made to ensure that the paint of light-vessel stays on XY. If the paint, in this case, moves to the west of XY, an alteration of course to port is to be made, and vice versa.

2.2. *On a TM display*, mark L the present position of the light-vessel, on the reflection plotter as shown in the foregoing figure, right. From L, lay off X, the intended alteration position of own ship - 270°(T) 3 miles from L, using the parallel index. Using the parallel index again, read off the bearing of X from the electronic centre and this the initial course to steer. With the help of the parallel index, draw line LN opposite to the initial course and adjust the VRM such that it is tangential to line LN. The readout of the VRM now indicates the intended distance to pass off the light-vessel. From X, lay off XY in the direction 340°(T) - the final course.

Con the vessel such that the VRM remains tangential to line LN. In the foregoing figure, right, if the VRM overlaps LN, a slight alteration of course to port is to be made; if it falls short of the line, a slight starboard alteration is to be made.

If at any time during the manoeuvre, the paint of the light-vessel moves on the PPI, due to sea-stabilisation or improper ground-stabilisation, it must be brought back to L by shifting the entire picture by means of the TM N-S and E-W shift controls, and the manoeuvre continue without a break. It is ***very important*** that the paint of the light-vessel must always be at L, during the manoeuvre. Just as the electronic centre is about to come under X, course should be altered to 340°(T) and, thereafter, the electronic centre should move along XY, while the paint of the light-vessel is stationary at L.

3. *Anchoring with no navigational mark right ahead*:
In the following figure, left, A is the desired anchoring position off a conspicuous point of land on the chart. CA is the desired approximate direction of approach. Through the point of land draw a line parallel to CA and measure off AB (called the cross index range) and also the distance of B from the point of land (called the dead range).

ANCHORING TECHNIQUE

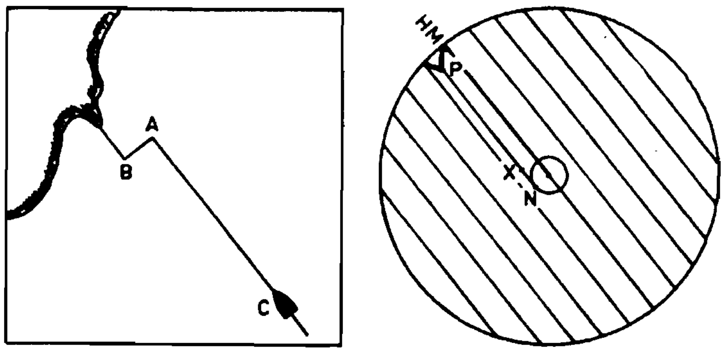


Chart RM Display

3.1. *On a gyro-stabilised RM Display*, set the VRM to the cross-index range. On the reflection plotter, mark P, the present position of the point of land, and draw the tangent PN to the VRM circle. On NP, mark off NX equal to the dead range.

To lay off the distance NX, rotate the parallel index until the lines are perpendicular to NP. Then estimate the desired distance NX, bearing in mind that the distance between consecutive index lines is one-sixth the range scale in use. Alternatively, the ERBL or a pair of rubber-tipped dividers may be used.

Rotate the parallel index until the lines are parallel to tangent NP and the reading of the mechanical cursor is the course to steer.

While on this course, the paint of the point of land should move along the tangent PN. If, due to wind or current, the paint of the point of land moves to port of the tangent, make a small course alteration to port, and vice versa. In other words, con the ship to keep the paint, of the point of land, on the tangent. When the paint of the point of land comes directly under X, the ship is in the desired anchoring position.

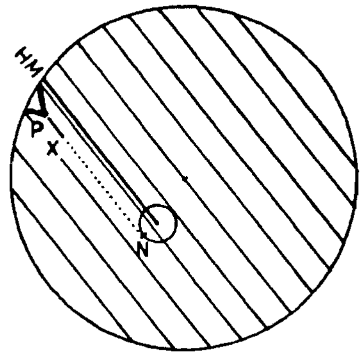
While approaching the anchoring position, the speed of the ship should be reduced progressively and necessary course alterations made each time, to ensure that the paint of the point of land moves along the tangent PN. By this technique, the progress of the ship is continuously monitored and the ship is manoeuvred precisely, quickly and safely. In direct contrast to this, the method of plotting the position on the chart does seem less efficient and less precise. However, the chart should be studied properly before hand and off-lying dangers such as shoals, submerged rocks, etc., noted carefully before deciding on the most favourable direction of approach.

3.2. *On a TM display*, mark P, the present position of the point of land, on the reflection plotter. Set the VRM to the cross-index range and draw the tangent PN, from P to the VRM circle. Rotate the parallel index until the lines are parallel to NP. The reading of the mechanical cursor is the initial course to steer. Mark point X on line PN such that PX is equal to the dead range.

While on the above course, the point of land should remain stationary under mark P on the reflection plotter while the electronic centre moves across the screen. The

VRM circle should remain tangential to PN always. If, in the following figure, the VRM circle overlaps the line PN, a slight alteration of course to starboard is to be made; if it falls short, a slight alteration to port.

ANCHORING TECHNIQUE



TM Display

It is ***important to ensure*** that the paint of the point of land remains stationary under mark P of the reflection plotter, during the entire manoeuvre. If at any time due to sea-stabilisation improper ground-stabilisation, it moves out of its original position, it must be brought back under mark P by shifting the entire picture by means of the TM N-S and E-W shift controls. The ship's speed should be reduced progressively, well in time, and when mark N (the point of contact between tangent PN and the VRM circle) on the reflection plotter reaches X, the ship has reached the desired anchorage position.

Note: While approaching the anchoring point, it must be remembered that, as the speed of the ship is gradually reduced, the effect of tide and wind on the ship's progress would be more and more pronounced. Increasingly larger course corrections would then become necessary.

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CHAPTER 33

CONCLUDING REMARKS

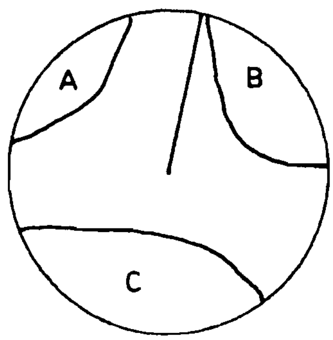
ON PRACTICALS

Radar assisted fixes

The following are some radar-assisted fixes, in descending order of accuracy:

(1) Visual bearings and radar ranges of two or more objects.
(2) Radar ranges of several objects used as radii of position circles.
(3) Radar range and radar bearing of a single identified feature (end of land).

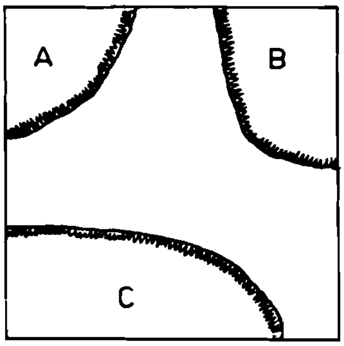
Of the fixes mentioned above, the use of several radar ranges, as radii of position circles, sometimes poses a problem. Suppose a ship is in a position where she is surrounded by land, as shown in the figure below:-



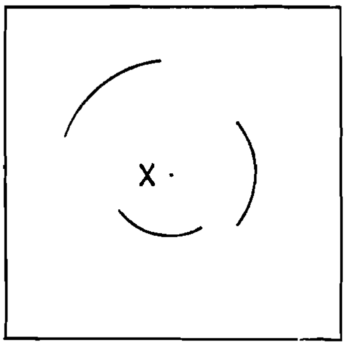
No radar or visual bearings being available, it is desired to use the observed radar ranges of A, B and C, as radii of position circles, on the chart. The position circles cannot be drawn accurately on the chart because the point from which each position circle should be drawn is not known. One simple way to overcome this difficulty is as follows:

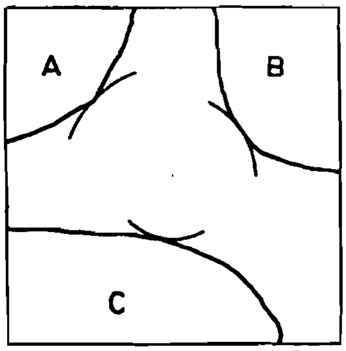
In the centre of a sheet of tracing paper of suitable size, mark a point X to represent the position of the ship. Set a drawing compass to the radar range of A, using the scale of the chart. With centre X, draw a large arc on the approximate bearing of A from the ship. Draw similar arcs, from X, for B and C, using their respective ranges, on their approximate bearings.

Part of the chart



Tracing paper



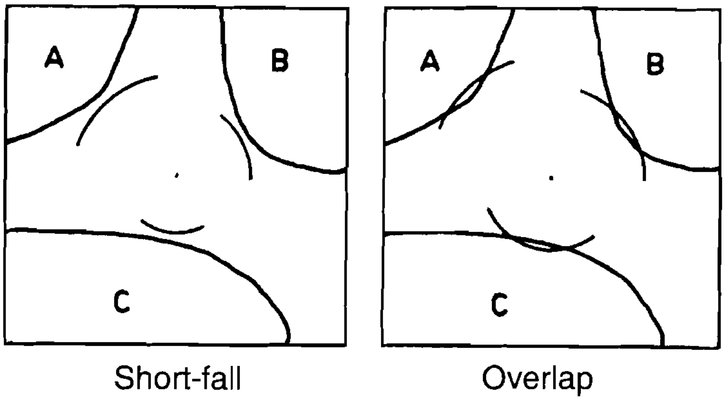


Tracing paper placed on chart – ideal fix

Transfer the tracing paper over to the chart and shift it about until the three arcs touch their coastlines correctly. Prick the position of X, through the tracing paper, on to the chart.

It is possible that the three arcs do not exactly touch the coastlines - they may fall short or they may overlap the coastlines by a small amount. If so, shift the tracing paper so as to give equal short-fall or overlap to all three coastlines. The reason for such short-fall or overlap could be the fact that the radar shows the position of the coastlines at the present level of tide, whereas the chart shows them at the level of MHWOS (see chapter 22).

TRACING PAPER PLACED ON CHART



The range of scale to use

When using the radar for coasting (pilotage), the range scale used should be such that the objects used for fixing the position of the ship should be near the edge of the display. This will ensure better bearing accuracy and also better range accuracy - the lower the range scale used, the greater the accuracy of range measurements.

When using radar for anti-collision purposes, the range scale used should be such that there is enough time to:

1. Assess the situation.
2. Evaluate possible actions to be taken.
3. Take the decided action.
4. Ensure that the action taken is having the desired effect.

Factors such as traffic density, sea room available, traffic separation schemes, navigational hazards, size and manoeuvrability of own ship, speeds of ships involved, prevailing visibility, wind and weather conditions, etc., affect the four points listed above.

In open sea, range scales less than 12M would not suit the above requirements. The 12M range scale seems most suitable, with frequent switching over to the 24M range scale to detect targets, such as large ships, as early as possible.

The importance of the manual

Because of the fair amount of standardisation of the basic controls of marine radar sets, there is a tendency among modern radar observers to get used to any particular set by hearsay and also by trial and error during use. This is a wrong approach. The hearsay information is not always correct and should not be relied upon. The operating manual supplied by the manufacturer must be read and understood so that the radar observer uses the set to best advantage, correctly and efficiently. There have been cases where modern radar sets with semi-automatic plotting devices were provided on board by the shipowner, at great expenses, but were put to only limited use because the officer on board did not know the full extent of its capabilities. Had the manufacturer's operation manual been consulted, much greater ease and efficiency could have been achieved.

Fair weather practice

The radar observer should practice pilotage and radar plotting in clear weather where his observations and predictions can be visually verified. The time and range at CPA, proposed alterations of course and their consequences, etc., can be predicted and when the radar observer finds that his predictions fall correct with reasonable accuracy everytime, he begins to gain confidence in himself and his ability. Radar plotting should become a habit and not be a rare feat to be performed only in restricted visibility. Such practice in fair weather not only keeps the radar observer in touch with plotting, but may also be used to instruct those aspiring to become navigators i.e., cadets, seamen, etc.

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CHAPTER 34

RADAR AND THE COLLISION REGULATIONS

The object of this chapter is only to high-light some important aspects of "The International regulations for the prevention of collisions at sea", *as related to radar.*

The 1972 regulations are divided into five parts - part A (general), part B (steering and sailing rules), part C (lights and shapes), part D (sound and light signals) & part E (exemptions).

Use of radar, for anti-collision purposes, comes under part B (steering and sailing rules) which has been divided into three sections

Section I: Conduct of vessels in any condition of visibility.

Section II: Conduct of vessels in sight of one another.

Section III: Conduct of vessels in restricted visibility.

One main point of weakness, shown by candidates for competency examinations, is the failure to realise that when vessels are not in sight of one another owing to restricted visibility, Section II does not apply. Special emphasis is made here to point out that the rules relating to overtaking, crossing, meeting head-on, give-way vessel, stand-on vessel, etc., are applicable *only* when the vessels concerned are in sight of one another and *do not* apply to vessels which are not in sight of one another in restricted visibility.

In restricted visibility, when the vessels concerned are not in sight of one another, only Sections I and III are applicable. If in restricted visibility, the vessels do come into sight of one another, Section II then becomes applicable.

We will now examine the steering and sailing rules *as applicable to the use of radar*. The rules are not reproduced here in full, but suitable extracts are given wherever necessary for explanation.

Section I

This section deals with the conduct of vessels in any condition of visibility and consists of rules 4 to 10 (both inclusive).

Rule 5, which deals with look-out, states "Every vessel shall at all times maintain a proper look-out by sight and hearing as well as by all available means appropriate in the prevailing circumstances and conditions so as to make a full appraisal of the situation and of the risk of collision". Here the words *all available means* apparently refers to radar but may include VHF and RT. The words *full appraisal* may include radar plotting and communication by VHF/RT. The term *appropriate in the prevailing circumstances* gives room for the navigator to decide whether or not radar/VHF/RT must be used in clear weather, depending on other factors.

Rule 6, which deals with safe speed, states "Every vessel shall at all times proceed at a safe speed......". Paragraph (a) of this rule gives six factors to take into account in determining safe speed. Paragraph (b) of this rule specifically mentions the additional factors to be taken into account by vessels with operational radar:

(i) "The characteristics, efficiency and limitations of the radar equipment;" The characteristics of a radar set that affect its performance include VBW, HBW, PL, PRF, RPM and WL as explained in chapter 2. Efficiency of radar set has been explained in chapter 14. The limitations include range discrimination, bearing discrimination, minimum range, maximum range, range accuracy, bearing accuracy (as explained in chapter 3), shadow areas, shadow sectors and blind sectors (as explained in chapter 21), age and reliability of the set, the number of radars and displays fitted, interswitching facilities available, automatic or semi-automatic plotting aids provided, number of officers available for bridge watch, etc.

(ii) "any constraints imposed by the radar range scale in use;" The range scale in use should be such that there is sufficient time to detect targets, carry out a plot, analyse the situation, predict the action required to be taken, take the action and see that the action taken has the desired effect. In view of this, the 12 M range scale is generally preferred for plotting, with frequent long range scanning on the 24 M range scale for early warning of approaching targets. However, a very fast vessel may find that the 12 M range scale is not adequate, in areas of high traffic density or restricted visibility. The 24 M range sale provides too small a natural scale for effective plotting on a *reflection plotter*. Unless the vessel is using ARPA, it may have to reduce to such a speed that plotting on the 12 M range scale would be adequate, under the circumstances.

(iii) "The effect on radar detection of the sea state, weather and other sources of interference;" This refers to clutter (explained in chapter 10), weather effects (chapter 19), starring and spoking (chapter 24).

(iv) "The possibility that small vessels, ice and other floating objects may not be detected by radar at an adequate range;" this has been explained under 'Important characteristics of a target' in chapter 18 and under 'sub-refraction' in chapter 20.

(v) "The number, location and movement of vessels detected by radar;" This could mean that a vessel provided with automatic or semi-automatic plotting aids, an additional officer doing radar observation only, etc., can cope with more traffic density at greater speed than a vessel not so provided. Also, in areas of high traffic density and restricted sea room, safe speed would be much less than that in open sea.

(vi) "The more exact assessment of the visibility that may be possible when radar is used to determine the range of vessels or other objects in the vicinity".

Rule 7, which deals with risk of collision states in paragraph (a), "Every vessel shall use all available means appropriate to the prevailing circumstances and conditions to determine if risk of collision exists. If there is any doubt, such risk shall be deemed to exist". Here again, as in rule 5, *all available means* apparently refers to radar and radar plotting but possibly includes VHF/RT. The last sentence of paragraph (a) is very important. A contributory factor in many collisions in the past was that the navigating officer was in doubt whether risk of collision actually existed or not. The rule is now clear that if there is such a doubt, risk of collision shall be deemed to exist.

Paragraph (b) of rule 7 emphasises that *proper* use of radar shall be made including long-range scanning and also plotting or equivalent systematic observation. Though plotting may be done on a suitable range scale (usually 12 M), frequent switching over to a higher scale must be done in order to obtain early warning of approaching targets. This paragraph of the rule also acknowledges that automatic systems may be employed in lieu of manual plotting.

Paragraph (c) of rule 7 states "Assumptions shall not be made on the basis of scanty information, especially scanty radar information." Scanty radar information may consist of a single radar observation of a target (range and bearing), with or without the observation that the target is drawing forward or aft; the failure to carry out a radar plot; plotting with too short an interval for the range scale in use; plotting based on insufficient number of observations, etc.

Paragraph (d) of rule 7 emphasises that risk of collision should be deemed to exist if the *compass* bearing of an *approaching* vessel does not appreciably change. The term *compass bearing* is used to distinguish it from relative bearing. Relative bearing is entirely dependent on the ship's head at that time. When the display is unstabilised, the radar observer who relies on relative bearings instead of compass bearings, may fail to realise that the bearing of a target on the radar screen is changing considerably because of own ship's yaw or alteration of course and he may thus mistakenly assume that risk of collision does not exist.

Many radar observers fail to realise that constant compass bearing alone does not necessarily mean a collision risk - decreasing range is also essential (as explained later in chapter 36 under 'Constant bearing cases') and hence the importance of the words *approaching vessel* in rule 7(d).

Paragraph (d) (ii) of rule 7 also cautions that risk of collision may sometimes exist, even if the compass bearing of an approaching vessel appreciably changes, as in the case of a very large vessel, a tow or when approaching a vessel at close range.

Rule 8, which has the heading "Action to avoid collision", has five paragraphs of which only paragraph (b) requires elaboration here. Rule 8(b) states "Any alteration of course and /or speed to avoid collision shall, if the circumstances of the case admit, be large enough to be readily apparent to another vessel observing visually or by radar; a succession of small alterations of course and/or speed should be avoided". Many collisions have occurred in the past whereby a vessel executed a series of small alterations that were not obvious to the other vessel. This paragraph emphasises that the action taken should be substantial so that the action is clear to all vessels in the vicinity, visually and/or on the radar screen. Because of this, if the avoiding action is a course alteration, it should be at least 30° or more and if it is a speed reduction, at least 50%. When observing visually, a course alteration is more readily apparent than a speed alteration and it is hence preferred, in clear visibility.

Section II

This section, consisting of rules 11 to 18 (both inclusive), deals with the conduct of vessels in sight of one another and does not require any explanation from the point of view of radar.

Section III

This section, consisting only of rule 19, deals with the conduct of vessels not in sight of one another in restricted visibility, and states as follows:

(a) "This rule applies to vessels not in sight of one another when navigating in or near an area of restricted visibility.

(b) Every vessel shall proceed at a safe speed adapted to the prevailing circumstances and conditions of restricted visibility. A power-driven vessel shall have her engines ready for immediate manoeuvre.

(c) Every vessel shall have due regard to the prevailing circumstances and conditions of restricted visibility when complying with the Rules of Section I of this Part."

From paragraph (a) above, it is clear that rule 19 (and hence Section III) does *not* apply when vessels are in sight of one another. Paragraphs (b) and (c) emphasise that restricted visibility must be taken into consideration when deciding on safe speed and that, in restricted visibility, the ship's engines must be ready for immediate manoeuvre. Paragraphs (d) and (e) contain more substantial directives:

(d) "A vessel which detects by radar alone the presence of another vessel shall determine if a close-quarters situation is developing and/or risk of collision exists. If so, she shall take avoiding action in ample time, provided that when such action consists of an alteration of course, so far as possible the following shall be avoided:

(i) an alteration of course to port for a vessel forward of the beam, other than for a vessel being overtaken;
(ii) the alteration of course towards a vessel abeam or abaft the beam.

(e) Except where it has been determined that risk of collision does not exist, every vessel which hears, apparently forward of her beam, the fog-signal of another vessel, or which cannot avoid a close-quarters situation with another vessel forward of her beam, shall reduce her speed to the minimum at which she can be kept on her course. She shall if necessary take all her way off and in any event navigate with extreme caution until danger of collision is over".

Paragraph (d) clearly implies that not only must plotting be carried out (manually or automatically) to determine whether a close-quarters situation or collision is likely to occur, but also that early avoiding action *must* be taken.

Paragraph (d) prohibits certain course alterations (when the vessels are *not* in sight of one another in restricted visibility):

(i) Do *not* alter course to port for a vessel that is forward your beam. However, if you are overtaking another vessel, you may take early avoiding action by altering course to either side as per Rule 19(d). *Note*: Rule 13 (Overtaking) becomes applicable only when the vessels come in sight of one another.

(ii) Do not alter course towards a vessel that is on your beam or abaft your beam.

Paragraph (e) implies that if a fog signal is heard forward of the beam (from a vessel that is not visually seen), own ship should reduce speed to bare steerage-way and, if necessary, take all her way off. Own ship must navigate with extreme caution until the danger of collision is over. However, if the Master of the own ship is satisfied that there is no risk of collision, he need not reduce speed to bare steerage-way or take all the way off his ship when he hears a fog signal forward of the beam. Some of the reasons whereby the Master may decide that risk of collision does not exist between his ship and another which is forward of his beam may be:

(i) Where direct communication has been established between the vessels by VHF or RT, and identification is absolute, and the intention of each is known to the other.

(ii) Where both ships are proceeding along a narrow channel or traffic-lane.

(iii) Where, just before entering fog, the ships were visible to each other and the Master has observed that there is no risk of collision.

(iv) By radar plotting.

However, each of the foregoing cases should be supported by continuous radar plotting. The other ship may, at any time, alter course suddenly to avoid immediate danger or due to failure of engines, steering, etc., and only continuous radar plotting can ensure that risk of collision which develops suddenly is noticed in time to avert collision.

Paragraph (e) further implies that if it is determined (by radar plotting or other means) that a close-quarters situation, with another ship forward of own ship's beam, is unavoidable, then own ship should reduce speed to bare steerage-way and, if necessary, take all her way off. Own ship must navigate with extreme caution until the danger of collision is over.

Generally speaking, avoiding action may consist of an alteration of course to port or starboard (whichever is admissible under the rules), a reduction of speed or taking all way off the ship. An increase of speed is not generally resorted to (except to avoid immediate danger) because the own vessel would already be proceeding at a safe speed and any increase would result in a greater-than-safe speed.

In conclusion, few illustrations of suitable avoiding actions as per Rule 19 (in *restricted visibility* when vessels *are not in sight of one another*) are given below:

(a) For a vessel end-on, or nearly end-on, a reduction of speed would only delay, but not avoid, the close-quarters situation and/or collision. So a large alteration of course to starboard would be suitable, provided that there is enough sea room and provided that such a large alteration to starboard will not result in a close-quarters situation with another vessel. An alteration of course to port is prohibited, in this case, by Rule 19(d)(i).

(b) When a faster vessel is approaching from well abaft the beam, and risk of collision exists, the best action would be to alter course away from her (i.e., if she is approaching from the starboard quarter, alter course to port and vice versa) so as to bring the other vessel dead astern. Then increase the frequency of the fog signals and post a lookout aft. Alteration of course towards the approaching vessel, in this case, is prohibited by Rule 19 (d)(ii). A reduction of speed, in this case, may not have the desired effect - on the contrary, if might only advance the time of the close-quarters situation and/or collision. However, if the other vessel is approaching from abeam, or from just abaft the beam, reduction of speed may be preferable to an alteration of course away from the approaching vessel. This is because the necessary alteration of course would be very large and then the vessel would have to remain off course for a considerably long time until the danger of a close-quarters situation and/or collision is over.

(c) If a vessel is crossing from the starboard bow, on a collision course, alteration of course to port is prohibited by Rule 19 (d)(i). Alteration of course to starboard or reduction of speed are both permissible and either action seems reasonable. However, many shipmasters are reluctant to make large course alterations towards an approaching vessel, especially if it is not in sight and its distance is closing fast. Such masters would prefer to reduce speed.

(d) If a vessel is crossing from the port bow, on a collision course, alteration of course to port is prohibited by Rule 19(d)(i). A reduction of speed or an alteration of course to starboard are both permissible.

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Notes

Part IV
PLOTTING

CHAPTER 35

GENERAL IDEAS

ON RADAR PLOTTING

Radar plotting is the art of obtaining all necessary collision avoidance and navigational information from two or more observations of each target on a radar screen. It involves the construction of a triangle of relative velocities and, once properly understood, is very simple. Plotting may be basically divided into two parts - relative plotting and true plotting - and each is explained separately in this book, though they are the same in basic principle.

When plotting *on paper*, any problem may be worked using a relative plot or a true plot, regardless of whether the observations were made on a RM or a TM display. This is because the radar gives correct bearings and ranges, at all times, regardless of the type of presentation in use.

However, when plotting on a reflection plotter, a relative plot would have to be made when using RM and a true plot when using TM.

The basics of plotting should be thoroughly understood by practice plots on specially printed plotting sheets and later on, whilst out at sea, plotting may be done directly on the radar screen.

Though plotting has been highly simplified by the invention of computerised semi-automatic and automatic plotting devices, the knowledge of basic manual plotting is absolutely essential.

For radar plotting practice, the following equipment is recommended:

(i) Plotting sheets.
(ii) Pencil (preferably HB or H).
(iii) Eraser.
(iv) Drawing compass.
(v) A 30 cm ruler and a large setsquare, or a parallel ruler, for drawing parallel lines.

A speed-time table, which gives the distance travelled in various intervals at various speeds, will be very useful. One such table is included at the end of this book.

A pair of dividers will be an asset but is not necessary as the compass can be used just as well.

A protractor is not necessary as the plotting sheet itself can be used for measuring angles, and that too, with greater accuracy because of its larger diameter.

Though plotting may also be done ship's head-up, the north-up plot has been shown throughout, owing to its easier comparison with a chart and also with a gyro-stabilised display.

The interval between two observations of a radar plot is called the plotting interval. This depends on the range scale in use, the speed of own ship, the speeds of targets, etc., but, most often, 6 or 12 minutes are used, being 0.1 or 0.2 of an hour.

In the worked examples of this book, the following letters are used to denote various points on the plotting sheet:

C: Centre of plotting sheet, representing the origin of the display, regardless of whether the display is actually centred or off-centred.

O: Relative position of target at the beginning of the plotting interval.

A: Relative position of target at the end of the plotting interval.

OA: The relative movement of the target across the radar screen. This line produced is called the line of approach.

N: The closest point of approach (CPA). CN is perpendicular to OA produced.

CN: Nearest approach or range at CPA.

WO: Own ship's course and distance during the plotting interval.

WA: Target's course and distance during the plotting interval.

Aspect of a target is the relative bearing of the own vessel *from* the target (or the angle between the target's course and the theoretical line of sight), expressed in degrees between 0° and 180° red or green. Red means that the own vessel is on the target's port side and green, the target's starboard side (see para 5 of chapter 18). Knowledge of the bearing of a target from the own vessel and the aspect gives an idea of the angle of approach between the two ships, which is necessary from the ROR point of view.

The closest point of approach (CPA) is that point where the range of the target would be minimum assuming that both, own ship and target, maintain the courses and speeds that they had during the plotting interval. The range at CPA is also called 'Nearest approach'.

All bearing are expressed in the three figure notation and are either true or relative, measured from the own vessel.

The scale used to plot the position on the plotting sheet should be as large as possible to ensure greater accuracy. Even if a position falls outside the printed range circles, it may be used as such so long as it falls on the plotting sheet. When more than one target is being plotted on the same plotting sheet, it is better to use the same scale for all of them, in order to reduce the chances of error.

When an alteration of course and/or speed is made, by own vessel or by a target, the action may be considered to be instantly effective, unless otherwise stated (see under 'Performance delay' in chapter 38).

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CHAPTER 36

RELATIVE PLOTTING -

PASSIVE DERIVATIONS

Worked example 1

While on a course of 340°(T) at 15 knots, a target on the radar screen was observed at 0800 to bear 020°(T) at a range of 12 M. At 0812, it bore 017°(T) at 9 M range. Find the time and range at CPA, course and speed of target and the aspect at 0812.

36.1 To find the distance off at CPA

(i) On the circumstance of the plotting sheet, mark the course of the own ship with an arrow (such that the zero of the graduated circle represents true north) and enter the speed of own ship next to it.

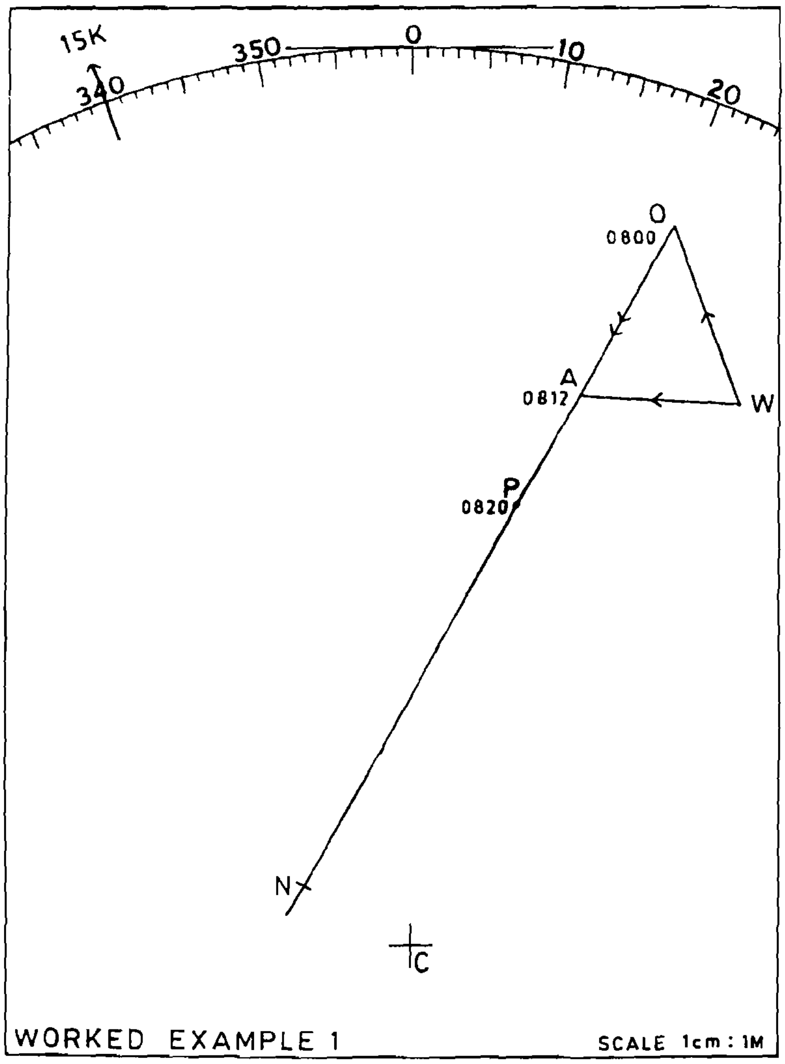
(ii) From C, the centre of the plotting sheet, lay off the first bearing and range and call that point O. This point is called the origin of the plot (not to be confused with the origin of the trace on the display).

(iii) From C, lay off the bearing and range at the end of the plotting interval (12 minutes in this case) & call that point A.

(iv) Enter the respective times of observation next to O & A.

(v) Join OA and produce it beyond C. This is the line of approach. If both, own vessel and target, maintain their respective courses and speeds, the relative movement of the target will be along this line.

(vi) Drop a perpendicular from C to the line of approach and call the point of intersection N. This is the closest point of approach (CPA).



(vii) The distance CN is the nearest approach, or range at CPA. In this case, CPA range is 1.9 M.

Note: (1) The target passes ahead of own ship, own ship's course being 340°(T).

(2) For the sake of familiarisation, note that the range when the target would bear 000°(T) is 4 M; 270°(T) is 2.2 M; right ahead is 2.5 M; abeam to port is 3 M.

(3) The reading where the line CN, if produced, would meet the graduated ring of the plotting sheet would be the true bearing of the target when it is at CPA. In this case, bearing at CPA is 300°(T).

36.2 To find the time of CPA

The distance OA was relatively covered by the target during the plotting interval. Hence find how long it would take to cover the distance AN.

In this case

$$\text{Time to CPA from 0812} = \frac{AN}{OA} \times \text{plotting interval}$$

$$= \frac{8.8}{3} \times 12 = 35 \text{ minutes.}$$

$$\therefore \text{CPA time} = 0847.$$

Note: (1) For this purpose, AN and OA may both be measured in any convenient units (miles or centimetres) as it makes no difference to the answer.

(2) The time should be squared off to the nearest whole minute.

36.3 To find the course and speed of target

(i) At O, draw a line parallel to the own ship's *reversed* course.

(ii) On this line, cut off OW equal to the distance travelled by the own ship during the plotting interval. In this case, 12 minutes at 15 knots is 3 M. Join WA.

(iii) In triangle WOA, WO represents the true course and distance covered by the own ship during the plotting interval, WA represents the course and distance covered by the target during the same interval and OA represents the relative direction and rate of approach.
(iv) Using the plotting sheet as a compass rose, read off the direction of WA, the course of the target. In this case, course of target comes to 273°(T).
(v) During the plotting interval (12 minutes in this case), the target has covered a distance of WA (2.5 M in this case). Hence find the speed of the target. This comes to 12.5 knots.

Note: The speed obtained may be squared off to one decimal place.

36.4 To find aspect at the last observation

The definition of aspect is given in chapters 18 and 35. The aspect of a target changes as the plot progresses but will remain constant only if the bearing of each ship, from the other, remains constant (see under 'Constant bearing cases' at the end of this chapter).

The angle between WA produced and AC is the aspect at the end of the plotting interval (0812 in this case). The most common mistake, made in haste, is measuring the angle between WA produced and AN instead of AC.

However, it is neither necessary to produce WA nor to use a protractor. Aspect can easily be computed as follows:

Bearing of A from C =	017°(T)
	± 180°
Bearing of C from A =	197°(T)
Course of target =	273°(T)

∴ Own ship lies 76° on target's port side

∴ Aspect at 0812 = 76° Red.

36.5 Report to make to the Master

A target should be reported to the Master in stages, as and when more information becomes available. The target, in worked example 1, should be reported as follows:

Report at 0800: Target bearing 020°(T); range 12 M.
Report at 0806: Target bearing 019°(T) drawing forward; range 10.5 M decreasing.
Report at 0812: Target bearing 017°(T) drawing forward; range 9 M decreasing; CPA 1.9 M in 35 minutes (or at 0847); target's course and speed 273°(T) 12.5 knots; aspect Red 76°.

Note: (1) Drawing forward means that the change of target's bearing (in this case from 020° to 017°) is towards the own ship's course of 340°(T). For example, while on the same course, if the bearing changed from 020° to 025° it is said to draw aft and from 240° to 246° it is said to draw forward.

(2) If there is more than one target to report, each is given an international phonetic name such as Alpha, Bravo, Charlie, etc.

36.6 To predict the position of the target

Suppose, in worked example 1, it is desired to predict the position (P) of the target at 0820 i.e., 8 minutes after the last known position. During the plotting interval, the target has relatively moved through distance OA. Hence calculate the relative distance moved during the desired interval. This distance is AP, along OA produced. Thus the predicted position P may be laid off on the plotting sheet.

$$\text{In this case, AP} = \frac{\text{Desired interval}}{\text{Plotting interval}} \times \text{OA}$$

$$= \frac{8}{12} \times 3 = 2\ \text{M.}$$

36.7 To predict the aspect

If, in worked example 1, it is desired to predict the aspect at 0820, first predict position P of the target at 0820 and measure its bearing from C. Then proceed as follows:

	Bearing of P from C	= 013°(T)
∴	Bearing of C from P	= 193°(T)
	Course of target	= 273°(T)
∴	Own ship lies	= 80° on target's port side.
∴	Aspect at 0820	= 80° Red.

36.8 To find the set and drift of current

The set and drift of current can be obtained by plotting the movement, on the radar screen, of a target that has been definitely identified as a stationary object (such as a point of land, a light-vessel, a vessel at anchor, etc.). Points O and A are plotted and point W is inserted in the usual manner. If there is no current, W and A will coincide (i.e., WA will be zero). If a current did exist, W and A would be separate. The direction AW (not WA) is the set of current.

The reason for this can be easily illustrated by an example. If a ship, which is underway but stopped and making no way through the water, observes a lighthouse to move NE, it must be because the current is setting the ship SW.

The distance AW is the drift of current during the plotting interval and is easily converted into knots.

The set and drift of current are not taken into account whilst plotting moving targets because it is reasonably assumed that all moving targets seen on the radar screen are near enough to experience the same set and drift. Any error due to this assumption is insignificant because the relative movement on the radar screen, from which the nearest approach (CPA range) and time are obtained, is the final resultant of the target's course and speed, the reversed course and speed of own ship and any such difference in current experienced.

36.9 Constant bearing cases

An inexperienced radar observer is likely to jump to the conclusion that whenever the bearings of a target are constant, risk of collision exists. This paragraph is intended to emphasise that change of range also is important as illustrated in the following cases:-

(i) Constant bearing and *increasing range* means that the other vessel does not constitute a collision risk if both own ship and target maintain their respective courses and speeds.

(ii) Constant bearing and *constant range* means that the courses and speeds of target and own ship are the same.

(iii) Constant bearing and *decreasing range* means that the own vessel and the target are on collision courses.

Exercise 1

Compile a full report of each target in problems 1 to 6.
(T) indicates true bearing. (Rel) indicates relative bearing.

Question No.	Own Course (T)	Own Speed (knots)	Ship's time	Bearing	Range (miles)
1	042°	15	0640	351°(T)	11.0
			0652	355°(T)	7.1
2	270°	8	1620	305°(T)	7.0
			1630	306°(T)	5.4
3	146°	14	1220	073°(Rel)	13.0
			1235	068°(Rel)	9.0
4	180°	6	2104	030°(T)	6.5
			2116	036°(T)	4.6
5	334°	16	0418	076°(Rel)	24.0
			0424	078°(Rel)	22.0
			0430	081°(Rel)	19.8
6	114°	10	0912	142° (T)	11.0
			0919½	145½° (T)	9.9
			0927	149½° (T)	8.9

7. Own course 217°(T) at 12 knots.

Time	Target A	Target B	Target C
0020	214°(T) 11.7M	260°(T) 10.0M	170°(T) 12.0M
0026	218°(T) 10.8M	260°(T) 10.0M	170°(T) 10.7M
0032	223°(T) 9.9M	260°(T) 10.0M	170°(T) 9.4M

Report each target at 0032.

8. Whilst steering 076°(T) at 13 knots, a lighthouse bore 046°(T) 4.5 M off at 0800. At 0809, it bore 029°(T) 2.5 M off.
   Find (i) Range, bearing and time at CPA.
   (ii) Range, bearing and time when abeam.
   (iii) Set and rate of current.

9. At 0200, a light vessel bore 225°(T) 3.0 M off.
   At 0230, it bore 140°(T) 2.0 M off. If the own ship's course and speed were 282°(T) and 6 knots, find:
   (i) CPA range, bearing and time.
   (ii) Beam range, bearing and time.
   (iii) Set and rate of current.
   If a buoy was detected right ahead 3 M off at 0230, find:
   (iv) Its time and range at CPA and state on which side of own ship it would pass.

10. Whilst steering 005°(T) at 18 knots, the following observations were made on the radar screen:

Time	Lightvessel A	Target B	Target C
1300	126° (T) 7.6M	310° (T) 11.5M	345°(T) 10.0M
1306	135½°(T) 9.0M	307½° (T) 9.5M	342°(T) 8.1M
1312	142° (T) 10.4M	304° (T) 7.5M	338°(T) 6.4M

Find (i) Set and rate of current.
(ii) CPA range and time of all three targets.
(iii) Course, speed and aspect (at 1312) of moving targets.

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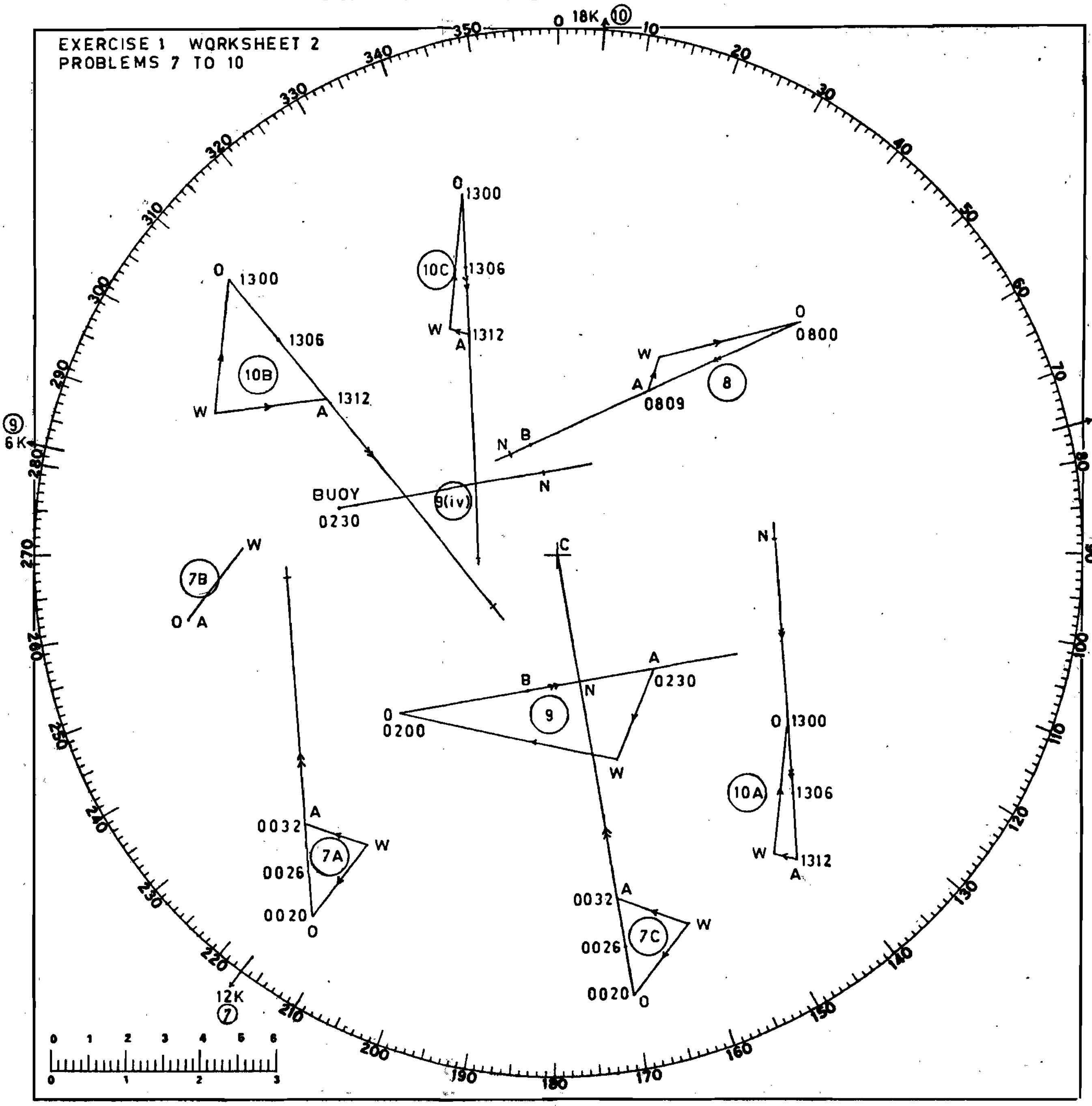
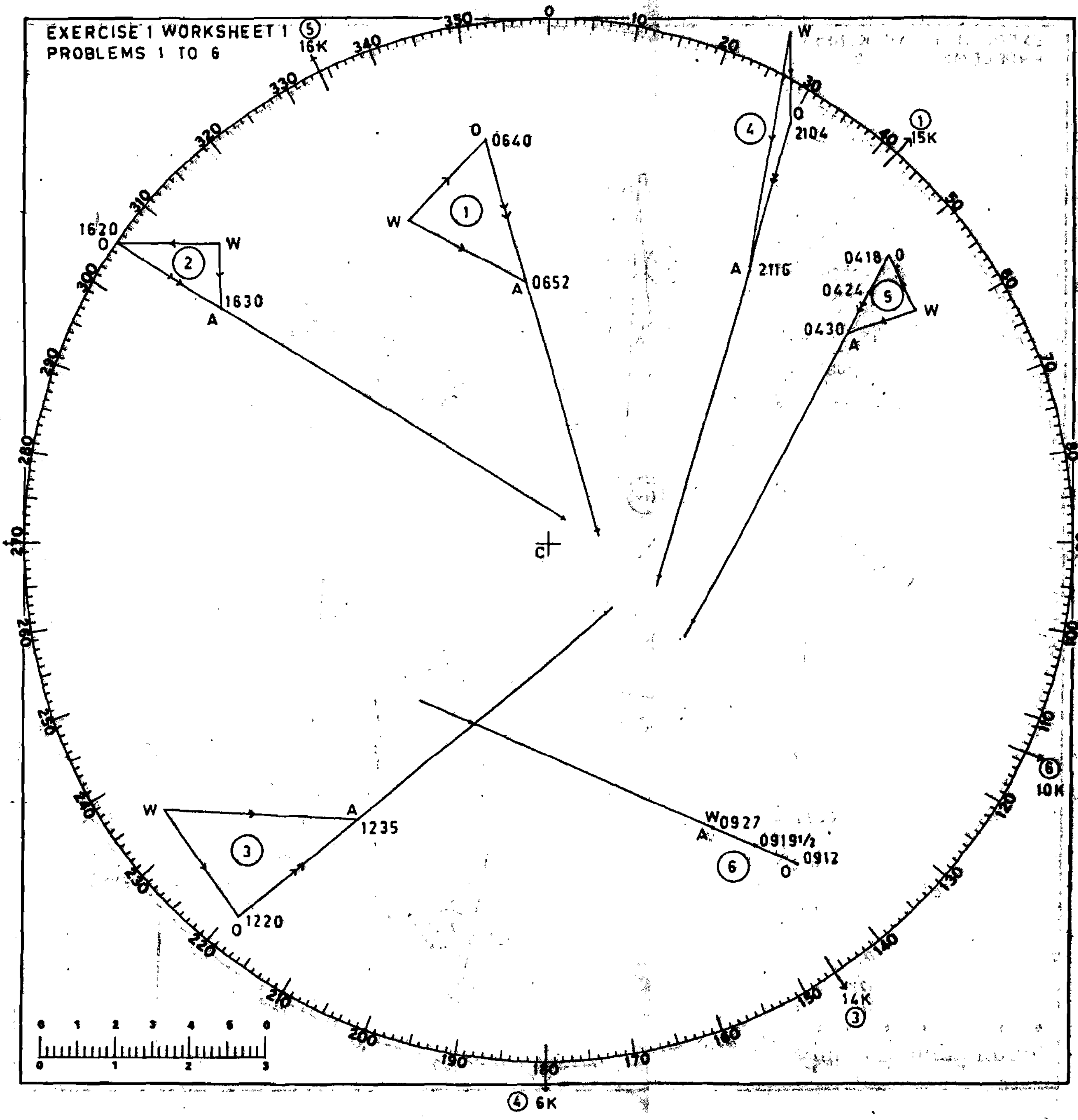
RADAR PLOTTING SHEET



RADAR PLOTTING SHEET



Answers to exercise 1

No.	Bearing	Drawing	Range	Increasing/	CPA		Target's		
	(True)		(M)	Decreasing	Range	Time	Course	Speed	Aspect
1	355°	Forward	7.1	Decreasing	1.4	0713	117°	17.5	58°G
2	306°	Aft	5.4	Decreasing	0.4	1704	179°	5.1	53°R
3	214°	Forward	9.0	Decreasing	2.5	1307	093°	20.4	59°R
4	036°	Forward	4.6	Decreasing	1.6	2142	190°	16.0	26°G
5	055°	Aft	19.8	Decreasing	9.0	0516	252°	19.0	17°R
6	149½°	Aft	8.9	Decreasing	5.2	1011	Stationary target		
7	A 223°	Aft	9.9	Decreasing	7.3	0104	289°	9.0	114°G
	B 260°	Constant	10.0	Constant	-	-	217°	12.0	137°R
	C 170°	Constant	9.4	Decreasing	0.0	0115	290°	10.0	60°G

8. (i) CPA 1.5 M, 335°(T) at 0817.
   (ii) Abeam 1.55 M, 346°(T) at 0816.
   (iii) Set 018°(T), rate 3.3 knots.

9. (i) CPA 1.75 M, 170°(T) passed at 0221.
   (ii) Abeam 1.85 M, 192°(T) passed at 0215.
   (iii) Set 201°(T), rate 2.6 knots.
   (iv) Buoy CPA 1.1 M at 0254 on starboard side.

10. (i) Set 285°(T), rate 3 knots.
    (ii) CPA A: 5.8 M passed at 1245.
    B: 2.2 M at 1333.
    C: 2.1 M at 1331.
    (iii) Course, speed, aspect at 1312
    A: Stationary object.
    B: 083°(T), 15 knots, 41°G.
    C: 105°(T), 3 knots, 53°G,
    OR a stationary object.

CHAPTER 37

RELATIVE PLOTTING -

ACTION TAKEN BY TARGET

37.1 To find the action taken by a target

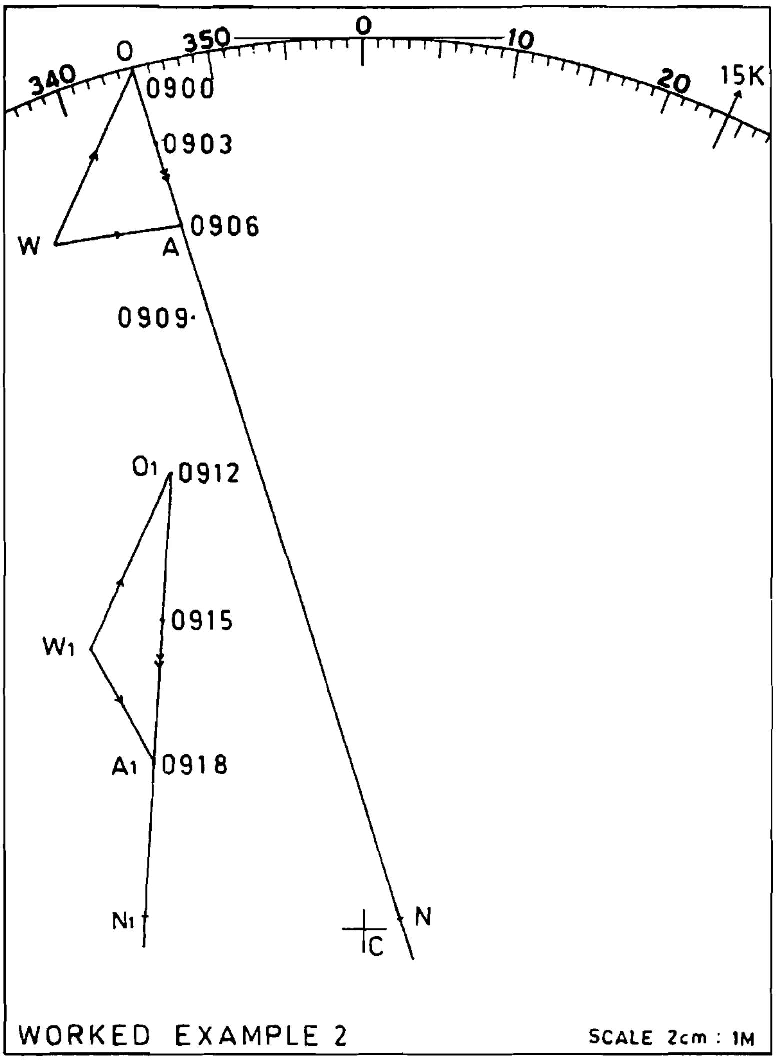
When given a series of observations, the action taken by a target can be easily determined. If both, the direction and the rate of approach, remain constant, no action has been taken by the target during that period. A change in the direction of approach indicates an alteration of course and/or speed by target. It is possible, under rare circumstances, that a target alters course *and* speed and the resultant direction of approach remains the same as before, but the rate of approach will then not be the same.

Worked example 2

While steering 024°(T) at 15 knots, the following observations of a target were made on the radar screen:

Time	Bearing (T)	Range (M)
0900	345°	7.0
0903	345°	6.4
0906	345½°	5.75
0909	344½°	5.0
0912	337°	3.9
0915	327°	2.9
0918	308°	2.1

Find (a) The initial CPA range and time.
(b) The initial course and speed of the target.
(c) The new CPA range and time.
(d) The action, if any, taken by the target.


0
350
10
340
20
15K
O
0900
0903
W
A
0906
0909
O1
0912
0915
W1
A1
0918
N1
C
N
WORKED EXAMPLE 2
SCALE 2cm : 1M

WORKING

(i) Plot all the given observations on the plotting sheet.

(ii) Draw a straight line through as many of the earlier observations as possible, calling the first one O and the last one, on this line, A.

(iii) This line OA is the initial line of approach. Produce OA and obtain the range and time of CPA, as usual. This is answer (a) of the worked example. CPA range 0.3 M at 0934, target passing ahead of own ship.

(iv) Complete the relative velocity triangle WOA as usual and obtain the initial course and speed of the target. This is answer (b) of the worked example. Initial course and speed of target 081°(T) 10 knots.

(v) Draw a straight line through as many of the subsequent observations as practicable. On this line, call the first position O_1 and the last position A_1. O_1A_1 is the new line of approach. Produce this line and obtain the new range and time of CPA. This is answer (c) of the worked example. New CPA range 1.7 M at 0921, target passing astern of own ship.

(vi) Draw new relative velocity triangle $W_1O_1A_1$ and obtain the new course and speed of target. In this case, new course and speed: 151°(T) 10 knots.

(vii) Compare the initial course and speed of the target with its new course and speed and obtain the alteration made by it. This is answer (d) of the worked example - alteration of course 70° to starboard, speed maintained at 10 knots. The time of alteration is anything between the last observation on the initial line of approach (A) and the first observation on the new line of approach (O_1). In this case, the action was taken between 0906 and 0912.

Note: (1) The two lines of approach should be drawn through as many observed positions as possible, to ensure greater accuracy.

(2) The plotting interval may be different for the two relative velocity triangles.

(3) Each triangle is treated as if it is part of a separate problem.
(4) In comparing the initial and the final courses & speeds of the target, small alterations in course (less than about 5°) and of speed (less than about 2 knots) may be assumed to be due to inaccuracies inherent in plotting and hence ignored.
(5) It is likely that one or two positions in between may not fall on either of the two lines of approach (like the 0909 position in the worked example). This is probably because the action had been commenced but had not been completed by the target, during those observations by own ship.

37.2 To find the new CPA range and time, given an alteration of speed and/or course by target.

In the relative velocity triangle WOA, WA represents the course and distance covered by the target during the plotting interval. Hence, any action taken (course and/or speed alteration) by the target will shift A to A_1 and the new triangle would be WOA_1. The new line of approach would be OA_1, but becoming effective only when the target takes the action.

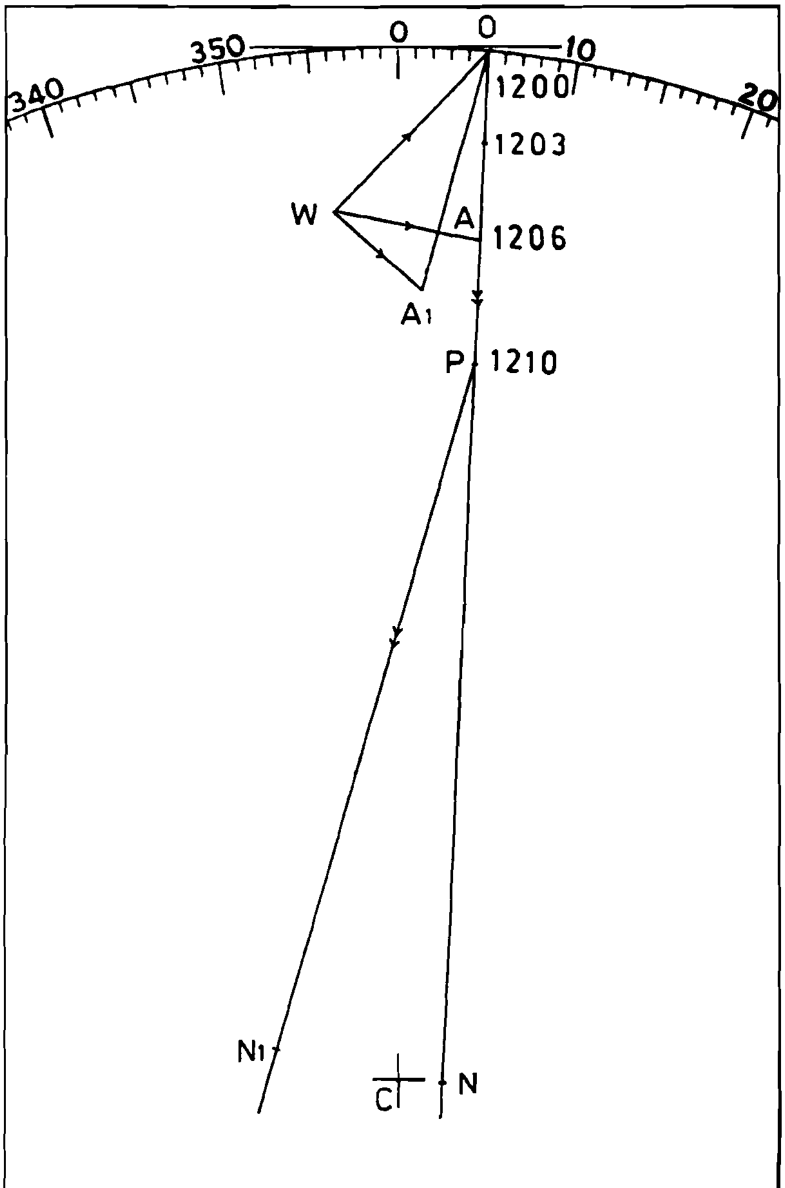
Since W is a common point for both WA and WO, it is kept fixed in the relative velocity triangle, regardless of any action taken by target or by own vessel.

The foregoing can be clearly illustrated by worked example 3:

Worked example 3

Whilst steering 044°(T) at 15 knots, the following observations were made on the radar screen:

Time	Bearing (T)	Range (M)
1200	005°	7.0
1203	005°	6.4
1206	005½°	5.75



WORKED EXAMPLE 3 SCALE 2cm : 1M

Find (a) The range and time of CPA
(b) The course and speed of target.

At 1207, the target indicates its intention to take action at 1210 by altering her course 30° to starboard and also reducing her speed by 4 knots. Find (c) the new CPA range and time.

WORKING

As explained in worked example 1 (in chapter 36) and as shown in the foregoing figure,

(a) CPA range and time = 0.3 M at 1234, target passing ahead of own vessel.
(b) Course and speed of target = 101°(T) at 10 knots.

To find new CPA range and time

(i) Since the time of action by target is 1210, the original conditions prevail until then. Hence predict position P of the target, at 1210, along OA produced, as explained in the previous chapter under 36.6.
(ii) In triangle WOA, lay off the new course of the target, from W, and cut off distance WA_1 that the target would do, at the new speed, during the same number of minutes as the plotting interval. In this case, at a new speed of 6 knots in 6 minutes, WA_1 = 0.6 mile on the new course of 131°(T).
(iii) Join OA_1, the new direction and rate of approach, which will become effective when the target takes the action. Since the action is taken at 1210, draw a line parallel to OA_1 through P and produce it beyond C. This is the new line of approach, from 1210 onwards.
(iv) From C, drop a perpendicular to this new line of approach to intersect it at N_1.
(v) The new CPA range is CN_1. In this case, new CPA range is 1.35 M and the target is now going to pass astern of own vessel.
(vi) The distance OA_1 will be relatively covered by the target during a number of minutes equal to the plotting

interval. Hence compute how long it would take to cover the distance PN_1.

In this case

$$\text{Time to new CPA from 1210} = \frac{PN_1}{OA_1} \text{ x plotting interval}$$

$$= \frac{4.75}{1.6} \text{ x 6 x 18 minutes.}$$

∴ New CPA time = 1228.

Note: (1) If, in this question, it was stated that the target altered course (and not speed) at 1210, then the only change in the procedure would be to make distance WA_1 equal to WA, as the new distance covered by the target, in 6 minutes, would be the same as before.

(2) If, in this question, it was stated that the target altered speed (and not course) at 1210, the distance WA_1 must be laid off in direction WA (same course as before).

Exercise 2

1. Own course 340°(T) at 12 knots.

Ship's time	Bearing (T)	Range (M)
0500	285°	7.0
0503	285½°	6.15
0506	286°	5.3

Report the target at 0506. If subsequent observations were as follows, state what action, if any, has been taken by the target and thence the new CPA range and time:

Ship's time	Bearing (T)	Range (M)
0509	285½°	4.4
0512	280°	3.5
0515	272°	2.5
0518	253°	1.6

2. Own course 090°(T) at 8 knots.

Ship's time	Bearing (T)	Range (M)
0930	015°	8.00
0933	015°	7.25
0936	015°	6.50

Report the target at 0936. If subsequent observations were as follows, state what action, if any, has been taken by target and also the new CPA range and time:

Ship's time	Bearing (T)	Range (M)
0939	014½°	5.8
0942	013½°	5.4
0945	011½°	4.9
0948	009°	4.4
0951	006½°	3.85

3. Whilst steering 130°(T) at 15 knots, the following observations of a target were made on the radar screen:

Ship's time	Bearing (T)	Range (M)
0200	100°	14.0
0206	099°	11.0
0212	097°	8.0
0218	093½°	5.6
0224	088°	3.5
0230	065°	1.6

State what action, if any, has been taken by the target and the subsequent CPA range and time.

4. Whilst on a course of 103°(T) at 10 knots, the following observations, of a target, were made on the radar screen:

Ship's time	Bearing (T)	Range (M)
1630	228½°	6.5
1636	228°	5.75
1642	227½°	5.0

Report the target at 1642.
It at 1652, the target altered course 20° to port, find the new CPA range and time.

5. Whilst steering 182°(T) at 16 knots, the following observations of a target were made on the PPI:

Ship's time	Bearing (Rel)	Range (M)
2040	348°	14.0
2046	349°	11.3
2052	350°	08.6

Report the target at 2052.
If at 2055, the target altered course to starboard by 35°, find the range and time at the new CPA.

6. Whilst steering 129°(T) at 6 knots, the following observations of a target were made on the radar screen:

Ship's time	Bearing (T)	Range (M)
0200	050°	6.0
0212	050°	4.2

Report the target at 0212
If at 0220, the target reduced speed to 6 knots, find the new CPA range and time.

7. Own course 005°(T) at 12 knots.

Time	Bearing (Rel)	Range (M)
0100	285°	7.0
0106	285½°	5.5

Report the target at 0106.
If at 0116 the target reduced speed to 10 knots, find the new range and time at CPA.

8. Own course 018°(T) at 10 knots.

Ship's time	Bearing (T)	Range (M)
1100	143½°	6.5
1112	142½°	5.0

Find: (i) CPA range and time.
(ii) Course and speed of target.
If at 1122, the target altered course to port by 20°, find (iii) the new CPA range and time.
If at 1137, the target resumed her original course and speed, find (iv) the new CPA range and time.
In each case, (i) (iii) and (iv), state on which side, of own vessel, the target would pass.

9. Own course 060°(T) at 6 knots.

Ship's time	Bearing (T)	Range (M)
0340	341°	6.0
0352	341°	4.2

Find: (i) CPA range and time.
(ii) Course and speed of target.
If at 0400 the target reduced speed to 6 knots, find (iii) the new CPA range and time.
If at 0416 the target resumed its original speed, find (iv) the new CPA range and time.

10. Whilst steering 080°(T) at 10 knots the following observations were made on the radar screen:

Ship's time	Bearing (T)	Range (M)
0610	010°	14.0
0622	013°	11.0

Find: (i) CPA range and time.
(ii) Course and speed of target.
If at 0625, the target reduced speed to 12 knots, find (iii) the new CPA range and time.
If at 0640, the target altered course to starboard by 30°, find (iv) the new CPA range and time.

Answers to exercise 2

1. Report at 0506: Crossing vessel bearing 286°(T) drawing forward, range 5.3 M decreasing, CPA range 0.4 M at 0525, target's course and speed 058°(T) 15 knots, aspect green 48°. Target's new course 088°(T) i. e., altered 30° to starboard soon after 0506. New CPA range 1.15 M at 0521.

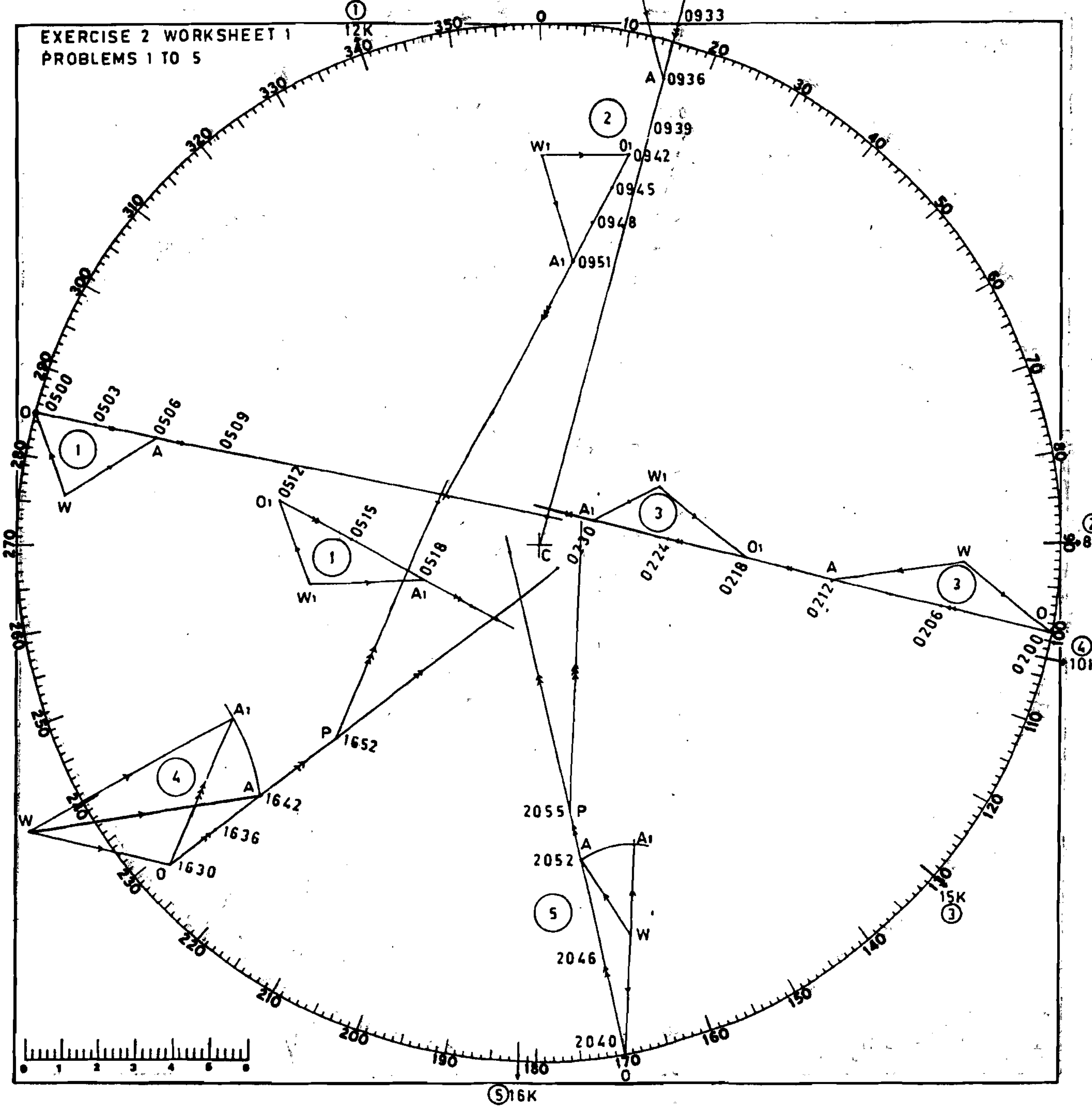
2. Report at 0936: Crossing vessel bearing 015°(T) constant, range 6.5 M decreasing, collision at 1002, target's course and speed 164°(T) 15 knots, aspect green 31°. Target's new speed 10 knots i.e., reduced speed by 5 knots soon after 0936. New CPA range 1.4 M at 1011.

3. 0200 to 0212: Target's course 262°(T) speed 18 knots. 0218 onwards: Target's course 244°(T) speed 10 knots. Sometime between 0212 and 0218, target has altered course 18° to port and also reduced speed by 8 knots. CPA range 1.0 M remains unaffected but time of CPA changes from 0228 to 0234.

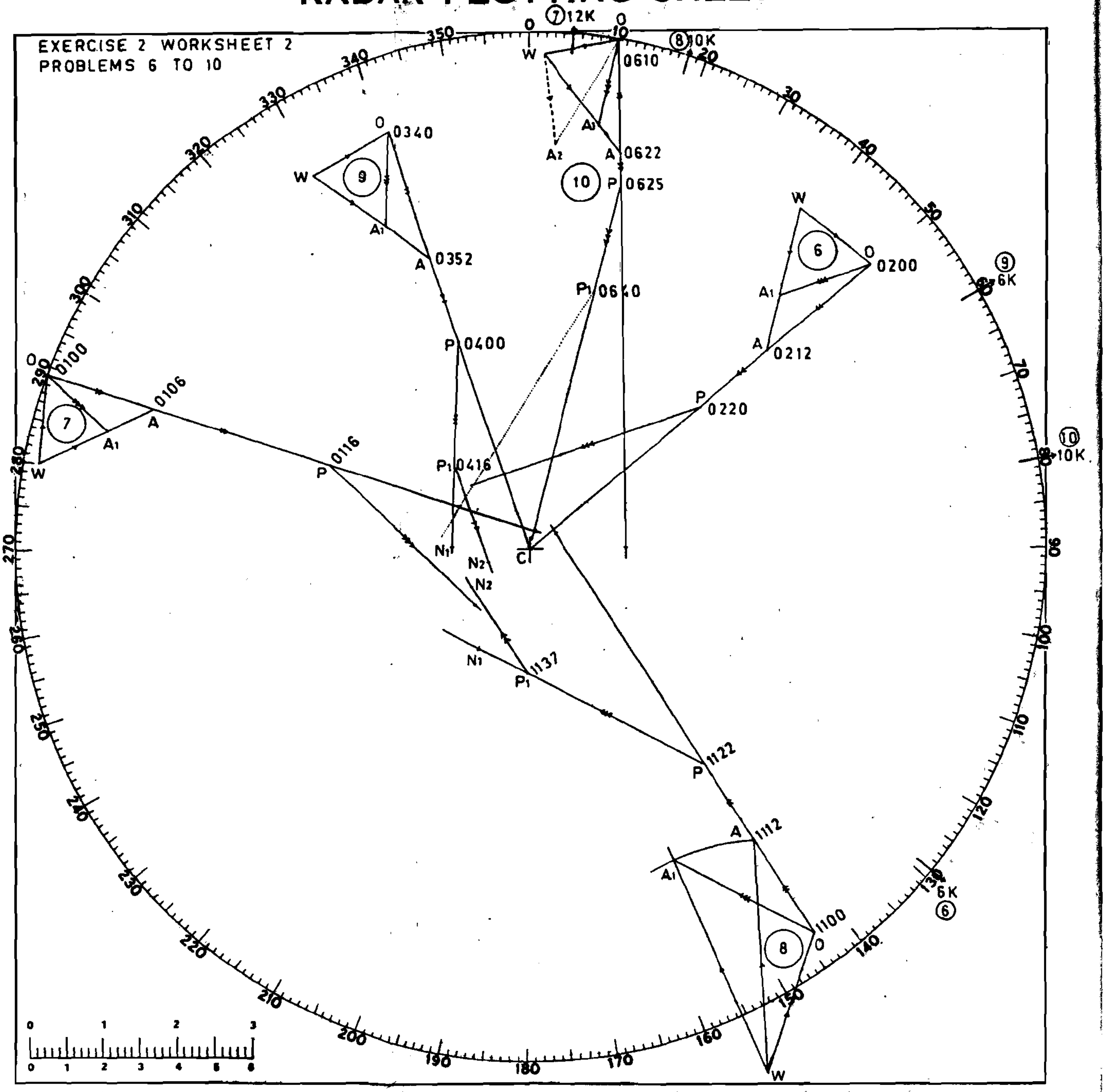
4. Report at 1642: Overtaking vessel bearing 227½°(T) drawing forward, range 5 M decreasing, CPA range 0.4 M at 1722, target's course and speed 081°(T) 16 knots, aspect red 33.5°. New CPA range 1.5 M at 1711.

5. Report at 2052: Crossing vessel bearing 172°(T) drawing forward, range 8.6 M decreasing, CPA range 0.8 M at 2111, target's course and speed 327°(T) 12.5 knots, aspect green 25°. New CPA range 1.1 M at 2110.

RADAR PLOTTING SHEET



RADAR PLOTTING SHEET



6. Report at 0212: Crossing vessel bearing 050°(T) constant, range 4.2 M decreasing, collision at 0240, target's course and speed 193°(T) 10 knots, aspect green 37°.
   New CPA 1.1 M at 0246.

7. Report at 0106: Crossing vessel bearing 290½°(T) drawing forward, range 5.5 M decreasing, CPA range 0.25 M at 0128, target's course and speed 065°(T) 17 knots, aspect green 45½°.
   New CPA 1.1 M at 0131.

8. (i) CPA 0.4 M at 1152 (on starboard bow).
   (ii) Course 356°(T) at 15.75 knots.
   (iii) CPA 1.5 M at 1141 (on port quarter).
   (iv) CPA 0.95 M at 1148 (on port quarter).
   (v) Stated above in brackets.

9. (i) Collision at 0420.
   (ii) Course 124°(T) speed 10 knots.
   (iii) CPA 1.0 M at 0427.
   (iv) CPA 0.6 M at 0425.

10. (i) CPA 2.6 M at 0703.
    (ii) Course 143°(T) speed 17 knots.
    (iii) Collision at 0717.
    (iv) CPA 2.3 M at 0705.

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CHAPTER 38

RELATIVE PLOTTING -

ACTION TAKEN BY OWN SHIP

38.1 To find the new CPA range and time, given an alteration of course and/or speed by own ship.

In the relative velocity triangle WOA, WO represents the course and distance covered by the own ship during the plotting interval. Hence any action taken (course and/or speed alteration) by the own vessel will shift O to O_1 and the new triangle would be WO_1A. The new line of approach would be O_1A but becoming effective only when the own ship takes the action.

Since W is a common point for both WO and WA, it is kept fixed in the relative velocity triangle, regardless of any action taken by the own vessel or by the target.

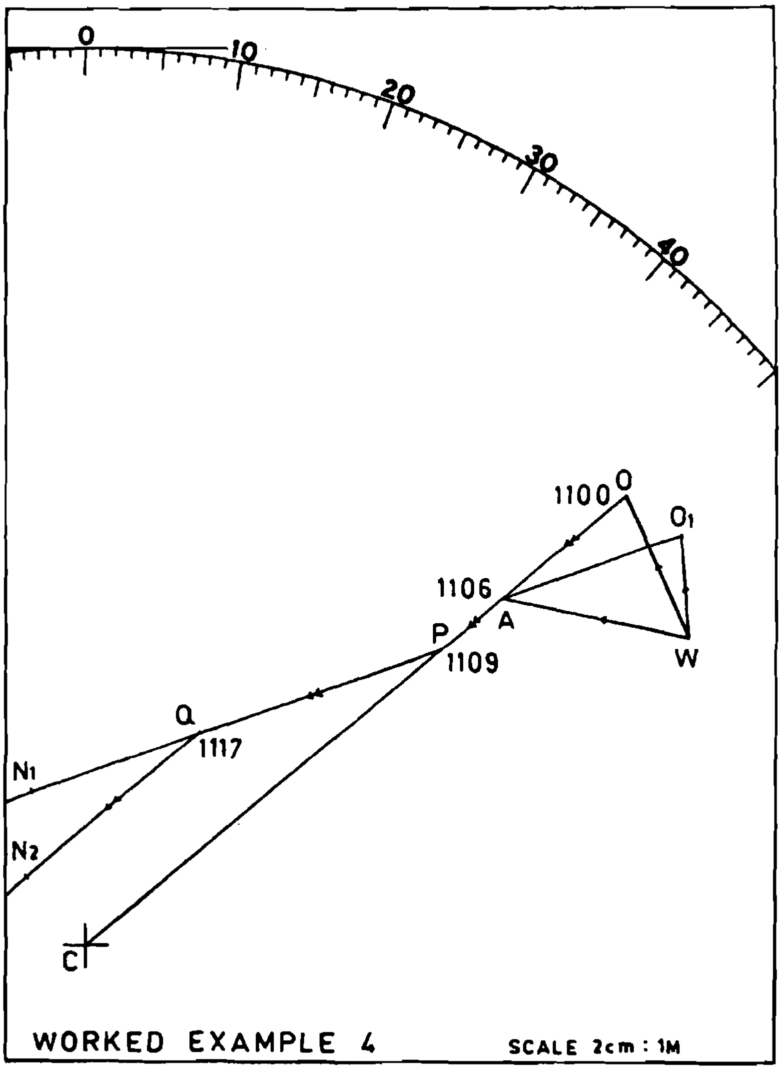
The foregoing is clearly illustrated by worked example 4:

Worked example 4

Whilst steering 336°(T) at 12 knots, the following observations of a target were made on the radar screen:

Ship's time	Bearing (T)	Range (M)
1100	050°	5.50
1106	050°	4.25

Find (a) Time and range at CPA.
(b) Course and speed of target.
(c) Aspect at 1106.



At 1109, own ship altered course 20° to starboard and reduced speed to 8 knots. Find (d) the new range and time at CPA.

As explained in worked example 1 (in chapter 36) and as shown in the foregoing figure,

(a) Collision at 1126.
(b) Course and speed of target: 282°(T) 15 knots.
(c) Aspect at 1106: red 52°.

To find (d) the new CPA range and time

(i) Since the time of action by own ship is 1109, the original conditions prevail until then. Hence predict position P of the target, at 1109, along OA produced, as explained earlier under paragraph 36.6 in chapter 36.
(ii) In triangle WOA, lay off the new course of own ship, from W, and cut off distance WO_1 that the own ship would do, at the new speed, during the same number of minutes as the plotting interval. In this case, at a new speed of 8 knots, in 6 minutes, WO_1 = 0.8 M on the new course of 356°(T).
(iii) Join O_1A, the new direction and rate of approach, which will become effective when the own ship takes the action. Since the action is taken at 1109, draw a line parallel to O_1A through P and produce it beyond C. This is the new line of approach, from 1109 onwards.
(iv) From C, drop a perpendicular to this new line of approach to intersect it at N_1.
(v) The new CPA range is CN_1. In this case, new CPA range is 1.3 M, and target is going to pass ahead of own ship.
(vi) The distance O_1A will be relatively covered by the target during a number of minutes equal to the plotting interval. Hence compute how long it will take to cover the distance PN_1.

In this case,

$$\text{Time to CPA from 1109} = \frac{PN_1}{O_1A} \times \text{plotting interval}$$

$$= \frac{3.45}{1.5} \times 6 = 14 \text{ minutes.}$$

$\therefore$ CPA time = 1123.

Note: (1) If, in this question, if was stated that the own ship altered course (and not speed) at 1109, then the only change in the procedure would be to make distance WO_1 equal to WO, as the new distance covered by the own ship, in 6 minutes, would be the same as before.

(2) If, in this question, it was stated that the own ship altered speed (and not course) at 1109, the distance WO_1 must be laid off in the direction WO (the same course as before).

Resumption of course and speed

If in worked example 4, the own ship resumed its original course and speed at 1117, find (e) the new CPA range and time.

(i) Predict the 1117 position Q, on PN_1, using the relative velocity triangle WO_1A. In 6 minutes, the target would have relatively covered distance O_1A. So compute how far it would cover in 8 minutes and lay off position Q.

$$\text{Distance PQ} = \frac{8}{6} \times 1.5 = 2.0 \text{ M}$$

(ii) At 1117, the original course and speed were resumed. So the direction and rate of approach would again be OA but from position Q onwards. Draw a line from Q, parallel to OA, and produce it beyond C. Drop a perpendicular from C to this line and call the point of intersection N_2. CN_2 is the new CPA range and, in this case, it is 0.7 M.

(iii) $$\text{Time to CPA from 1117} = \frac{QN_2}{OA} \times \text{plotting interval}$$

$$= \frac{1.8}{1.25} \times 6 = 9 \text{ minutes}$$

$\therefore$ New CPA time = 1126

38.2 Performance delay

Performance delay is the interval between the commencement and the completion of an alteration of course and/or speed. In the case of a course alteration, the time lag from the moment the helm is put over until the moment that the ship has actually settled on the new course is called the performance delay or turning time. In the case of a speed alteration, the time lag from the moment the telegraph is operated until the moment that the ship has actually settled on the new speed is called the performance delay.

Performance delay depends on the magnitude of the action, the type of ship, displacement, trim, wind, etc., and may vary for the same ship under different circumstances.

Performance delay is normally neglected in radar plotting. The radar observer should, however, be aware that his predictions may be in slight error due to this.

Where the performance delay is known (or given in a problem) an allowance can be made for it as illustrated in worked examples 5 and 6.

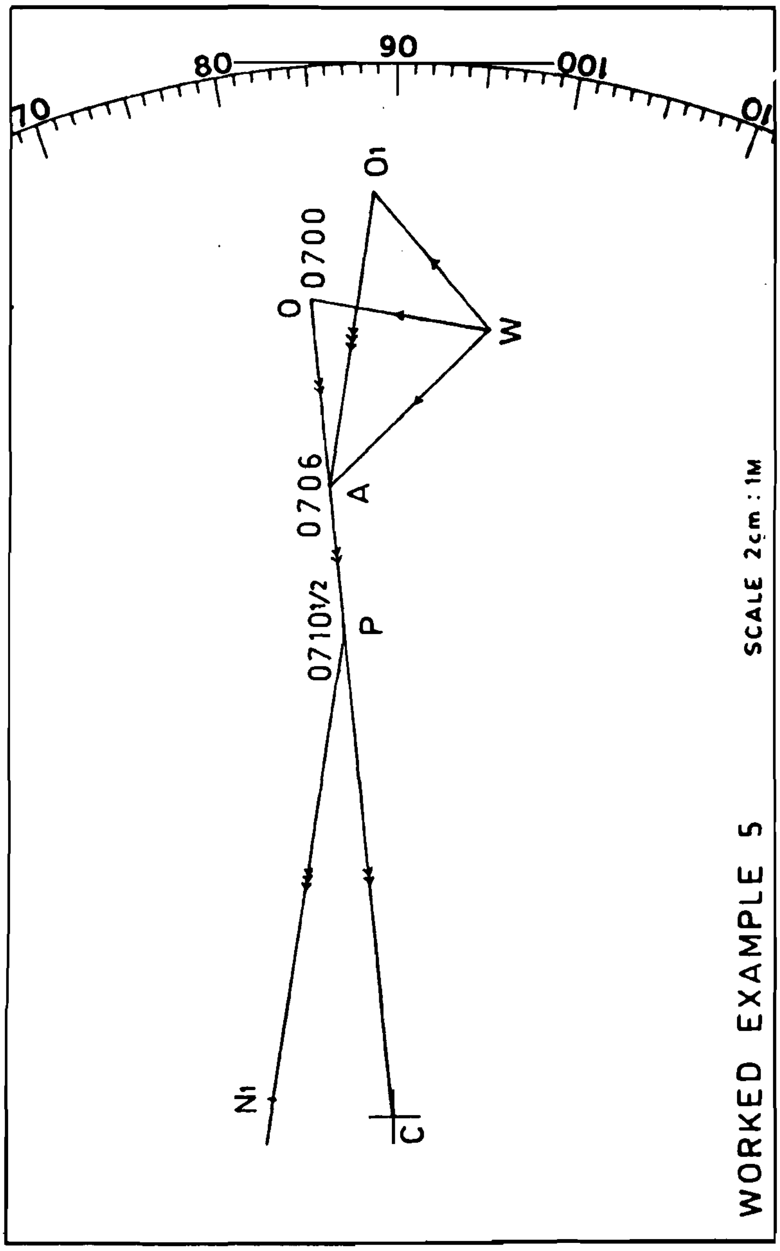
Worked example 5

Whilst steaming 010°(T) at 12 knots, the following observations of a target were made on the radar screen:

Ship's time	Bearing (T)	Range (M)
0700	084°	5.50
0706	084°	4.25

Find: (a) The CPA range and time.
(b) Course and speed of target.

At 0709, Master of own ship ordered a course alteration to 050°(T). If the turning time (i.e., performance delay) is known to be 3 minutes, find the new CPA and TCPA.


70
80
90
100
110
O1
0700
O
W
A
0706
0710½
P
N1
C
SCALE 2cm : 1M
WORKED EXAMPLE 5

WORKING

By constructing the relative velocity triangle WOA as usual (see foregoing figure), obtain answers (a) and (b).

(a) Collision at 0726.

(b) Course and speed of target 315°(T) 15 knots.

To find the new CPA range and time

The action was commenced at 0709 and completed at 0712 (i.e., performance delay was 3 minutes). Between 0709 and 0712, the vessel would have followed a curved path which can be approximated by two straight lines – the original course and the new course, the change over being assumed to be midway during the performance delay. In other words, we allow the old course till 0710½ and the new course from then onwards.

The foregoing explanation can be summarised as follows:

Action commenced at 0709 and completed at 0712. Hence assume the alteration to be made at 0710½, and instantly effective.

(i) Predict position P for 0710½, along OA produced, as explained under paragraph 36.6 in chapter 36.

(ii) In triangle WOA, lay off new course from W and cut off WO_1 equal to WO (speed of own ship has not been altered).

(iii) Join O_1A.

(iv) Draw a line parallel to O_1A, through P, and produce it beyond C. This is the new line of approach from 0710½ onwards.

(v) Draw CN_1 perpendicular to the new line of approach and measure off the new range at CPA. In this case, new CPA range is 0.8 M, target passing ahead of own ship.

(vi) The distance O_1A would be relatively covered by the target during a number of minutes equal to the plotting interval. Hence compute how long it will take to cover distance PN_1.

In this case,

$$\text{Time to CPA from } 0710\tfrac{1}{2} = \frac{PN_1}{O_1A} \times \text{ plotting interval}$$

$$= \frac{3.2}{2} \times 6 = 9\tfrac{1}{2} \text{ minutes}$$

∴ New CPA time = 0720.

Worked example 6

While steaming 010°(T) at 12 knots, the following observations of a target were made on the radar screen:

Ship's time	Bearing (T)	Range (M)
0700	084°	5.50
0706	084°	4.25

Find: (a) The CPA range and time.
(b) Course and speed of target.

At 0711, Master orders speed to be reduced to 8 knots. If the vessel takes 2 minutes to settle down to the new speed, find the new range and time at CPA.

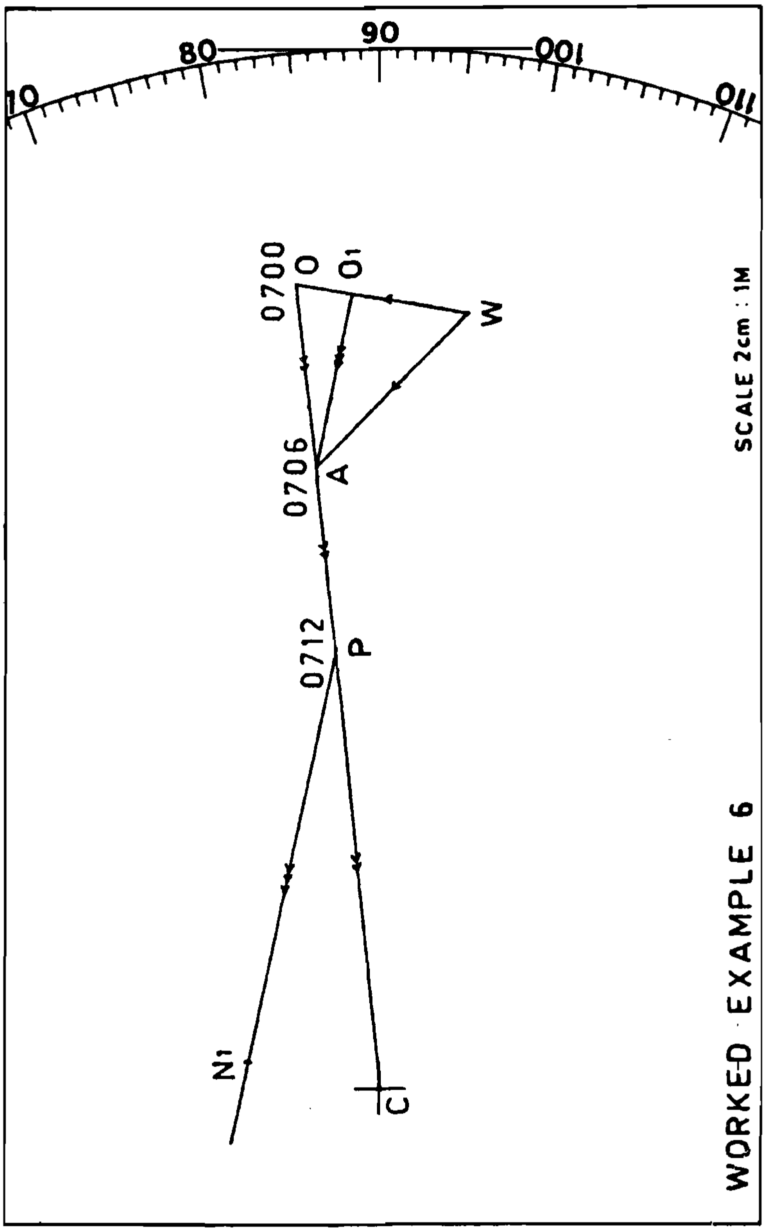
WORKING

The first part is the same as worked example 5. Hence answers (a) and (b) are the same.

(a) Collision at 0726.
(b) Course and speed of target 315°(T) 15 knots.

To find new CPA range and time

The action was commenced at 0711 and completed at 0713 (i.e., performance delay was 2 minutes). During this interval, the speed of the vessel will be dropping from the old speed of 12 knots to the new speed of 8 knots. The movement of the vessel can be approximated by allowing the old speed until 0712 (the mid-point of the performance delay) and allowing the new speed from 0712 onwards. The foregoing can be summarised as follows:


70
80
90
100
110
0700
O
O1
W
0706
A
0712
P
N1
C
SCALE 2cm : 1M
WORKED EXAMPLE 6

Action was commenced at 0711 and was completed at 0713. Hence assume the alteration to be made at 0712, and instantly effective (see accompanying figure).

(i) Predict position P for 0712, along OA produced, as explained under paragraph 36.6 in chapter 36.

(ii) On WO cut off new distance WO_1 that the own ship would do in a number of minutes equal to the plotting interval. In this case, at a new speed of 8 knots in 6 minutes, $WO_1 = 0.8$ M.

(iii) Join O_1A.

(iv) Draw a line parallel to O_1A from P and produce it beyond C. This is the new line and rate of approach from 0712 onwards.

(v) Draw CN_1 perpendicular to the new line of approach and measure off the new range at CPA. In this case, new CPA range is 0.9 M, target passing ahead of own ship.

(vi) Time to CPA from 0712 $= \frac{PN_1}{O_1A} \times$ plotting interval

$$= \frac{2.9}{1.2} \times 6 = 14 \text{ minutes}$$

$\therefore$ New CPA time = 0726.

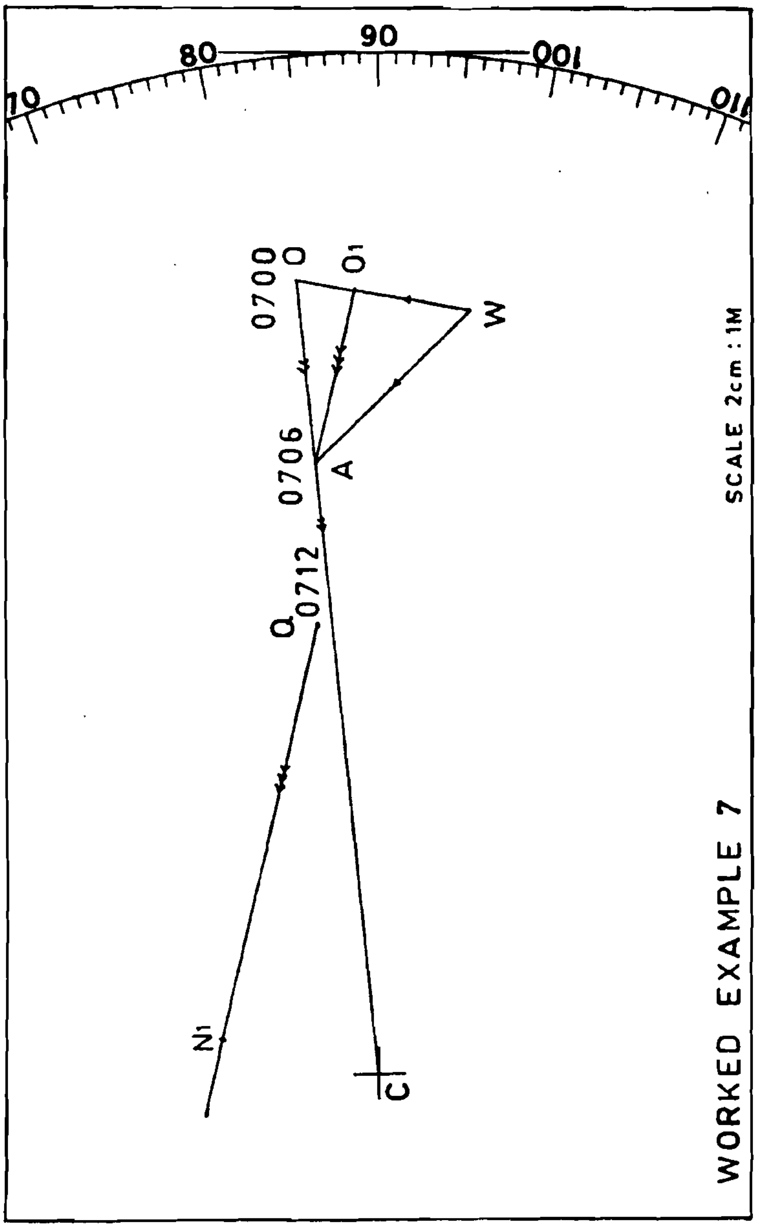
38.3 Special note

Where a bearing and a range of a target are given *after* an action by own vessel has become effective, the new line of approach must be transferred through that position, as illustrated in worked example 7.

Worked example 7

Whilst on a course of 010°(T) at 12 knots, a target was observed on the radar screen as follows:

Ship's time	Bearing (T)	Range (M)
0700	084°	5.50
0706	084°	4.25


70
80
90
100
110
0700
O
O1
W
A
0706
0712
Q
N1
C
SCALE 2cm : 1M
WORKED EXAMPLE 7

Find: (a) CPA range and time.
(b) Course and speed of target.

At 0710, Master of own ship order the speed to be reduced to 8 knots. At 0712, after the vessel had settled on the new speed, the target bore 082°(T) 3.1 M. Find the new CPA range and time.

The first part of the question is similar to worked examples 5 & 6. Hence answers (a) and (b) are the same.

(a) Collision at 0726.
(b) Course and speed of target 315°(T) 15 knots.

To find new CPA range and time

(i) Plot given position for 0712 and call it Q. This position is not a predicated position hence it is not called P. If P was predicted for 0712, it will, most probably, *not* coincide with Q.
(ii) On WO, cut off new distance WO_1, as done in worked example 6, and join O_1A.
(iii) Draw a line, parallel to O_1A, from Q and produce it beyond C.
(iv) Measure off new CPA range. In this case it is 1.1M.
(v) Time to CPA from 0712 $= \frac{QN_1}{O_1A} \times$ plotting interval

$$= \frac{2.9}{1.2} \times 6 = 14 \text{ minutes}$$

$\therefore$ New CPA time = 0726.

38.4 Head reach

If, when going ahead, the engines are stopped, the distance covered by the ship before it comes to rest is called head reach. The head reach for any given ship depends on several factors such as the speed, displacement, trim, tides, winds, sea, swell, etc.

Application of head reach in plotting is illustrated in worked example 8.

Worked example 8

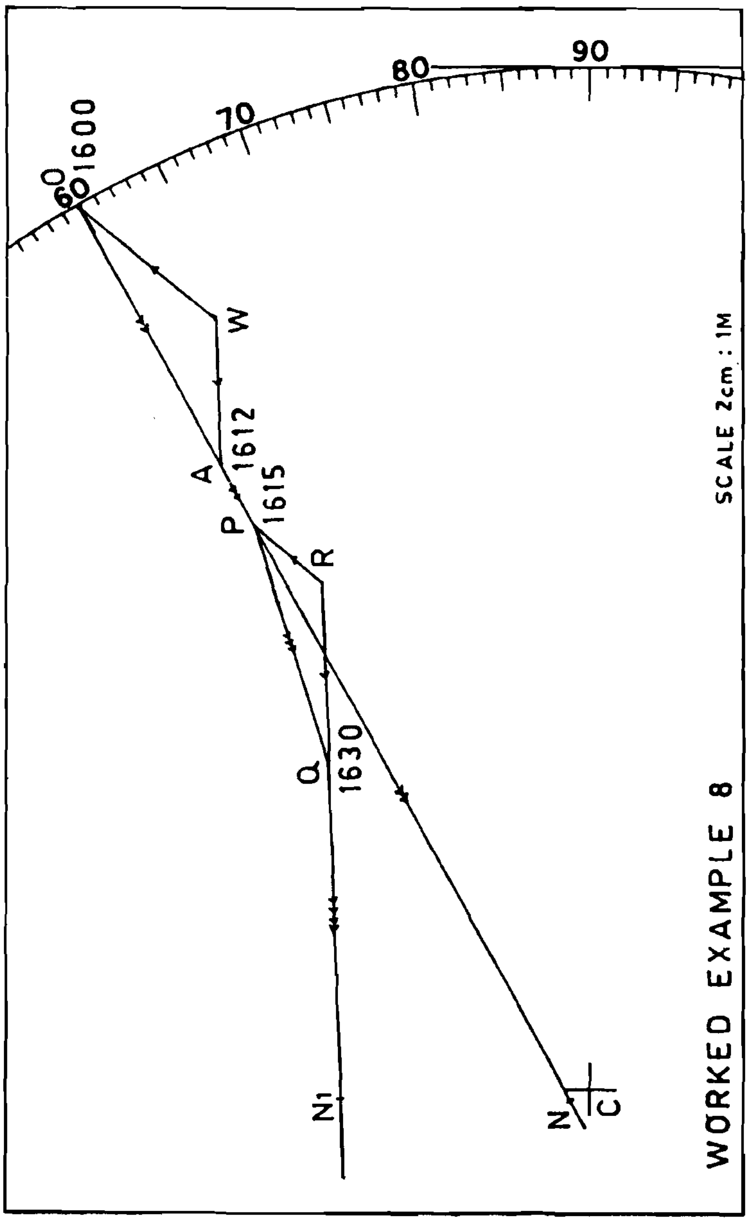
In thick fog, while on a course of 040°(T) at 6 knots, a target was observed on the radar screen as follows:

Ship's time	Bearing (T)	Range (M)
1600	060°	7.0
1612	059½°	5.0

Find: (a) CPA range and time.
(b) Course and speed of target.
At 1615, own ship's engines were stopped. If a head reach of 0.6 M is expected in 15 minutes, predict the new CPA range and time.

WORKING

(i) Plot the positions given, construct the triangle WOA and obtain the answers (a) and (b) as explained in earlier chapters.
(a) CPA range 0.15 M at 1642.
(b) Course and speed of target 268°(T) 5 knots
(ii) Since the action was taken only at 1615, the original line and rate of approach prevail till then. Hence predict position P, of the target, at 1615, as explained earlier under paragraph 36.6 in chapter 36.
(iii) The head reach time is given as 15 minutes. So between 1615 and 1630, the own ship's course is the same as before but the distance covered is the head reach of 0.6 M. Hence lay off PR (own ship's course reversed) equal to 0.6 M.
(iv) Between 1615 and 1630, the target's course and speed (268°T - 5 knots) is the same. So lay off RQ in direction 268° (i.e., parallel to WA) equal to 1.25 M.
(v) Join PQ. This is the line of approach from 1615 to 1630. Q is the predicted position of the target at 1630.



60
70
80
90
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1600
W
1612
A
1615
P
R
Q
1630
N1
N
C
SCALE 2cm : 1M
WORKED EXAMPLE 8

(vi) From 1630 onwards, own ship is stationary, whereas the target maintains its course and speed. So the line of approach from 1630 onwards will be RQ produced.

(vii) Drop a perpendicular from C to RQ produced, meeting it at N_1. CN_1 is the new CPA range. In this case new CPA range = 1.7 M.

(viii) The distance RQ will be relatively covered by the target in 15 minutes. Hence compute how long it will take to cover distance QN_1.

$$\text{Time to CPA from 1630} = \frac{QN_1}{RQ} \times 15$$

$$= \frac{2.30}{1.25} \times 15 = 28 \text{ minutes}$$

$\therefore$ New CPA time = 1658.

Exercise 3

1. Own course 212°(T) at 16 knots.

Ship's time	Bearing (T)	Range (M)
0200	240°	6.5
0206	238°	4.3

Report the target at 0206. At 0210, own ship altered course to starboard by 30°. Find the new CPA range and time.

2. Own course 043°(T) at 10 knots.

Ship's time	Bearing (T)	Range (M)
0700	043°	6.0
0703	043°	5.1
0706	043°	4.2

Find: (a) CPA range and time.
(b) Course and speed of target.
(c) Aspect at 0706.

At 0708, own ship altered course to 060°(T). Find (d) the new CPA range and time.

3. Own course 340°(T) at 12 knots.

Ship's time	Bearing (T)	Range (M)
1640	010°	6.50
1645	009½°	5.15
1650	009°	3.75

Find: (a) Range and time at CPA.
(b) Course and speed of target.
(c) Aspect at 1650.

At 1652, own ship reduced speed to 4 knots. Find (d) the new CPA range, time and bearing.

4. Own course 234°(T) at 14 knots.

Ship's time	Bearing (T)	Range (M)
2008	300°	6.00
2014	299°	3.95

Find: (a) CPA range, time and bearing.
(b) Course and speed of target.
(c) Aspect at 2014.

At 2016, own ship reduced speed to 6 knots. Find (d) the predicted CPA range and time.
(e) State whether the actual CPA range now experienced will be less than or greater than the CPA range predicted in (d).

5. Own course 085°(T) at 16 knots.

Ship's time	Bearing (T)	Range (M)
0024	130°	6.5
0030	129°	3.8

Find: (a) CPA range and time.
(b) Course and speed of target.
(c) Aspect at 0030.

At 0032, own ship stopped and at 0038, own ship resumed full speed. Find (d) the new CPA range and time assuming both actions to be instantly effective.

6. Course 335°(T) speed 18 knots.

Ship's time	Bearing (T)	Range (M)
0900	340°	6.00
0903	339½°	4.60
0906	339°	3.25

Find: (a) CPA range and time.
(b) Course and speed of target.
(c) Aspect at 0906.

At 0907, own ship altered course to 352°(T) and also reduced speed to 8 knots. Find (d) the new CPA range and time.

7. Course 214°(T) at 5 knots.

Ship's time	Bearing (T)	Range (M)
1120	034°	6.5
1126	034°	5.0

Find: (a) Nearest approach range and its time.
(b) Course and speed of target.
(c) Aspect at 1126.

At 1128, own ship altered course 30° to starboard and increased speed to 10 knots. Find (d) the new nearest approach range and time.

At 1140, own ship resumed her original course and speed. Find (e) the new nearest approach range and time.

8. Own ship, a small coaster of very small draft, on a course of 318°(T) at a speed of 10 knots, observes a target as follows:

Ship's time	Bearing (T)	Range (M)
0730	240°	6.5
0740	239°	5.0

Find: (a) CPA range, time and bearing
(b) Course and speed of target.
(c) Aspect at 0740.

Observing that the target is a VLCC, contained by her draft to navigate inside a dredged channel, own ship takes the following action:

At 0745, alters course 30° to port and at 0750, reduces speed to 6 knots. Find (d) the new CPA range, time and bearing.

9. While on a course of 301°(T) at a speed of 12 knots, a target was observed as follows:

Ship's time	Bearing (T)	Range (M)
1400	290°	6.0
1406	289½°	3.4

Find: (a) CPA range, time and bearing.
(b) Course and speed of target.
(c) Aspect at 1406.

At 1406, speed was reduced to 6 knots. Find (d) the new CPA range, time and bearing.

Thereafter, at 1410, course was altered 60° to starboard. Find (e) the new CPA range, time and bearing.

10. Course 136°(T) speed 16 knots.

Ship's time	Bearing (T)	Range (M)
2215	136°	5.5
2230	136°	4.0

Find: (a) CPA range and time.
(b) Course and speed of target.
(c) Aspect at 2230.

At 2240, own ship altered course to 160° (T). At 2255, own ship resumed original course. Find (d) the new CPA range, time and bearing.

11. Course 074°(T) speed 15 knots.

Time	Bearing	Range
0620	018°(T)	11.0 M
0623	018½°(T)	10.0 M
0626	019°(T)	09.1 M

Find: (a) Range, time and bearing at CPA.
(b) Target's course and speed.
(c) Aspect at 0626.

At 0630, own ship reduced speed to 10 knots. At 0642, own ship resumed her original speed. Find (d) the new range, time and bearing at CPA.

12. Own course 307°(T) at 8 knots.

Ship's time	Bearing (T)	Range (M)
1900	341°	6.50
1906	342°	4.95

Find: (a) CPA range and time.
(b) Course and speed of target.
(c) Aspect at 1906.

At 1907, engines of own ship stopped. If the own ship is expected to come to a dead stop in 15 minutes with head reach of 0.8 M, find (d) the new CPA range and time.

13. Course 226°(T) at 12 knots.

Ship's time	Bearing (T)	Range (M)
0200	256°	13.0
0210	256½°	09.0

Find: (a) CPA range, time and bearing.
(b) Course and speed of target.
(c) Aspect at 0210.

At 0212, own ship stopped engines. If a head reach of 1.8 M is expected in 20 minutes, find (d) the new CPA range, time and bearing.

14. Course 192°(T) at 16 knots.

Ship's time	Bearing (T)	Range (M)
0400	220°	6.5
0406	218°	4.3

Find: (a) CPA range and time.
(b) Course and speed of target.
(c) Aspect at 0406.

At 0409, an alteration of course by 30° to starboard was ordered. If the turning time expected is 2 minutes, find (d) the new range and time at CPA.

15. Course 053°(T) at 10 knots.

Ship's time	Bearing (T)	Range (M)
0900	053°	6.0
0903	053°	5.1
0906	053°	4.2

Find: (a) CPA range and time.
(b) Course and speed of target.
(c) Aspect at 0906.

At 0908, a course alteration of 20° to starboard was ordered. If the performance delay is expected to be 3 minutes, find (d) the new CPA range and time.

16. Course 060°(T) at 14 knots.

Time	Bearing	Range
1800	120°(T)	6.00 M
1806	119°(T)	3.95 M

Find: (a) CPA range and time.
(b) Course and speed of target.
(c) Aspect at 1806.

At 1809, a speed reduction to 6 knots was ordered. If a performance delay of 2 minutes is expected, find (d) the new CPA range and time.

17. Own course 270°(T), speed 12 knots.

Ship's time	Bearing (T)	Range (M)
1630	300°	6.50
1635	299½°	5.15
1640	299°	3.75

Find: (a) CPA range and time.
(b) Course and speed of target.
(c) Aspect at 1640.

At 1643, the telegraph was put to dead slow ahead (4.8 knots). Allowing a speed reduction time of 3 minutes, find the new CPA range and time.

18. Course 330°(T) at 18 knots.

Ship's time	Bearing (T)	Range (M)
0500	000°	13.0
0512	010°	10.0

Find: (a) Time and range at CPA. State on which side, of own ship, the target would pass.
(b) Course and speed of target.

At 0514, alteration of course to 040°(T) was ordered. At 0518, after settling down on the new course, the target bore 015°(T) 7.2 M off. Find (c) the new CPA range and time. State on which side, of own ship, the target would now pass.

19. Course 180°(T), speed 13 knots.

Time	Bearing	Range
1120	235°(T)	6.50 M
1130	229°(T)	3.05 M

Find: (a) CPA range and time.
(b) Course and speed of target.

At 1130, speed reduction to 4 knots was ordered. At 1135, after settling down on the new speed, the target bore 210°(T) range 1.75 M. Find (c) the new CPA range and time.

20. While on a course of 070°(T) at a speed of 12 knots, a target was observed as follows:

Ship's time	Bearing (T)	Range (M)
0730	135°	6.00
0736	136°	4.45

Report the target at 0736.

At 0738, a reduction of speed by 4 knots and an alteration of course by 30° to starboard were ordered. At 0742, after both the actions became effective, the target bore 130°(T) at a range of 3.0 M. Find the new CPA range and time.

Answers to exercise 3

1. Report at 0206: Crossing vessel bearing 238°(T) drawing forward, range 4.3 M decreasing, CPA range 0.45 M at 0218, course and speed of target 108°(T) 12 knots, aspect red 50°. New CPA range 1.3 M at 0216.

2. (a) Collision at 0720.
   (b) Course and speed of target 223°(T) 8 knots.
   (c) Aspect at 0706: 000°.
   (d) New CPA 0.65 M at 0720.

3. (a) CPA 0.15 M at 1704.
   (b) Course and speed of target 236°(T) 9 knots.
   (c) Aspect at 1650 : red 47°.
   (d) New CPA 1.4 M at 1708, bearing 303°(T).

4. (a) CPA range 0.2 M at 2026, bearing 212°(T).
   (b) Course and speed of target 162°(T) 20 knots.
   (c) Aspect at 2014: red 43°.
   (d) New CPA range 1.5 M at 2025.
   (e) Actual CPA range experienced will be slightly less than the CPA range predicted in (d). This is because the reduction of speed from 14 knots to 6 knots will not be instantly effective.

5. (a) CPA 0.15 M at 0038.
   (b) Course and speed of target 347°(T) 20 knots.
   (c) Aspect at 0030: red 38°.
   (d) New CPA range 1.35 M at 0041.

6. (a) CPA 0.1 M at 0913.
   (b) Course and speed of target 172°(T) 10 knots.
   (c) Aspect at 0906: red 13°.
   (c) New CPA range 0.7 M at 0916.

7. (a) Collision at 1146.
   (b) Course and speed of target 214°(T) 20 knots.
   (c) Aspect at 1126: 000°
   (d) New nearest approach 1.8 M at 1148.
   (e) New nearest approach 1.0 M at 1149.

8. (a) CPA range 0.2 M at 0813, bearing 152°(T).
   (b) Target's course and speed 006°(T) 12 knots.
   (c) Aspect at 0740: green 53½°.
   (d) New CPA range 1.4 M at 0804, bearing 305°(T).

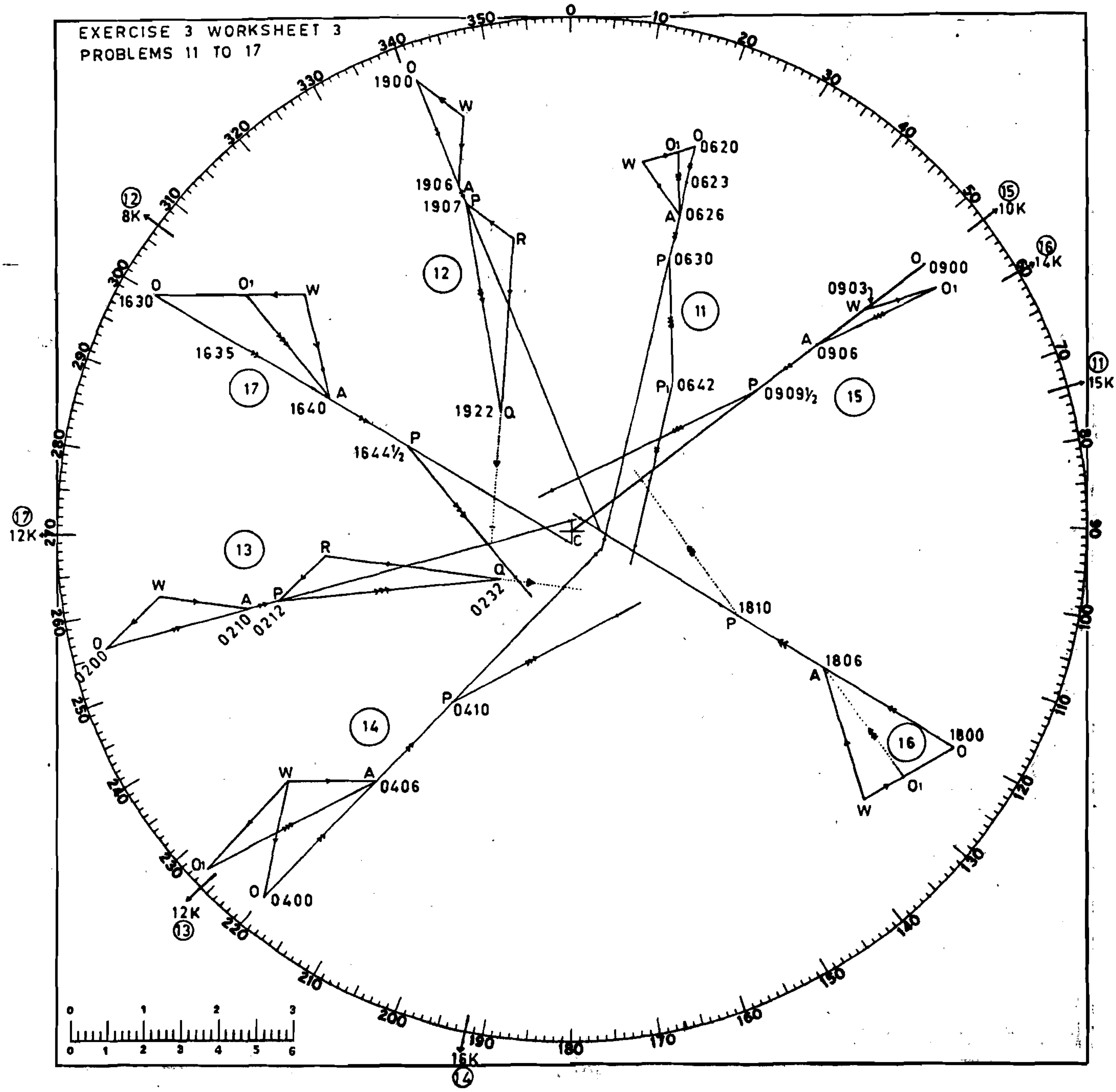
9. (a) CPA 0.1 M at 1414, bearing 200°(T).
   (b) Course and speed of target 102°(T) 14.5 knots.
   (c) Aspect at 1406: green 7½°.
   (d) New CPA 0.15 M at 1416, bearing 017°(T).
   (e) New CPA 0.4 M at 1417, bearing 213°(T).

10. (a) Collision at 2310.
    (b) Course and speed of target 136°(T) 10 knots.
    (c) Aspect at 2230: 180°.
    (d) New CPA range 1.6 M at 2313, bearing 046°(T).

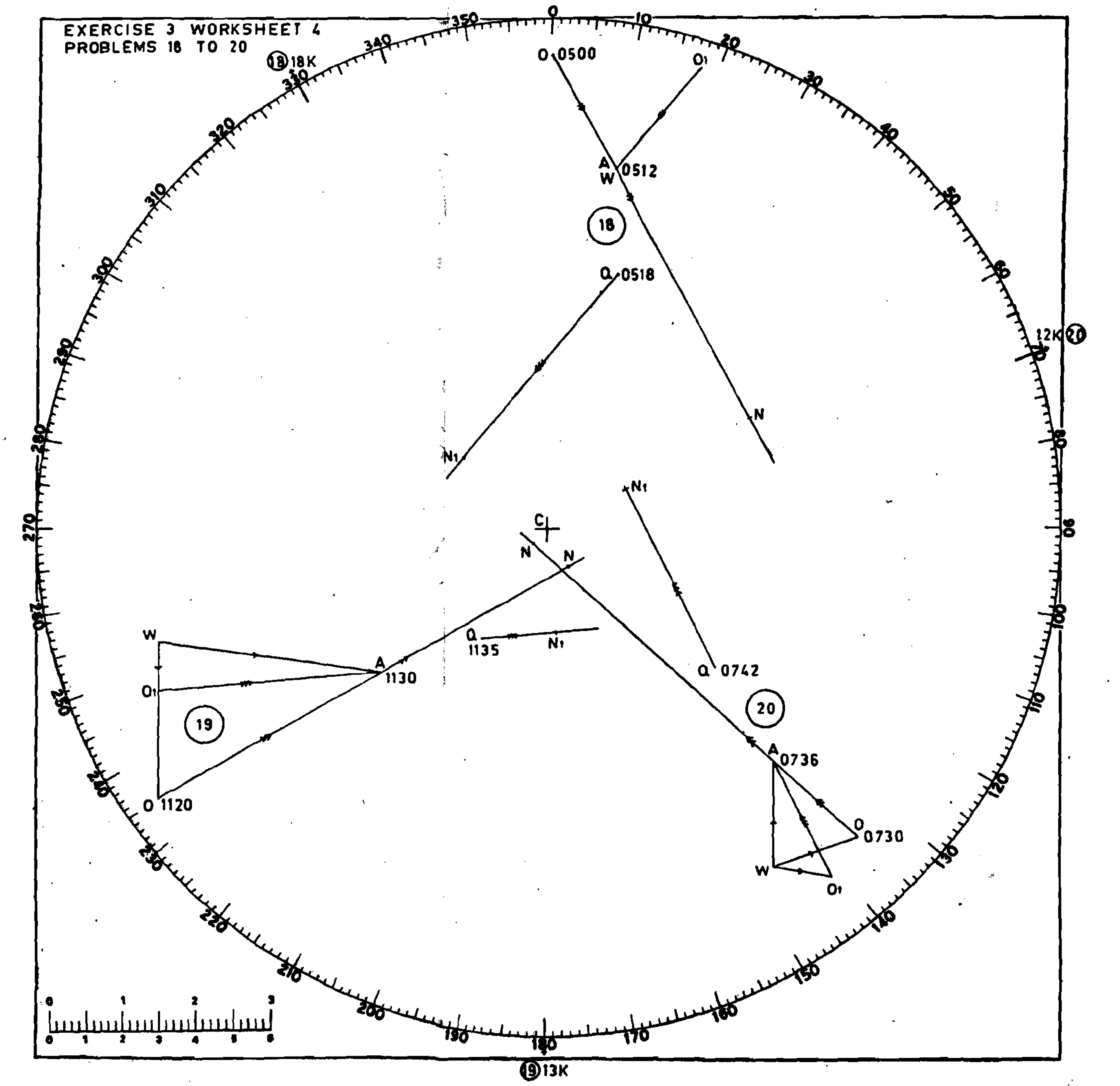
11. (a) CPA 0.9 M at 0655, bearing 103°(T).
    (b) Target's course and speed 145°(T) 18 knots.
    (c) Aspect at 0626: green 54°
    (d) New CPA 1.7 M at 0656, bearing 103°(T).

12. (a) CPA 0.35 M at 1925.
    (b) Course and speed of target 184°(T) 9.5 knots.
    (c) Aspect at 1906: red 22°.
    (d) New CPA 1.1 M at 1932.

RADAR PLOTTING SHEET



RADAR PLOTTING SHEET



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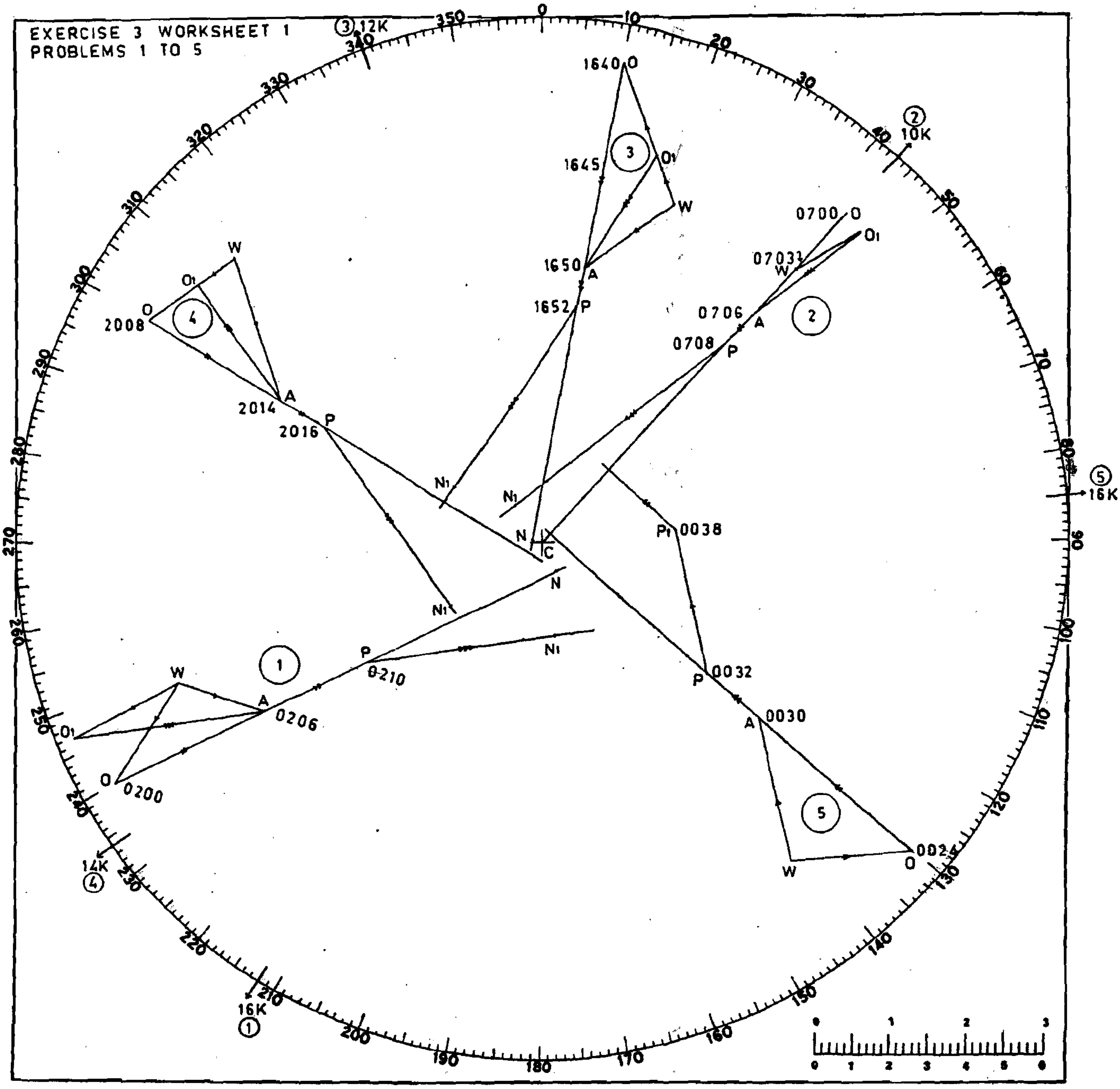
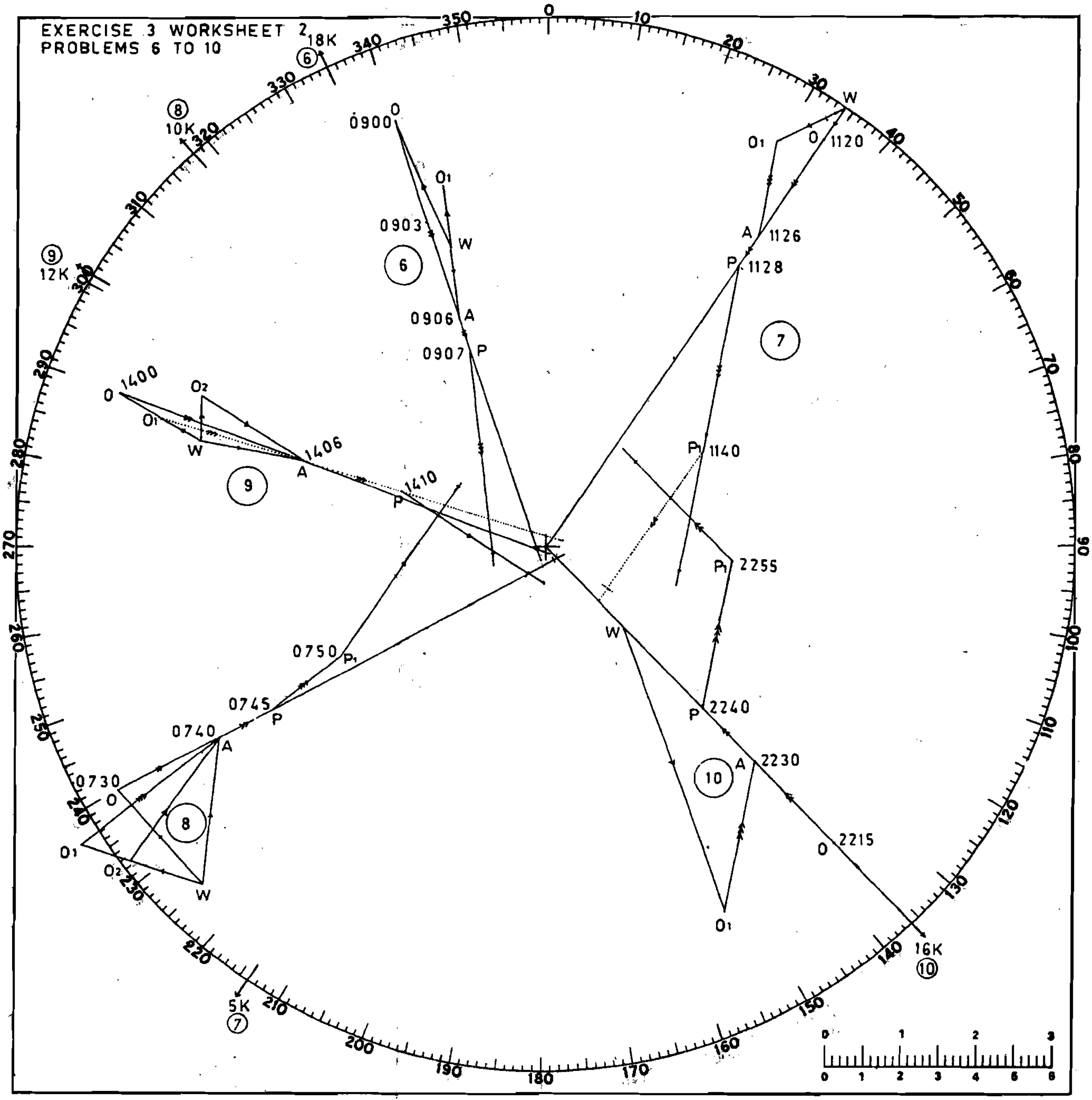


RADAR PLOTTING SHEET



13. (a) CPA 0.25 M at 0232, bearing 345°(T).
    (b) Course and speed of target 098°(T) 14.4 knots.
    (c) Aspect at 0210: red 21.5°.
    (d) New CPA 1.6 M at 0239, bearing 188°(T).

14. (a) CPA 0.45 M at 0418.
    (b) Course and speed of target 090°(T) 12 knots.
    (c) Aspect at 0406: red 52°.
    (d) New CPA 1.3 M at 0416.

15. (a) Collision at 0920.
    (b) Course and speed of target 233°(T) 8 knots.
    (c) Aspect at 0906: 000°.
    (d) New CPA 0.6 M at 0920.

16. (a) CPA 0.2 M at 1818.
    (b) Course and speed of target 343°(T) 18.5 knots.
    (c) Aspect at 1806: red 44°.
    (d) New CPA 1.15 M at 1818.

17. (a) CPA 0.15 M at 1654.
    (b) Course and speed of target 167°(T) 9 knots.
    (c) Aspect at 1640: red 48°.
    (d) New CPA 1.0 M at 1657.

18. (a) CPA 6.3 M at 0538 on starboard side.
    (b) Stationary object.
    (c) New CPA 3.0 M at 0540 on port side.

19. (a) CPA 0.6 M at 1139.
    (b) Course and speed of target 098°(T) 18.3 knots.
    (c) New CPA 1.45 M at 1138.

20. Report at 0736: Target bearing 136°(T) drawing aft, range 4.45 M decreasing, CPA range 0.3 M at 0753, course and speed of target 000°(T) 14.5 knots, aspect red 44°.
    New CPA 1.2 M at 0751.

-o0o-

CHAPTER 39

RELATIVE PLOTTING -

TO PREDICT ACTION TO TAKE

To predict the action to take in order to achieve a desired result is usually the correct procedure to follow in actual situations at sea. In the previous chapter, the action taken by own ship was given and it was desired to find the consequences of taking such action. In this chapter, a desired result, such as CPA range, is given and the student is gradually led up to situations where he has to choose a particular action to take, out of a number of possibilities, all of which would achieve the same result.

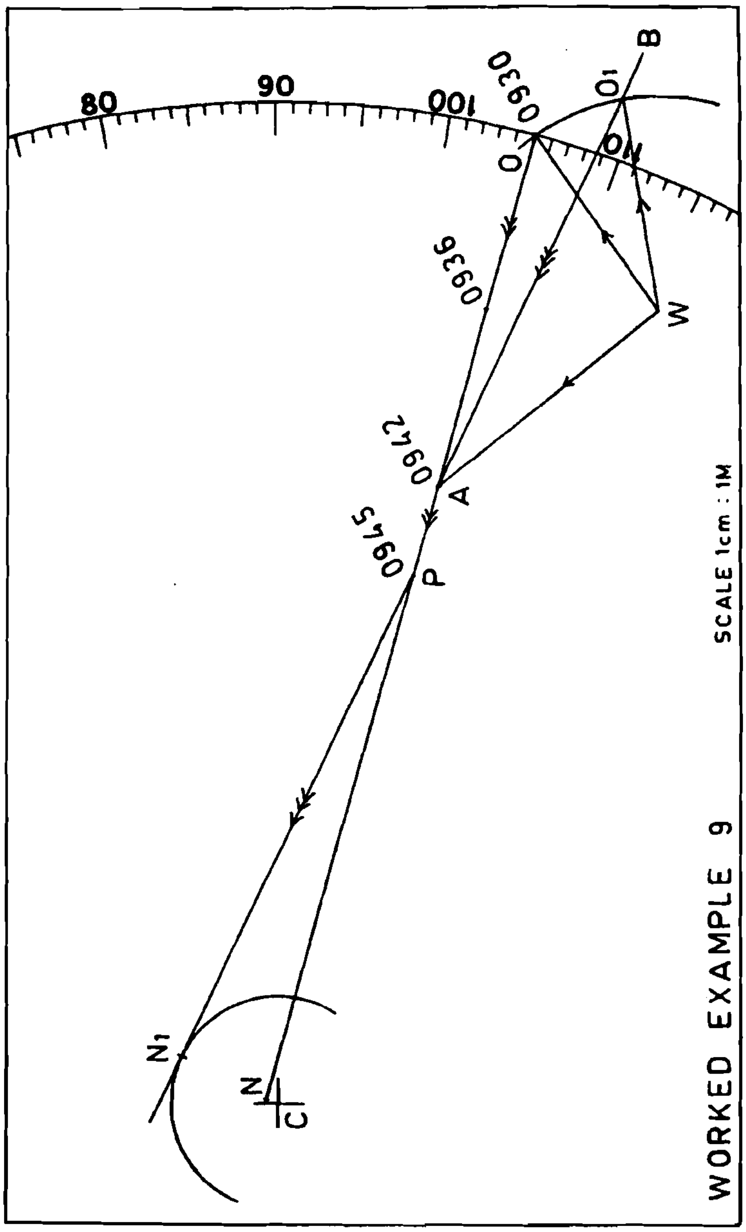
However, the previous chapters on plotting are absolutely essential, not only to understand the subject but also cope with situations where a specific action has to be taken, by own ship or by target, for navigational or operational reasons and it is desired to find the result of taking such action.

In this chapter, the desired future line of approach is transferred back into the triangle of relative velocities and the action to be taken by the own ship is computed, as illustrated in the worked examples that follow.

39.1 To predict course alteration to starboard

Worked example 9
While on a course of 055°(T) at 15 knots, a target was observed as follows:

Time	Bearing	Range
0930	105°(T)	14.0 M
0936	105°(T)	11.5 M
0942	104½°(T)	08.9 M


80
90
100
0930
0936
0942
0945
O
O1
B
W
A
P
N1
N
C
SCALE 1cm : 1M
WORKED EXAMPLE 9

Find (a) CPA range and time.
(b) Course and speed of target.
(c) Aspect at 0942.

The captain of the own ship decides to let the target pass ahead of own ship with a CPA of 1.5 M by altering course *to starboard* at 0945. Find (d) the alteration necessary and (e) the new CPA time.

WORKING

The first three parts of the question have already been illustrated in earlier chapters.

(a) CPA 0.2 M at 1003.
(b) Course and speed of target 322°(T) 20 knots.
(c) Aspect at 0942: red 37½°.

To find required starboard alteration

(i) Predict position P, for the time given for alteration (0945 in this case), as explained in earlier chapters.
(ii) With centre C, radius equal to the desired CPA range (1.5 M in this case), draw a large arc ahead of own ship.
(iii) From P, draw a tangent to this arc and call the point of contact N_1.
(iv) From A, draw a long line AB, parallel to N_1P.
(v) With centre W, radius equal to WO, cut off O_1 on AB, to the starboard side of WO. Join WO_1.
(vi) The new triangle of relative velocities is WO_1A. O_1A is the new line of approach, becoming effective from the time of alteration. Hence O_1A and PN_1 were made parallel by construction.
(vii) WO_1 equals WO because the speed of the own ship has not been altered.
(viii) WO_1 is the new course to steer from 0945 onwards. Transfer direction WO_1 to the centre of the plotting sheet and using the plotting sheet as a compass rose,

read off new course WO_1. In this case, the new course is 081°(T).

(ix) Compute the new CPA time as usual.

$$\text{Time to CPA from 0945} = \frac{PN_1}{O_1A} \times \text{plotting interval}$$

$$= \frac{7.5}{6.0} \times 12 = 15 \text{ minutes}$$

∴ New CPA time = 1000.

39.2 To predict course alteration to port

Worked example 10

Own course 055°(T) at 15 knots.

Time	Bearing	Range
0930	105° (T)	14.0 M
0936	105° (T)	11.5 M
0942	104½° (T)	8.9 M

Find: (a) CPA range, time and bearing.
(b) Course and speed of target.
(c) Aspect at 0942.

The captain of the own ship decides to increase the nearest approach to 1.5 M by altering course *to port* at 0945. Find (d) the alteration necessary and (e) the new CPA time.

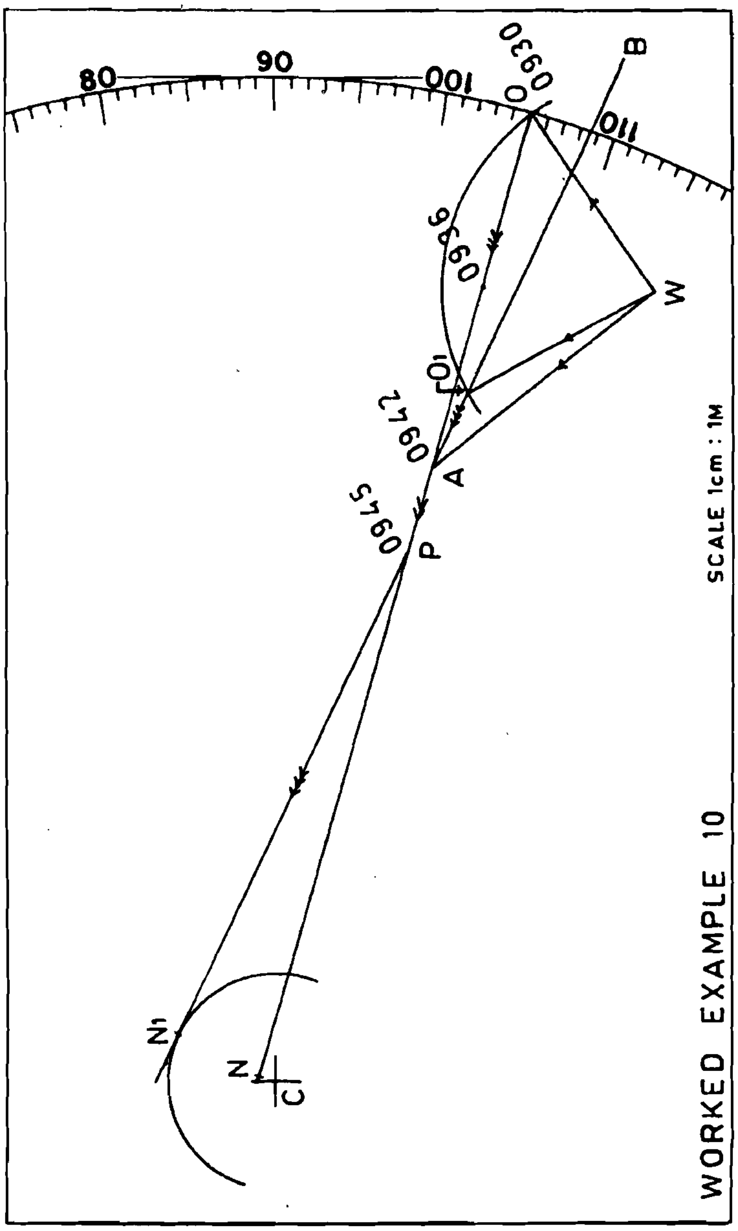
WORKING

The first three parts of the question have been illustrated in earlier chapters.

(a) CPA 0.2 M at 1003, bearing 016°(T).
(b) Course and speed of target 322°(T) 20 knots.
(c) Aspect at 0942: red 37½°.

To find required port alteration

(i) Predict position P for time given for alteration (0945 in this case), as explained in earlier chapters.


80
90
100
110
0930
O
B
0936
W
O1
0942
A
0945
P
N1
N
C
SCALE 1cm : 1M
WORKED EXAMPLE 10

(ii) With centre C, radius equal to the desired CPA range (1.5 M in this case), draw a large arc on same side as N.
(iii) From P, draw a tangent to this arc and call the point of contact N_1.
(iv) From A, draw a long line AB, parallel to N_1P.
(v) With centre W, radius equal to WO, cut off O_1, on AB, to the port side of WO. Join WO_1.
(vi) The new triangle of relative velocities is WO_1A. O_1A is the new line of approach, becoming effective from the time of alteration. Hence O_1A and PN_1 were made parallel by construction.
(vii) WO_1 equals WO because the speed of the ship has not been altered.
(viii) WO_1 is the new course from 0945 onwards. Transfer direction WO_1 to the centre of the plotting sheet and using the plotting sheet as a compass rose, read off the new course WO_1. In this case, the new course is 332°(T).

(ix) Time to new CPA from 0945 = $\frac{PN_1}{O_1A}$ x plotting interval

$$= \frac{7.5}{1.1} \times 12 = 82 \text{ minutes}$$

$$= 1 \text{ hour } 22 \text{ minutes.}$$

$\therefore$ New CPA time = 1107.

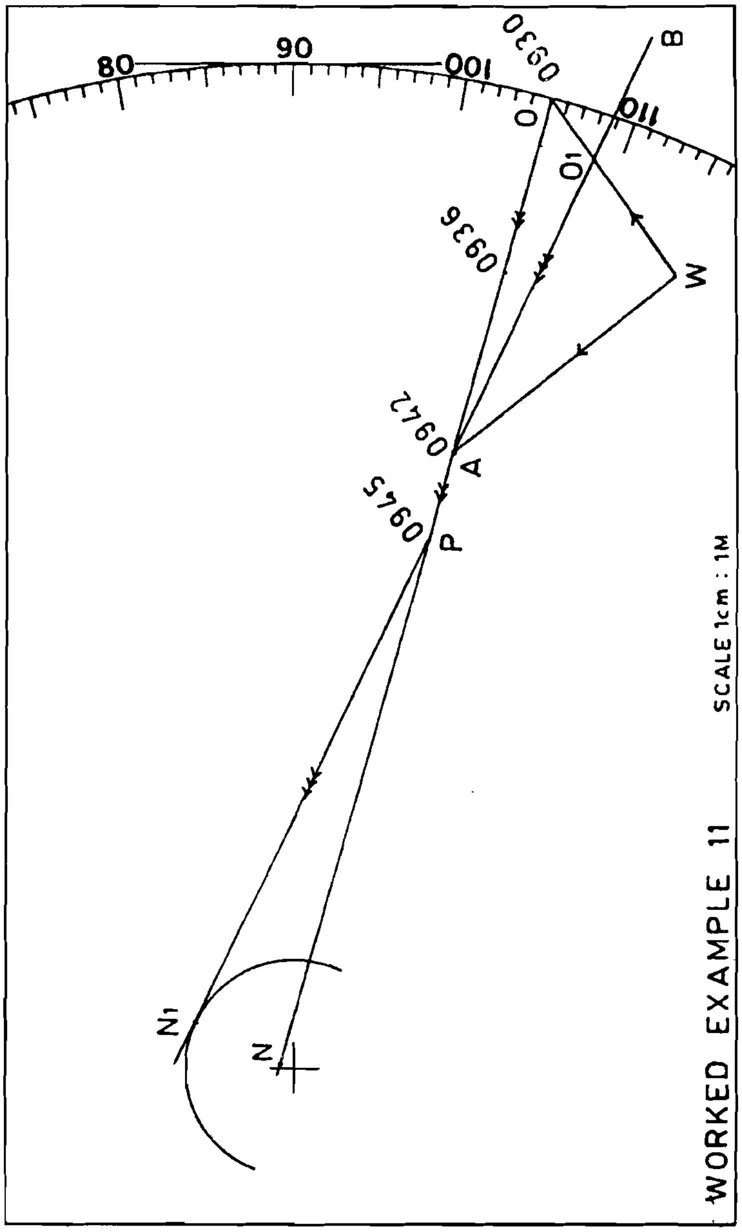
39.3 To predict speed alteration

Worked example 11

Own course 055°(T) at 15 knots.

Time	Bearing	Range
0930	105° (T)	14.0 M
0936	105° (T)	11.5 M
0942	104½°(T)	08.9 M

Find: (a) CPA range and time.
(b) Course and speed of target.
(c) Aspect at 0942.



80
90
100
110
0930
0936
0942
0945
O
O1
W
A
P
B
N
N1
0
10
SCALE 1cm : 1M
WORKED EXAMPLE 11

At 0945, own ship's captain desires to reduce speed so as to allow the target to pass ahead of own ship with a CPA of 1.5 M. Find (d) the necessary speed reduction and (e) the new CPA time.

WORKING

The first three parts of the question have been illustrated in earlier chapters.

(a) CPA 0.2 M at 1003.
(b) Course and speed of target 322°(T) 20 knots.
(c) Aspect at 0942: red 37½°

To find required speed reduction

(i) Predict position P for the time given for reduction (0945 in this case), as explained in earlier chapters.
(ii) With centre C, radius equal to the desired CPA range (1.5 M in this case), draw a large arc ahead of own ship.
(iii) From P, draw a tangent to this arc and call the point of contact N_1.
(iv) From A, draw a long line AB, parallel to N_1P.
(v) Call the point of intersection, between AB and WO, O_1.
(vi) The new triangle of relative velocities is WO_1A. O_1A is the new line of approach, becoming effective from the time of speed alteration. Hence O_1A was made parallel to PN_1 by construction.
(vii) Direction WO_1 is the same as direction WO because the course has not been altered.
(viii) Distance WO_1 is the distance the ship should cover during a number of minutes equal to the plotting interval. This converted to knots is the new speed. In this case, WO_1 is 2 M in 12 minutes. So new speed should be 10 knots.

$$\text{Time to new CPA from 0945} = \frac{PN_1}{O_1A} \times \text{plotting interval}$$

$$= \frac{7.5}{4.5} \times 12 = 20 \text{ minutes}$$

∴ New CPA time = 1005.

39.4 Choice of action to take

This is a combination of worked examples 9, 10 and 11 wherein the observer has to state the three possibilities available to him to achieve the same CPA range and then state his preference giving reasons. This is illustrated below.

Worked example 12

Own course 055°(T) at 15 knots.

Time	Bearing	Range
0930	105°(T)	14.0 M
0936	105°(T)	11.5 M
0942	104½°(T)	08.9 M

Find: (a) CPA range and time.
(b) Course and speed of target.
(c) Aspect at 0942

Captain of own ship decides to let the target pass ahead with a CPA of 1.5 M by taking a single action (i.e., an alteration of course or speed) at 0945. State the three possible actions open to him. Which of them is most preferable? Give reasons.

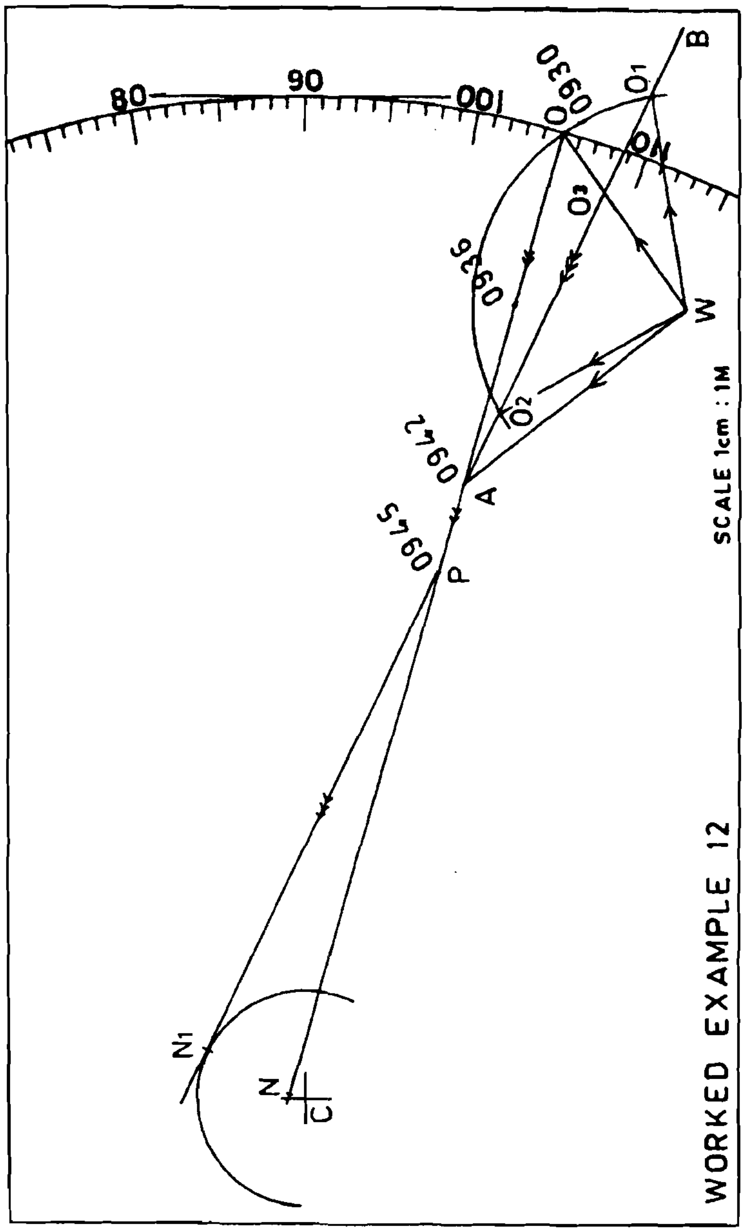
WORKING

The first three past of the question have been illustrated in earlier chapters.

(a) CPA 0.2 M at 1003.
(b) Course and speed of target 322°(T) 20 knots.
(c) Aspect at 0942: red 37½°.

To find the three possible actions

(i) Predict position P, for the given time of action (0945 in this case), as explained in earlier chapters.
(ii) With centre C, radius equal to the desired CPA range (1.5 M in this case), draw a large arc ahead of own ship.
(iii) From P, draw a tangent to this arc and call the point of contact N_1.
(iv) From A, draw a long line AB, parallel to N_1P.


WORKED EXAMPLE 12
SCALE 1cm : 1M
80
90
100
0930
0936
0942
0945
B
W
A
P
C

(v) With centre W, radius WO, cut off O_1 and O_2, on AB, to the starboard and port sides respectively, of WO. Join WO_1 and WO_2.

(vi) Read off new courses WO_1 and WO_2. In this case new courses are 081°(T) and 332°(T).

(vii) Call the point of intersection, between AB and WO, O_3. Convert distance WO_3 into knots. In this case new speed is 10 knots.

(viii) Compute the CPA times in each case.

For starboard alteration

$$\text{Time to CPA from 0945} = \frac{PN_1}{O_1A} \times \text{plotting interval}$$

$$= \frac{7.5}{6.0} \times 12 = 15 \text{ minutes}$$

∴ New CPA time = 1000.

For port alteration

$$\text{Time to new CPA from 0945} = \frac{PN_1}{O_2A} \times \text{plot interval}$$

$$= \frac{7.5}{1.1} \times 12 = 82 \text{ minutes}$$

$$= 1 \text{ hour } 22 \text{ minutes.}$$

∴ New CPA time = 1107.

For speed reduction

$$\text{Time to new CPA from 0945} = \frac{PN_1}{O_3A} \times \text{plotting interval}$$

$$= \frac{7.5}{4.5} \times 12 = 20 \text{ minutes}$$

∴ New CPA time = 1005.

(ix) The three possible actions to take at 0945 are:

(1)	(2)	(3)
New course 081°(T)	New course 332°(T)	New speed 10 knots
i.e., a/c stbd 26°	i.e., a/c port 83°	i.e., reduce by 5 knots
New CPA at 1000	New CPA at 1107	New CPA at 1005

Discussion on above

Since restricted visibility is not mentioned, the target, less than 8 M off at 0945, would be visible.

The two vessels are crossing with risk of collision. The own ship has the target on her own starboard side. As per ROR, own ship has to keep out of the way and shall, if the circumstances of the case admit, avoid crossing ahead of the other vessel. None of the three possible actions cited above contravene ROR. However alteration of course to port is ruled out, in this case, at it requires a much larger alteration than to starboard and even so, the own ship would have to remain off course very much longer.

Considering the first possibility (alteration to starboard) and the third (reduction of speed), both are reasonable. ***Out in open sea in good visibility, an alteration of course is preferable to a reduction of speed, as it would be readily apparent to the other vessel.***

Worked example 13

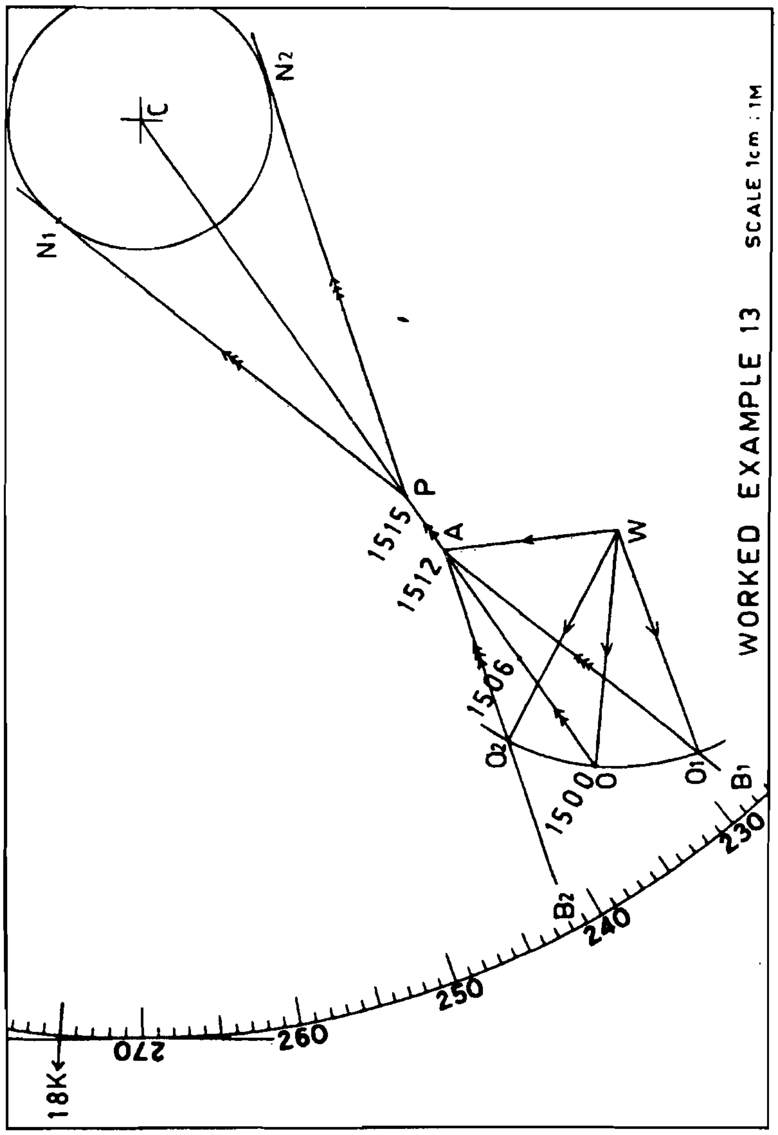
Own course 275°(T) at 18 knots.

Time	Bearing	Range
1500	235°(T)	12.0 M
1506	235°(T)	10.0 M
1512	235°(T)	08.0 M

Find: (a) CPA range and time.
(b) Course and speed of target.
(c) Aspect at 1512.

At 1514, the target is identified as a *vessel not under command.* Captain of own ship decides to alter course at 1515 so as to ensure a CPA range of 2 M.

Find (d) the course alteration required to let the target pass *ahead* of own ship and hence (e) the new CPA time.


WORKED EXAMPLE 13
SCALE 1cm : 1M
C
N1
N2
P
A
W
1515
1512
1506
1500
O
O1
O2
B1
B2
230
240
250
260
270
18K

Find (f) the course alteration required to make the target pass *astern* of own ship and hence (g) the new CPA time.
State (h), which action (d) or (f), is in accordance with ROR.

WORKING

The first three parts of the problem are as illustrated in earlier chapters.

(a) Collision at 1536.
(b) Course and speed of target 354°(T) 13 knots.
(c) Aspect at 1512: green 61°.

(d) *Course alteration to pass astern of target*:
  (i) Predict position P for 1515 (i.e., time of alteration).
  (ii) From P, draw a tangent to the 2 M circle (desired CPA range), on the *forward* side of C and call the point of contact N_1.
  (iii) From A, draw a long line AB_1 parallel to N_1P.
  (iv) Centre W, radius WO, cut off O_1 on AB_1. Join WO_1.
  (v) New course is WO_1. In this case new course is 249°(T). Therefore the alteration required is 26° to port.

(e) *Time to new CPA from 1515* = $\frac{PN_1}{O_1A}$ x plot interval

$$= \frac{6.7}{4.9} \times 12 = 16 \text{ mins}$$

∴ New CPA time = 1531.

(f) *Course alteration to pass ahead of target*:
  (i) From the 1515 position P, draw a tangent to the 2 M circle, *astern* of C, and call the point of contact N_2.
  (ii) From A, draw a long line AB_2 parallel to N_2P.
  (iii) Centre W, radius WO, cut off O_2 on AB_2. Join WO_2.
  (iv) New course is WO_2. In this case, new course is 296°(T). Therefore the alteration required is 21° to starboard.

(g) *Time to new CPA from 1515* = $\frac{PN_1}{O_2A}$ x plot interval

$= \frac{6.7}{3.1}$ x 12 = 26 mins

∴ New CPA time = 1541.

(h) Since the target is a 'not under command vessel', own ship is required to keep out of the way. Either action (d) or (f) is acceptable as neither contravenes ROR. Furthermore, the magnitudes of both the actions are nearly the same. However, most Masters would prefer to pass astern of the target and in this case, the new CPA time caused by the port alteration is 10 minutes earlier than that caused by the starboard alteration.

39.5 Given one of two actions, to find the other

Worked example 14

Own course 217°(T) at 20 knots.

Time	Bearing	Range
1620	263°(T)	12.0 M
1632	263½°(T)	08.0 M

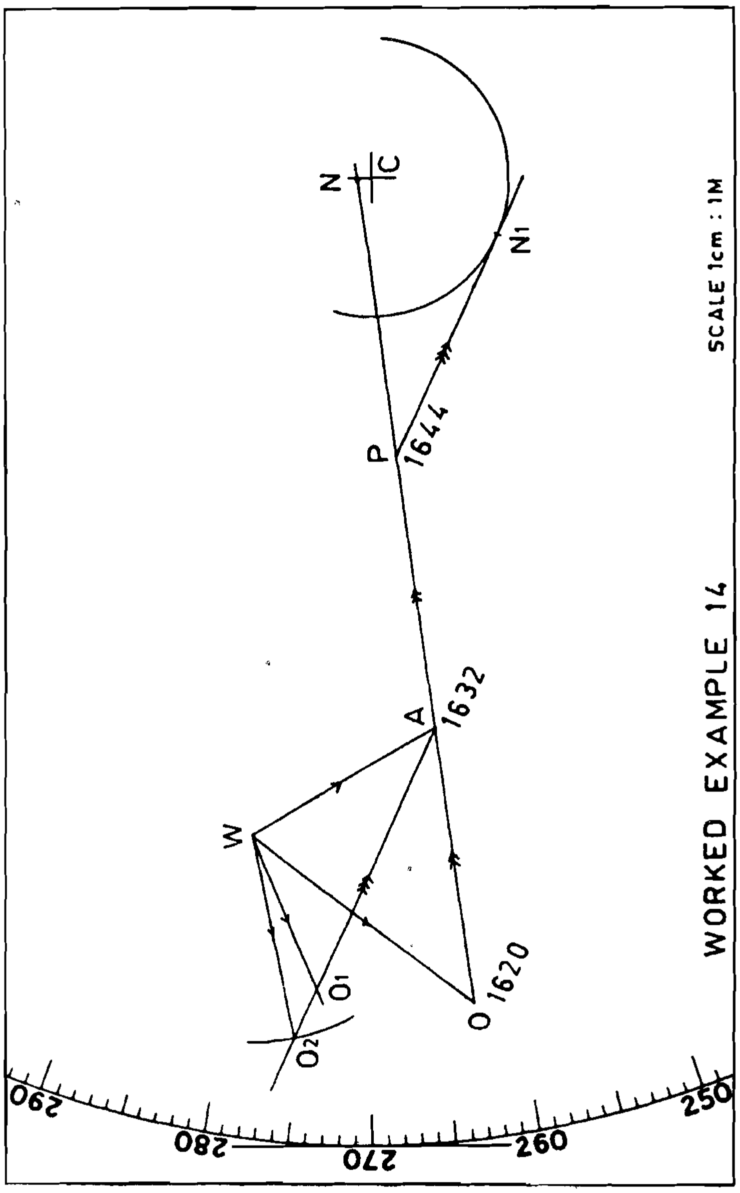
Find: (a) CPA range, time and bearing.
(b) Course and speed of target.
(c) Aspect at 1632.

(d) At 1644, if course is altered to starboard by 30°, what speed alteration is required at the same time to ensure 2 M CPA range?
(e) When would this new CPA occur?
(f) At 1644, if speed is reduced to 15 knots, what course alteration to starboard is required at the same time to ensure a CPA range of 2 M? (g) When would this new CPA occur?

WORKING

The first three parts of the question have been illustrated in earlier chapters.

(a) CPA 0.2 M at 1656, bearing 352°(T).
(b) Target's course 150°(T) speed 15 knots.
(c) Aspect at 1632: red 66½°.


WORKED EXAMPLE 14
SCALE 1cm : 1M
N
C
N1
P
1644
A
1632
W
O
1620
O1
O2
290
280
270
260
250

Predict position P for the time of alteration (1644). Draw a tangent from P to the 2 M circle, on the forward side of C, and call the point of contact N_1. From A, draw a long line AB, parallel to N_1P. Since the line of approach is to be PN_1, O_1 must lie on AB.

(d) To predict the new speed

From W, lay off the new course of 247°(T) and call the point, where this cuts AB, O_1. Distance WO_1, converted to knots, is the required new speed. In this case, WO_1 is 2.4 M in 12 minutes. So the new speed should be 12 knots from 1644 onwards.

(e) Time to new CPA from 1644 $= \dfrac{PN_1}{O_1A} \times$ plotting interval

$$= \frac{3.5}{4.1} \times 12 = 10 \text{ minutes}$$

∴ New CPA time = 1654.

(f) To predict the starboard alteration

The plotting interval is 12 minutes in this case. So at a new speed of 15 knots, the ship would do 3.0 M in 12 minutes.

With centre W, radius 3.0 M, cut off an arc to starboard of WO, to cut AB at O_2. WO_2 is the new course to steer from 1644 onwards. New course, in this case, should be 258°(T) i.e., an alteration of 41° to starboard.

(g) Time to new CPA from 1644 $= \dfrac{PN_1}{O_2A} \times$ plotting interval

$$= \frac{3.5}{4.9} \times 12 = 9 \text{ minutes}$$

∴ New CPA time = 1653.

39.6 Given an action, to find when to resume course and speed

Worked example 15

Own course 304°(T) at 16 knots.

Time	Bearing	Range
0200	304° (T)	6.5 M
0215	304° (T)	5.0 M

Find: (a) CPA range and time.
(b) Course and speed of target.
(c) Aspect at 0215.

At 0230, own course was altered 20° to port. Find (d) the time when own ship should resume her original course to achieve a CPA range of 1.0 M. State also (e) the new CPA time.

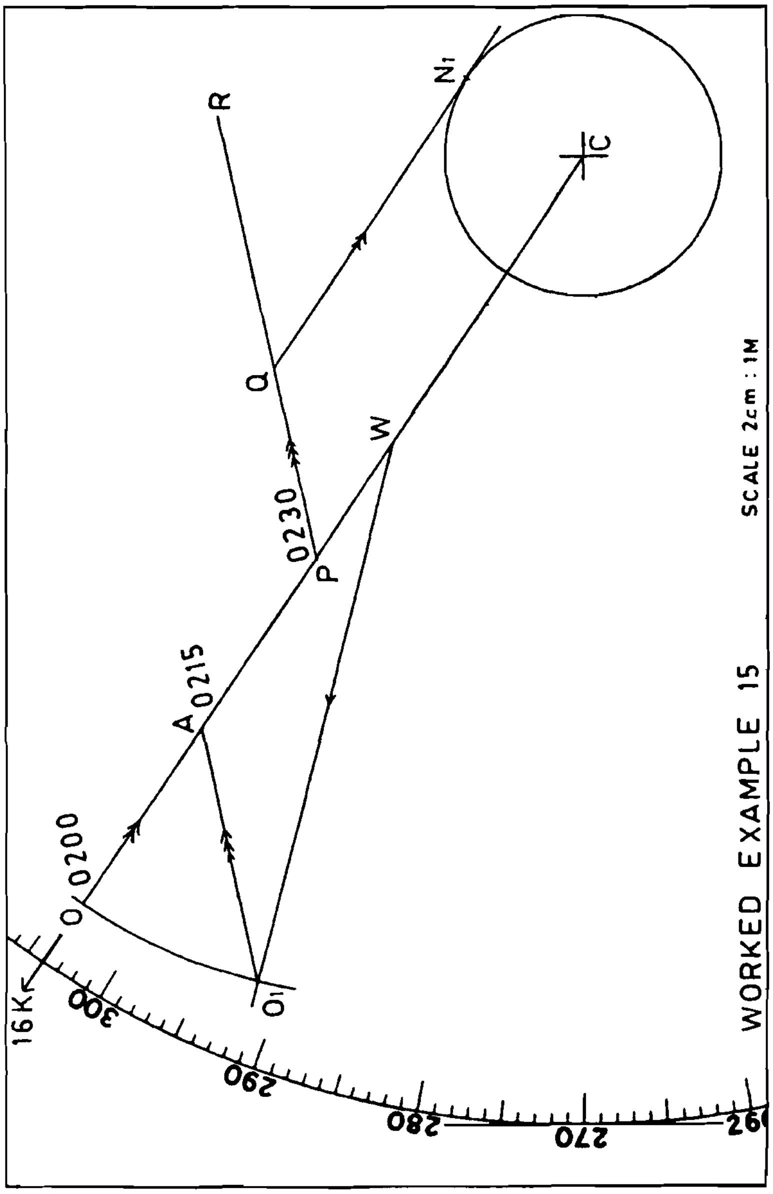
WORKING

The first three parts of the question have been illustrated in earlier chapters.

(a) Collision at 0305.
(b) Target's course 304°(T) speed 10 knots (target is being overtaken by own ship).
(c) Aspect at 0215: 180°.

Subsequent working as follows

(i) Predict position P for 0230.
(ii) Lay off the new course of 284°(T) from W and cut off WO_1 on it. WO_1 equals to 4 M i.e., 15 minutes at 16 knots. Join O_1A.
(iii) From P, draw a long line PR, parallel to O_1A. This is the line of approach from 0230 onwards, after the 20° alteration of course to port.
(iv) When the own ship resumes course, the line of approach will be parallel to OA. Hence draw a line, parallel to OA, as a tangent to the 1 M circle (desired CPA range). Call the point of contact N_1 and let this tangent intersect PR at Q.


WORKED EXAMPLE 15
SCALE 2cm : 1M
R
Q
W
P
0230
A
0215
O
0200
O1
N1
C
16K
300
290
280
270
260

(v) The line of approach from 0230 is PQ and after the own ship resumes course at Q, the final line of approach will be QN_1.

(d) Time to reach Q from 0230 $= \dfrac{PQ}{O_1A}$ x plotting interval

$= \dfrac{1.40}{1.85}$ x 15 = 11 minutes

∴ Own ship will reach Q at 0241, at which time she should resume course.

(e) Time to new CPA from 0241 $= \dfrac{QN_1}{OA}$ x plotting interval

$= \dfrac{2.5}{1.5}$ x 15 = 25 minutes

∴ New CPA at 0306.

Worked example 16

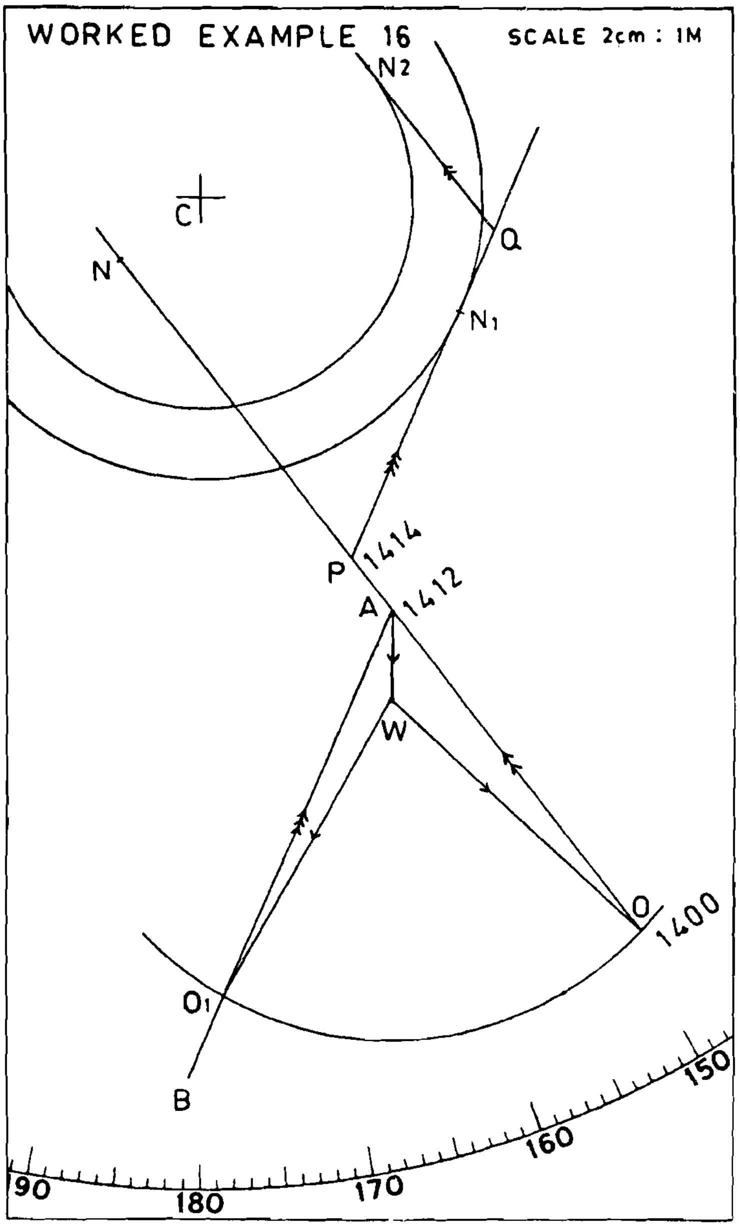
While on a course of 133°(T) at 12 knots in hazy weather, a target was observed on the radar screen as follows:

Time	Bearing	Range
1400	149° (T)	6.0 M
1412	155° (T)	3.2 M

(a) Find the CPA range, time and bearing.

If at 1412, the target was identified visually as a lighthouse, state

(b) The course and speed of own ship through the water.
(c) The course and speed of own ship over ground.
(d) The set and rate of current.
(e) The alteration of course to be made, at 1414, to pass the lighthouse to port with a CPA of 2 M.
(f) Having made the alteration as required in (e), when should the own ship resume her original course to obtain a CPA range of 1.5 M?
(g) When would the desired CPA of 1.5 M occur?


WORKED EXAMPLE 16
SCALE 2cm : 1M
N2
C
Q
N
N1
P
1414
A
1412
W
O
1400
O1
B
150
160
170
180
190

WORKING

(a) As shown in the accompanying plot, the expected CPA range is 0.7 M at 1425, bearing 232°(T).

(b) Course and speed of ship through the water is WO - 133°(T) at 12 knots.

(c) Course and speed of ship over ground is AO (the course and speed made good) - 142°(T) at 14.25 knots.

(d) Set and drift of current is AW i.e., set is 180°(T) & drift is 0.6 M in 12 minutes. Hence rate of current is 3 knots.

(e) (i) Predict position P for 1414.

(ii) From P, draw a tangent to the 2 M circle to the *port side* of C and call the point of contact N_1.

(iii) PN_1 is the desired line of approach from 1414 onwards.

(iv) Through A, draw a long line, AB, parallel to N_1P.

(v) With centre W, radius WO, cut off O_1 on AB. WO_1 is the new course to steer from 1414 onwards. In this case, new course is 209°(T).

(f) When the own ship resumes her original course, the line of approach will be parallel to OA. Hence draw the tangent QN_2 to the 1.5 M circle, parallel to OA, to meet PN_1 at Q and touch the circle at N_2. Q is the point where own ship should resume her original course in order to have a CPA range of 1.5 M.

$$\text{Time to point Q from 1414} = \frac{PQ}{O_1A} \times \text{plotting interval}$$

$$= \frac{2.50}{2.95} \times 12 = 10 \text{ minutes}$$

∴ Time to resume course = 1424.

$$\text{(g) Time to final CPA from 1424} = \frac{QN_2}{OA} \times \text{plotting interval}$$

$$= \frac{1.45}{2.85} \times 12 = 6 \text{ minutes}$$

∴ Final CPA time = 1430.

Exercise 4

1. Own course 242°(T) 16 knots.

Time	Bearing	Range
0400	270° (T)	6.5 M
0406	268° (T)	4.3 M

Report the target at 0406.
Find the course alteration to make to starboard at 0410, to ensure a CPA range of 1.5 M.
When would this new CPA occur?

2. Own course 073°(T) 10 knots.

Time	Bearing	Range
0900	073° (T)	6.0 M
0903	073° (T)	5.1 M
0906	073° (T)	4.2 M

Find: (a) CPA range and time.
(b) Course and speed of target.
(c) Aspect at 0906.
(d) Course alteration to starboard at 0908 to ensure a nearest approach of 1.0 M.
(e) Time when this new CPA would occur.

3. While on a course of 298° (T) at 10 knots, *a vessel not under command* was observed as follows:

Time	Bearing	Range
0330	220° (T)	6.5 M
0340	219½° (T)	5.0 M

Find: (a) CPA range and time.
(b) Course and speed of target.
(c) Aspect at 0340.
(d) Course alteration to port at 0345, to ensure a CPA range of 1.0 M.
(e) New CPA time.

4. Own course 168°(T) at 24 knots.

Time	Bearing	Range
1540	168° (T)	6.0 M
1600	168° (T)	3.0 M

Find: (a) CPA range and time.
(b) Course and speed of target.
(c) Aspect at 1600
(d) The course alteration to port required to be made at 1605, to achieve a CPA range of 1.0 M.
(e) When the new CPA would occur.
(f) Does action (d) contravene ROR?

5. Own course 330°(T) speed 15 knots.

Time	Bearing	Range
1848	040° (T)	12.0 M
1900	039½° (T)	8.8 M

Find: (a) CPA range and time.
(b) Course and speed of target.
(c) Aspect at 1900
(d) The speed reduction to be made at 1906 to ensure a CPA range of 3.0 M.
(e) The new CPA time
(f) In lieu of the speed reduction suggested in (d), what course alteration, to starboard at 1906, would achieve the CPA of 3.0 M?
(g) The new CPA time, after this course alteration.
(h) Which action (d) or (f) is preferable? Why?

6. While on a course of 018°(T) at 10 knots, a vessel *not under command* was observed as follows:

Time	Bearing	Range
1200	328° (T)	6.00 M
1212	330° (T)	3.65 M

Find: (a) CPA range and time.
(b) Course and speed of target.
(c) Aspect at 1212.

If the Master desires a CPA range of 1 M, find (d) the course alteration to port, required at 1214 & (e) the new CPA time. If own vessel is constrained by her draft and is unable to alter course, find (f) the speed reduction to be made at 1214 to achieve the CPA range of 1 M and (g) the new CPA time.

7. While leaving port, own ship is abeam of the fairway buoy on a course of 180°(T) at 6 knots and sights a fishing vessel as follows:

Time	Bearing	Range
0400	120° (T)	5.00 M
0412	120½° (T)	3.25 M

Find: (a) CPA range and time.
- (b) Target's course and speed.
- (c) Aspect at 0412.
- (d) The speed alteration to be made at 0415 to pass *astern* of the target with a CPA range of 1.0 M.
- (e) The new CPA time.
- (f) The speed alteration to be made at 0415 to pass *ahead* of the target with a CPA range of 1.0 M.
- (g) The new CPA time.
- (h) Which actions, (d) or (f), is permissible by ROR?

8. Own course 350°(T) speed 10 knots.

Time	Bearing	Range
2000	060° (T)	12.0 M
2015	059½° (T)	8.0 M

Find: (a) CPA range and time.
- (b) Course and speed of target.
- (c) Aspect at 2015.
- (d) The speed alteration to be made at 2020 to pass *astern* of the target with a CPA range of 2.0 M.
- (e) The time of new CPA.
- (f) The speed alteration to be made at 2020 to pass *ahead* of the target with a CPA range of 2.0 M.
- (g) The time of new CPA.
- (h) Which of the actions, (d) or (f) is preferable? Why?

9. Own course 152°(T) at 16 knots.

Time	Bearing	Range
0630	180° (T)	6.5 M
0636	178° (T)	4.3 M

Find: (a) CPA range and time
(b) Target's course and speed.
(c) Aspect at 0636.
(d) The course alteration to be made to starboard, coupled with a speed reduction to 12 knots, at 0639 in order to have a CPA range of 1.5 M.
(e) The new CPA time.

10. While on a course of 038°(T) at 10 knots, a vessel *restricted in her ability to manoeuvre* was observed as follows:

Time	Bearing	Range
0000	320° (T)	6.5 M
0010	319½° (T)	5.0 M

Find: (a) CPA range and time.
(b) Target's course and speed.
(c) Aspect at 0010.
(d) The course alteration to port, coupled with a speed reduction to 7.5 knots, at 0020, to let the target pass ahead with a CPA range of 1.0 M.
(e) The new CPA time.

11. Own course 140°(T) at 15 knots.

Time	Bearing	Range
1000	210° (T)	12.0 M
1012	209½° (T)	8.8 M

(a) Report the target at 1012.
(b) Find what speed alteration, coupled with a course alteration of 35° to starboard, at 1018, would cause the target to pass ahead with a CPA range of 3.0 M.
(c) Find the time of new CPA.

12. While on a course of 078°(T) at 10 knots, a vessel NUC was observed as follows:

Time	Bearing	Range
1600	028° (T)	6.00 M
1612	030° (T)	3.65 M

Find: (a) CPA range and time.
(b) Course and speed of target.
(c) Aspect at 1612.
(d) What speed alteration, coupled with a course alteration of 15° to port, as 1615, will allow the target to pass ahead with a CPA of 1.0 M.
(e) The new CPA time.

13. Own course 270°(T) at 16 knots.

Time	Bearing	Range
1412	272° (T)	13.0 M
1424	274° (T)	07.4 M

Find: (a) CPA range and time.
(b) Course and speed of target.
(c) Aspect at 1424.

At 1426,own ship altered course 60° to starboard. Find (d) when own ship should resume course to achieve a nearest approach of 2 M and (e) time when this CPA of 2 M would occur.

14. Own course 222°(T) at 17 knots.

Time	Bearing	Range
1115	229° (T)	5.5 M
1130	227° (T)	3.2 M

Find: (a) CPA range, time and bearing.
(b) Course and speed of target.
(c) Aspect at 1130.
(d) Whose duty it is to keep out of the way.

At 1135, own ship altered course 35° to port. Find (e) when she should resume her original course so as to achieve a CPA range of 1.5 M and (f) the new CPA time and bearing.

15. Own course 044°(T) at 12 knots.

Time	Bearing	Range
0730	030° (T)	6.5 M
0742	031½° (T)	3.5 M

Find: (a) CPA range and time.
(b) Course and speed of target.
(c) Aspect at 0742.

At 0744, the target was identified as a minesweeper and own ship's engines were stopped. Find (d) the time when own ship may proceed at Dead Slow Ahead (5 knots) to ensure a CPA range of 1.5 M and (e) the time when this 1.5 M CPA would occur. (Assume all actions to be instantly effective).

16. Own course 084°(T) at 8 knots. Visibility reduced to 4 miles due to haze.

Time	Bearing	Range
0600	150° (T)	12.0 M
0624	151½° (T)	8.0 M

Find: (a) CPA range and time.
(b) Course and speed of target.
(c) Aspect at 0624.

State (d) what speed alteration is to be made at 0636 to increase the CPA range to 2 M.

Having made the speed alteration in (d), state (e) when the own ship may resume her original speed to ensure a CPA range of 1.5 M and (f) the time when the 1.5 M CPA will occur.

(g) Discuss the ROR applicable in this case.

17. Own course 000°(T) speed 14 knots.

Time	Bearing	Range
1300	050° (T)	12.0 M
1312	049° (T)	7.0 M

Find: (a) CPA range and time.
(b) Course and speed of target.
(c) Aspect at 1312.

Master of own ship desires to let the target pass ahead with a CPA range of 2 M by taking a single action (alteration of either course or speed) at 1315. State (d) the three possible actions he can take to achieve the said result. State (e) which of the three is preferable and why.

18. Own ship on a course of 020°(T) at a maximum speed of 12 knots observes a fishing vessel as follows:

Time	Bearing	Range
1630	330° (T)	6.5 M
1642	330° (T)	4.5 M

Find: (a) CPA range and time.
(b) Target's course and speed.
(c) Aspect at 1642.
State (d) whose duty it is to keep out of the way.
The Master of the own ship decides to pass ahead of the target with a CPA of 1.0 M, by taking a single action (an alteration of course or speed) at 1645. State (e) the possible actions that he may take to achieve the desired result.

19. Own course 270°(T) at 15 knots.

Time	Bearing	Range
0900	240° (T)	13.0 M
0912	240° (T)	9.0 M

Find: (a) CPA range and time.
(b) Course and speed of target.
(c) Aspect at 0912.
If the Master of own ship desires to let the target pass ahead with a CPA of 2.0 M, by either altering course or speed, at 0912, find (d) the possible actions that he may take and state (e) which of these actions is in accordance with ROR.
If the own ship did not take any action at all till 0933, when the target bore 240°(T) 2.0 M off, discuss the various manoeuvres that the own ship may now take to avert collision.

20. Own course 135°(T) at 12 knots.

Time	Bearing	Range
0400	135° (T)	6.0 M
0430	135° (T)	4.0 M

Find: (a) CPA range and time.
(b) Target's course and speed.
(c) Aspect at 0430.

State (d) whose duty it is to keep out of the way.

If the own ship's Master desires to pass the target with a CPA range of 1.0 M, state (e) the possible actions that he can take at 0500.

State (f) which of the possible actions is in accordance with ROR and (g) the CPA time after taking the action as per (f).

Answers to exercise 4

1. Report at 0406: Crossing vessel bearing 268°(T) drawing forward, range 4.3 M decreasing, CPA 0.45 M at 0418, course and speed of target 139°(T) 12 knots, aspect red 51°. New course from 0410: 280°(T) i.e., a/c 38° to starboard. New CPA at 0416.
2. (a) Collision at 0920.
   (b) Target's course and speed 253°(T) 8 knots.
   (c) Aspect at 0906: 000°.
   (d) New Course 102°(T) i.e., a/c 29° to starboard.
   (e) New CPA at 0920.
3. (a) CPA 0.2 M at 0413.
   (b) Target's course and speed 346°(T) 11.75 knots.
   (c) Aspect at 0340: green 53½°.
   (d) New Course 254°(T) i.e., a/c 44° to port.
   (e) New CPA at 0401.
4. (a) Collision at 1620.
   (b) Target's course 168°(T) speed 15 knots.
   (c) Aspect at 1600: 180°.
   (d) New Course 158°(T) i.e., a/c 10° to port.

(e) New CPA at 1618.
(f) No. The overtaking vessel may alter to any side so long as she keeps out of the way of the overtaken vessel.

5. (a) CPA 0.3 M at 1933.
(b) Target's course 273°(T) speed 18 knots.
(c) Aspect at 1900: red 53½°.
(d) New speed 9 knots.
(e) New CPA at 1932, after speed reduction at 1906.
(f) New course 026°(T), i.e., a/c 56° to starboard.
(g) New CPA at 1921, after starboard alteration at 1906.
(d) Either action is in accordance with ROR. However, a course alteration is preferable to a speed reduction because it is readily apparent to the other vessel.

6. (a) CPA 0.3 M at 1231.
(b) Target's course 091°(T) speed 10 knots.
(c) Aspect at 1212: green 59°
(d) New course 354°(T) i.e., a/c 24° to port.
(e) New CPA at 1226.
(f) New speed 7.25 knots.
(g) New CPA at 1232.

7. (a) CPA range 0.1 M at 0434.
(b) Target's course 257°(T) speed 8 knots.
(c) Aspect at 0412: green 43½°
(d) New speed 3 knots.
(e) New CPA at 0435
(f) New speed 11.5 knots.
(g) New CPA at 0428.
(h) Either of the two actions, to keep out of the way of a fishing vessel, is in accordance with ROR

8. (a) CPA range 0.2 M at 2045.
(b) Course of target 278°(T) speed 16 knots.
(c) Aspect at 2015: red 38½°
(d) New speed 5.6 knots
(e) New CPA at 2045
(f) New speed 17 knots.
(g) New CPA at 2040.

(h) Action (d) is preferable to action (f) as the latter is prohibited by the crossing situation rule, the last part of which states ".... and if the circumstances of the case admit, avoid crossing ahead of the other vessel."

9. (a) CPA 0.45 M at 0648.
   (b) Target's course 049°(T) speed 12 knots.
   (c) Aspect at 0636: red 51°.
   (d) New Course 179°(T) i.e., a/c 27° to starboard.
   (e) New CPA at 0647.
10. (a) CPA range 0.2 M at 0043.
   (b) Target's course 086°(T) at12 knots.
   (c) Aspect at 0010: green 53½°.
   (d) New Course 007°(T) i.e., a/c 31° to port.
   (e) New CPA time 0036.
11. (a) Report at 1012: Crossing vessel bearing 209½°(T) drawing forward, range 8.8 M decreasing, CPA 0.3 M at 1045, target's course and speed 083°(T) at 18 knots, aspect red 53½°.
   (b) New speed 9.5 knots.
   (c) New CPA time 1038.
12. (a) CPA range 0.3 M at 1630.
   (b) Target's course 151°(T) speed 10 knots.
   (c) Aspect at 1612: green 59°.
   (d) New speed 8.25 knots.
   (e) New CPA at 1629.
13. (a) CPA range 0.6 M at 1440.
   (b) Course and speed of target 089°(T) 12 knots.
   (c) Aspect at 1424: green 5°.
   (d) Resume course at 1437.
   (e) New CPA at 1443.
14. (a) CPA 0.25 M at 1151, bearing 142°(T).
   (b) Target's course and speed 210°(T) 8 knots.
   (c) Aspect at 1130: 163° red.
   (d) Own ship is overtaking the target and must keep out of the way.

(e) To resume course at 1147.
(f) New CPA at 1157, bearing 322°(T)

15. (a) CPA 0.2 M at 0756.
(b) Course and speed of target 166°(T) 5 knots.
(c) Aspect at 0742: green 45½°.
(d) Engines may be put to Dead Slow Ahead at 0800.
(a) CPA 1.5 M at 0812.

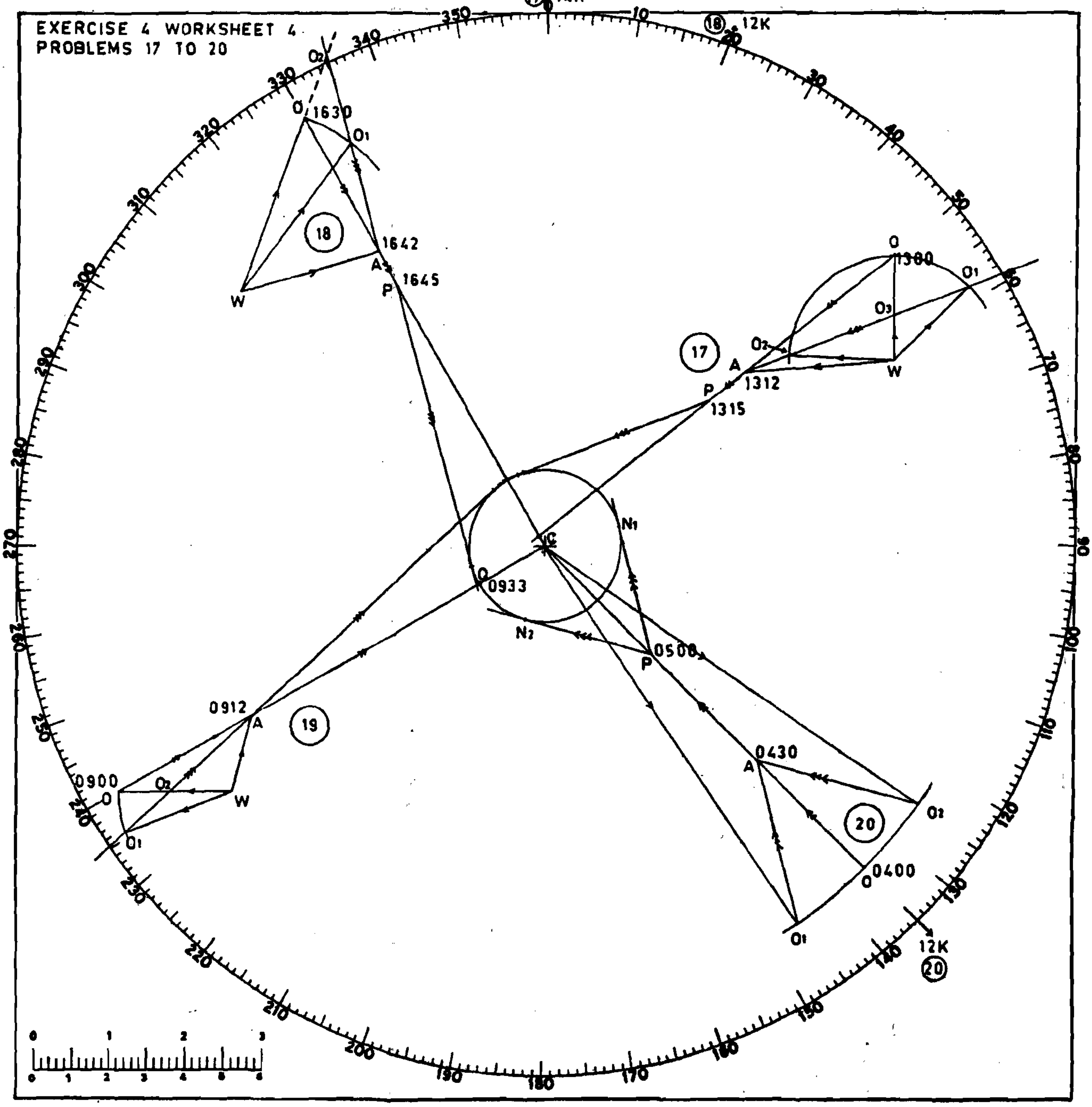
16. (a) CPA range 0.6 M at 0712.
(b) Target's course 015°(T) speed 9.5 knots.
(c) Aspect at 0624: red 43½°.
(d) New speed 11 knots i.e. increase by 3 knots.
(e) Resume speed at 0655.
(f) CPA 1.5 M at 0709.
(g) At 0636, range of target is 6 M whereas the visibility is only 4 M. The vessels are *not* yet in sight of one another and hence the crossing situation rule is not applicable. So own ship is free to take any action, which is early and substantial, to avoid a close-quarters situation, but she is not allowed to alter course to port as the target is forward of her beam.

If the target is using radar, she also is free to take early and substantial action but since own ship is forward of her beam, target is not allowed to alter course to port.

If the target is not using radar, she would, in this case, be unaware of the presence of the own vessel until the vessels are in sight of one another.

Having taken early and substantial action, to avoid a close-quarters situation, it must be ascertained, by careful radar watch, that it is having the desired effect. If should be borne in mind that the target has the option to alter course to starboard, before the vessels are in sight of one another, to avoid a close-quarters situation, and may do so, in which case the increase of speed by own ship may not have the desired effect. It may be more prudent to reduce speed rather than increase it.

RADAR PLOTTING SHEET



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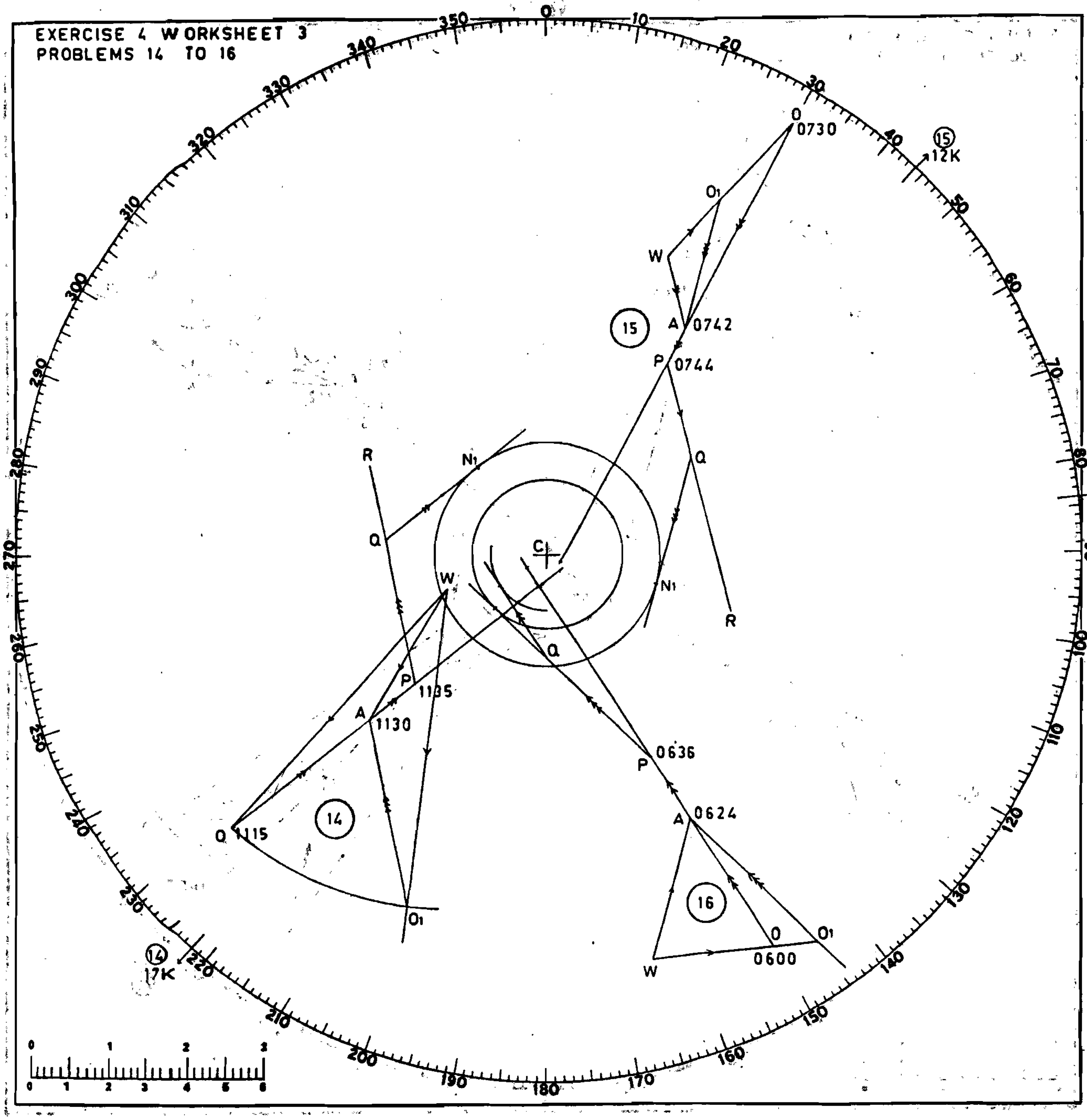

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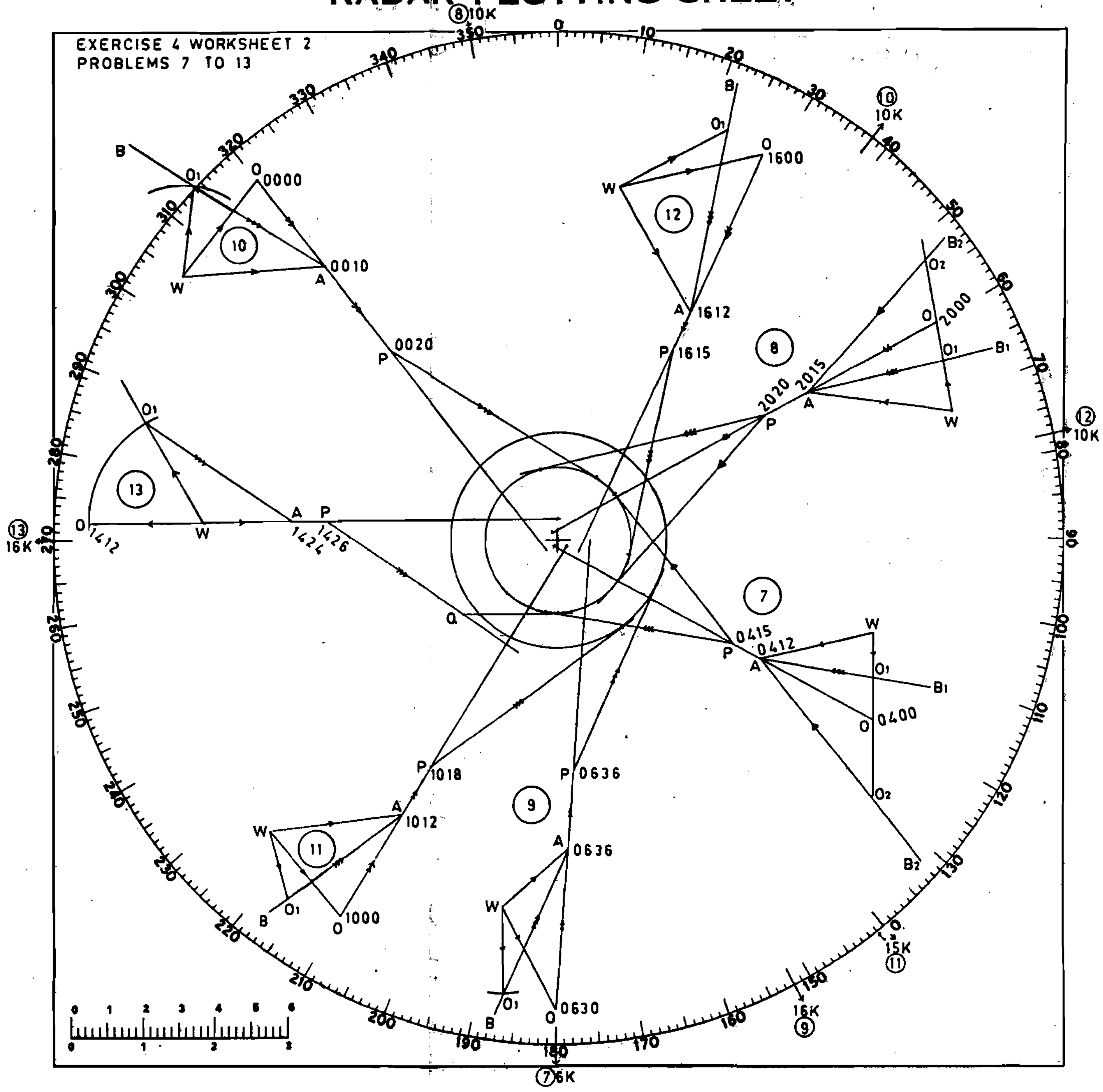

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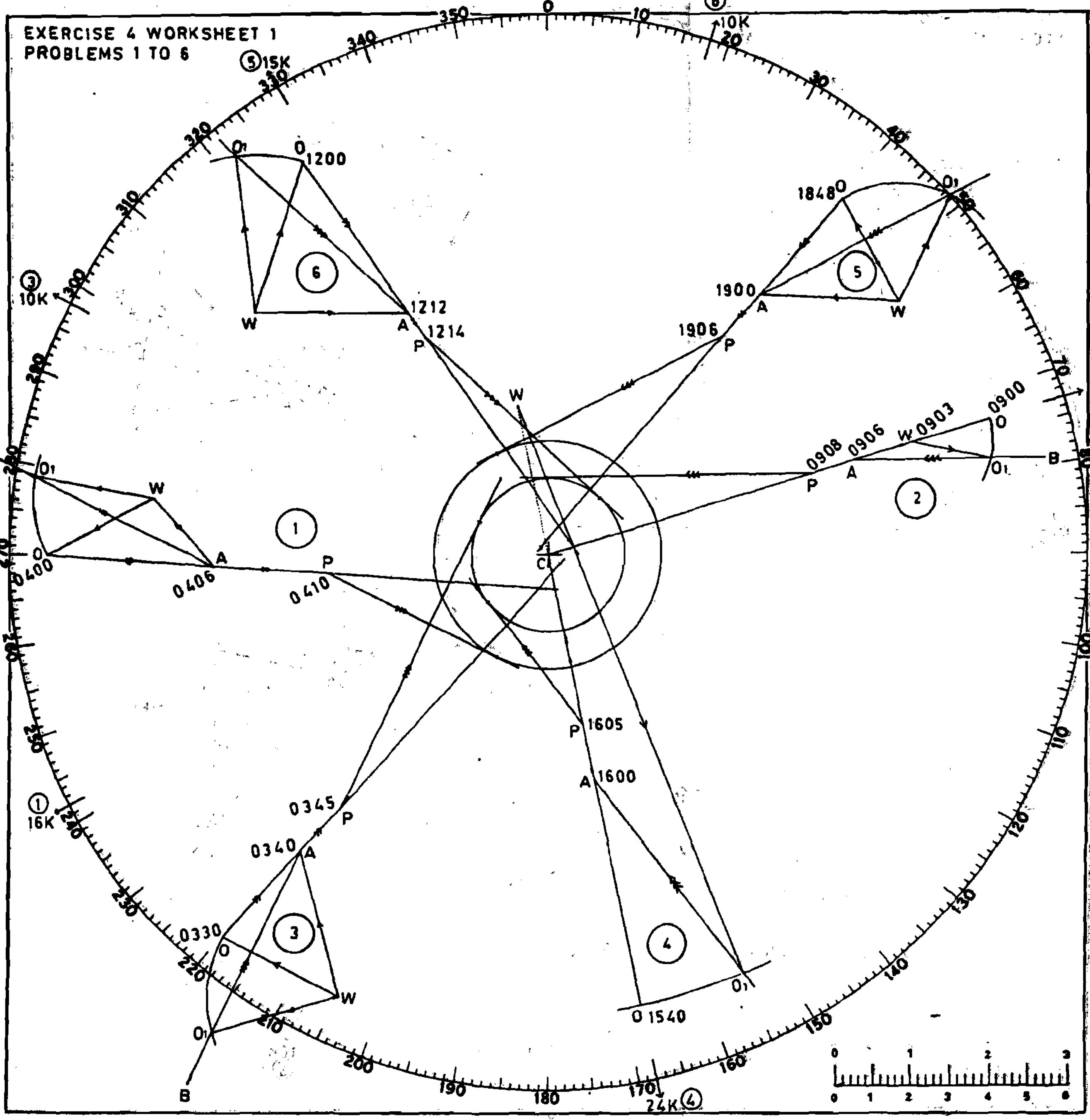


17. (a) CPA range 0.3 M at 1329.
    (b) Target's course 266°(T) speed 19.5 knots.
    (c) Aspect at 1312: red 37°.
    (b) (i) Alter course 45° to starboard i.e., new course 045°(T). New CPA at 1325.
        (ii) Alter course 87° to port i.e. new course 273°(T). New CPA at 1409.
        (iii) Reduce speed to 6 knots. New CPA at 1330.
    (c) None of the three actions contravene ROR. However, in this case, the port alteration is much larger than the starboard alteration and the vessel would stay off course unduly long. Hence the port alteration is ruled out. Both, the starboard alteration and the reduction of speed, seem reasonable but in open sea, at full away, a course alteration is preferable to a speed reduction because it is readily apparent to the other vessel. So out of the three actions, the starboard alteration is the best, in this case.
18. (a) Collision at 1709.
    (b) Target's course 074°(T) speed 9.5 knots.
    (c) Aspect at 1642: green 76°.
    (d) Own ship to keep out of the way as the target is a fishing vessel.
    (e) (i) Alter course 17° to starboard i.e. new course 037°(T).
        (ii) Increase speed to 16.5 knots. However, this is not possible, as the own ship's maximum speed is 12 knots.
19. (a) Collision at 0939
    (b) Target's course 014°(T) speed 10.5 knots.
    (c) Aspect at 0912: 46° green.
    (d) (i) Alter course 21° to port i.e., new course 249°(T).
        (ii) Reduce speed to 8 knots.
    (e) Both actions (d) (i) and (d) (ii) contravene ROR. This is a crossing situation, where vessels are in sight of one another, and as per ROR, own ship is the stand-on vessel required to maintain her course and speed.

(d) At 0933; the imminent collision is only 6 minutes away and it is apparent that the target is not taking the avoiding action required by ROR. Assuming that attempts have been made, in good time, to attract the other vessel's attention, the four possible avoiding actions that the own ship can take are discussed below:

(i) Increase of speed - not normally practicable as own ship is already doing maximum speed.

(ii) Reduction of speed or stoppage of engine - not recommended, in this case, as the target may alter course to starboard at the last instant whereby own ship's speed reduction may prove to be disastrous.

(iii) Alteration of course to port - expressly prohibited by ROR.

(iv) Alteration of course to starboard - appears to be the best action, under the circumstances. The starboard alteration may be either to execute a full circle and then resume course, by which time the target would have passed clear, or just enough to put own vessel on a parallel course and when sufficient overlap between the two vessels has been established, course may be resumed.

20. (a) Collision at 0530.

(b) Target's course 135°(T) speed 8 knots.

(c) Aspect at 0430: 180°.

(d) Own ship is overtaking the target and is hence required to keep out of the way.

(e) (i) Alter course 11° to starboard i.e., new course of 146°(T).

(ii) Alter course 11° to port i.e., new course of 124°(T).

(f) Either of the actions (i) or (ii) is in accordance with ROR.

(g) New CPA time 0524.

-oOo-

CHAPTER 40

TRUE PLOTTING

40.1 The basic true plot

In relative plotting, every observation of a target was laid off from the centre of the plotting sheet. Hence the apparent movement of a target on the plotting sheet was relative. If, however, the own ship was depicted to move, on the plotting sheet, at its correct course and speed, and if the target's positions were laid off from the corresponding position of the own ship at that time, the movement of the target, as depicted on the plotting sheet, would be its true course and speed - hence the term 'true plot'.

When plotting *on paper*, any problem may be worked by means of a relative plot or a true plot, regardless of whether the observations were made on a RM (relative motion) display or on a TM (true motion) display. This is because the radar gives correct bearings and ranges, at all times, regardless of the type of display in use.

However, when plotting on a reflection plotter, a relative plot would have to be made when using RM, and a true plot when using TM.

The difference between a relative plot and a true plot is easily illustrated by a simple example.

Worked example 17

Own course 340°(T) at 15 knots.

Time	Bearing	Range
0800	020°(T)	12.0 M
0812	017°(T)	09.0 M

Find (a) Course and speed of target.
(b) Aspect at 0812.

In the next two pages, this problem has been worked twice, first by a relative plot and second, by a true plot. The relative plot has been thoroughly described in earlier chapters and is hence not elaborated further here.

The construction of the *true plot*, step by step, is as follows:

(i) Draw the course line of the own ship through the centre of the plotting sheet and, on this line, mark off C_1 and C_2, the positions of the own ship at 0800 and 0812. It would make working more convenient if C_2, the position of own ship at the end of the plotting interval, is inserted at the centre of the plotting sheet. This is, however, not necessary.

(ii) Using the plotting sheet as a compass rose, lay off the 0800 bearing and range of the target from C_1.

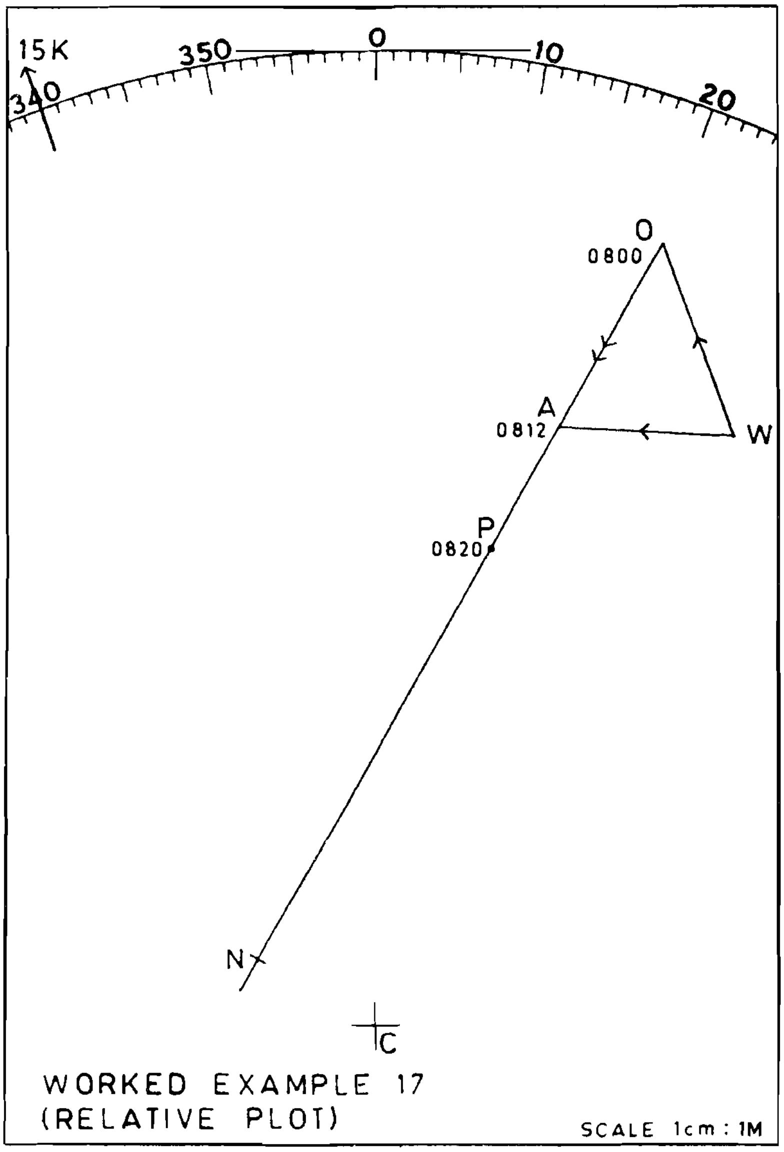
(iii) Lay off the 0812 bearing and range of the target from C_2.

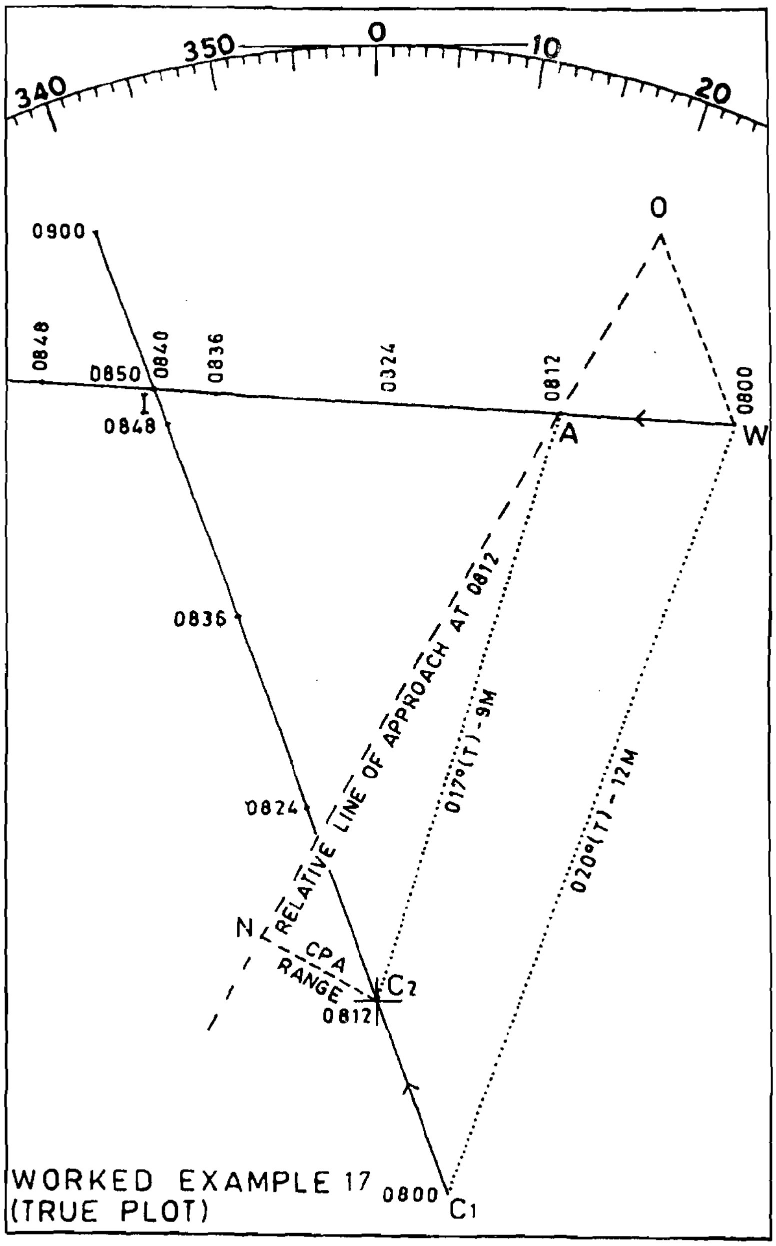
(iv) Join the two positions of the target and this is the true course and distance covered by the target between 0800 and 0812. In accordance with the lettering used for relative plotting, this line would be WA. In this case, WA is 273°(T) and 2.5 M in 12 minutes. Hence course and speed of target is 273°(T) 12.5 knots ......answer (a).

(v) Course of target 273°(T)
Reversed bearing at 0812 197°(T)
Aspect at 0812 76° red ....answer (b).

By this true plot, the target's course, speed and aspect were obtained straight away, without the construction of the plotting triangle.

To find out if there is risk of collision, produce WA and $C_1 C_2$ to meet at I. On AI, mark off the target's predicted positions at 12-minute intervals. On C_2I, mark off the predicted positions of the own ship, at 12-minute intervals. If both, the own ship and the target, are predicted to arrive at I at greatly differing times, risk of collision does *not* exist. If the predicted times of arrival at I are the same or very nearly the same, risk of collision exists.


15K
350
0
10
340
20
O
0800
A
0812
W
P
0820
N
C
WORKED EXAMPLE 17
(RELATIVE PLOT)
SCALE 1cm : 1M



340
350
0
10
20
O
0900
0848
0850
0840
0836
0324
0812
0800
I
0848
A
W
0836
RELATIVE LINE OF APPROACH AT 0812
017°(T) - 9M
020°(T) - 12M
0824
N
CPA RANGE
C2
0812
WORKED EXAMPLE 17
(TRUE PLOT)
0800
C1

In this case, the predicted time of arrival at I of target is 0840 and that of own ship, 0850, indicating a clearance time of 10 minutes. By predicting the own ship's position at 0840 (the time when the target will be at I), it is noted that the range of the target, when bearing *right ahead* at 0840, is 2.5 M. Though this is not the CPA range, some idea of the clearance is obtained by this, bearing in mind that if the vessels are crossing at right angles, this range would be the CPA range. If the vessels are crossing obliquely, the CPA range will be less than the range when bearing right ahead or right astern - the greater the obliquity, the greater the difference.

Any action taken by the target is apparent right away. If the target's position at any time is not on AI, it means that the target has altered course - the new course can be directly measured off, if desired. If the target's rate of movement along AI changes, it means that the target has altered speed - the new speed can be directly deduced.

At a single glance, the Master can assess the situation from the ROR point of view. If own ship alters speed, the new time of arrival at I should be computed. If the own ship alters course, the new course should be laid off from the corresponding position of own ship, at that time, and where this cuts AI may me called I_1. The times of arrival of both, the own ship and the target, at I_1 should be computed. The new clearance time and the range when right ahead or right astern can then be deduced.

The exact value of CPA range can be obtained only by construction of the plotting triangle. However this is rarely necessary as in most cases, avoiding action can be decided by inspecting the plot and computing the times of arrival at I.

To obtain CPA range

If it is desired to obtain the exact CPA range, insert WO (the course and distance covered by own ship during the plotting interval) at W. Join OA and produce it. This is the relative line of approach. Since A was for 0812, CPA range should be measured off from the 0812 position of own ship (C_2 in this case).

To obtain CPA time

Mark the CPA on the line of approach and call it N (as usually done in relative plotting).

$$\text{Time to CPA from A} = \frac{AN}{OA} \text{ x plotting interval.}$$

40.2 Set and drift

When a target has been positively identified as a stationary object, such as a light-vessel, rock, vessel at anchor, etc., its position on the plotting sheet, when doing a true plot, should always be the same i.e., W and A must coincide, indicating that the object has no course or speed. If, however, the target, which is known to be stationary, appears to have a course and speed, set & drift of current is being experienced. Naming the first position of the target W and its subsequent position A, AW (not WA) indicates the set and drift of current, as explained earlier in para 36.8 of chapter 36. This is illustrated in worked example 18.

Worked example 18

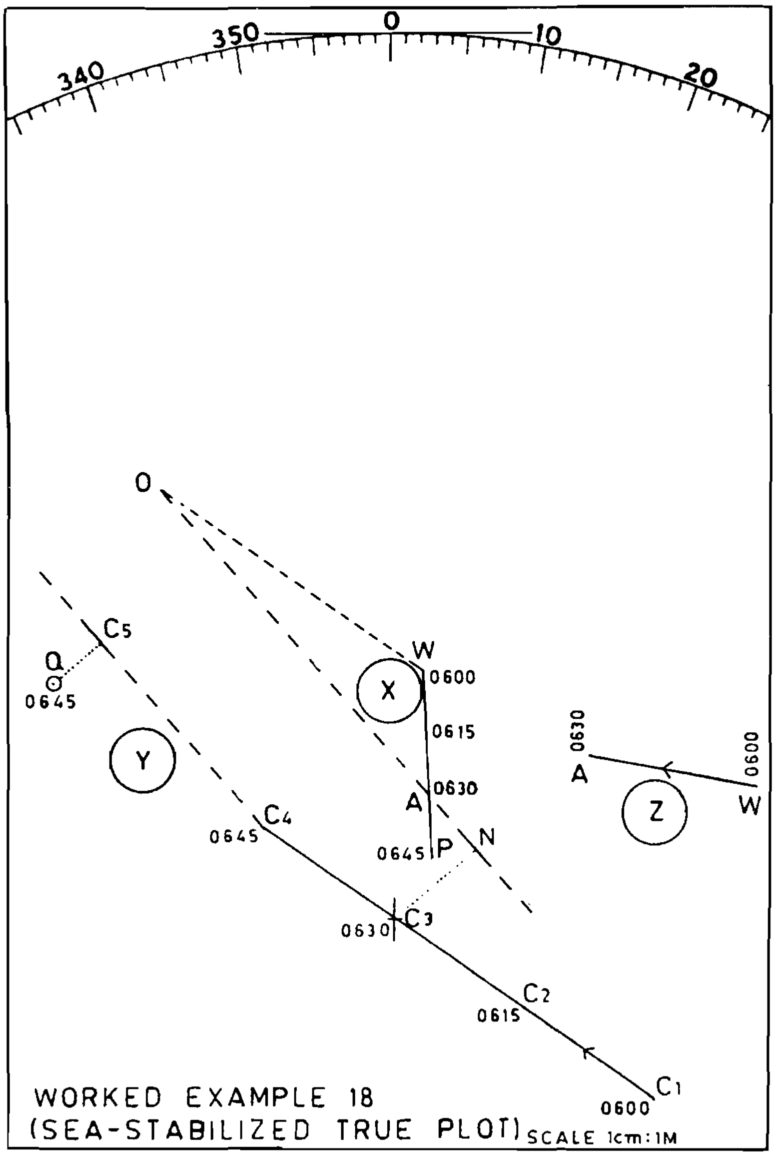
While on a course of 305°(T) at 10 knots, a light-vessel X was observed as follows:

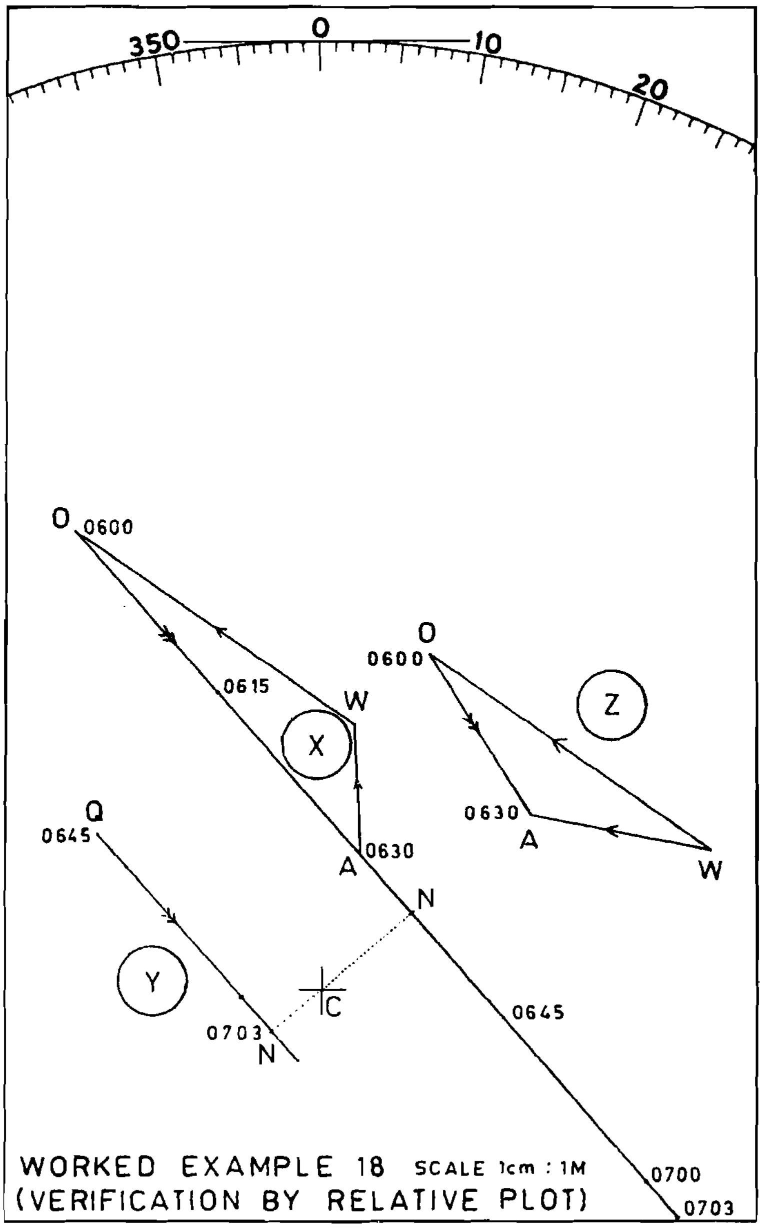
Time	Bearing	Range
0600	332° (T)	7.70 M
0615	341° (T)	4.65 M
0630	016° (T)	2.05 M

Construct a true plot and thence find (a) the set and rate of current; (b) course and speed over ground (i.e., course and speed made good); (c) CPA range and time.

If at 0645, a buoy Y was observed 4.0 M off, bearing right ahead, find (d) its CPA range and time and (e) the bearing and range of X when Y is at its CPA.

Verify your answers by working the entire problem by a relative plot.


350
0
10
340
20
O
W
0600
X
0615
0630
A
0645
P
N
Q
0645
C5
Y
C4
0645
C3
0630
C2
0615
C1
0600
0630
A
0600
W
Z
WORKED EXAMPLE 18
(SEA-STABILIZED TRUE PLOT)
SCALE 1cm:1M


350
0
10
20
O
0600
0615
W
X
O
0600
Z
Q
0645
0630
A
0630
A
W
N
Y
C
0703
N
0645
0700
0703
WORKED EXAMPLE 18 SCALE 1cm : 1M
(VERIFICATION BY RELATIVE PLOT)

WORKING

Relative plotting has been so thoroughly explained in earlier chapters that it is not proposed to elaborate it in this worked example. However, it has been drawn here and the student can consult it and make his observations.

Worked by a sea-stabilised true plot.

(i) Draw the course line of own ship through the centre of the plotting sheet [305°(T) in this case].

(ii) Insert C_1, C_2 & C_3, the positions of own ship at 0600, 0615 & 0630, such that C_3 is at the centre of the plotting sheet.

(iii) From C_1, lay off the position of the target at 0600 and call it W.

(iv) From C_2, lay off the position of the target at 0615.

(v) From C_3, lay off the position of the target at 0630 and call it A.

(vi) Join WA. WA would have been the course and speed of target if it was a moving object. Since the target is *known to be stationary*, AW is the set and drift of current. In this case set is 357°(T) and drift is 1.95 M in 30 minutes, i.e., rate is 3.9 knots. This is answer (a).

(vii) At W, insert WO - the course steered by own ship and log distance covered during the plotting interval - in this case 305°(T) 5 M. Join OA.

(viii) OA produced is the relative line of approach. This is necessary to obtain CPA range and time.

(ix) Since A is for 0630, measure off CPA range from the position of own ship at 0630 i.e., from C_3. In this case CPA range is 1.7 M. Call the CPA, N.

(x) Time to CPA from 0630 $= \frac{AN}{OA} \times$ plotting interval

$$= \frac{1.1}{6.4} \times 30 = 5 \text{ minutes.}$$

$\therefore$ CPA time = 0635, CPA range 1.7 M - answer (c).

(xi) Since target X is a stationary object, and its relative line of approach is OA, the own ship's course and speed made good (movement over ground) is AO. In this case, course and speed made good is 319°(T) 12.8 knots. This is answer (b).

(xii) Insert C_4, the position of own ship at 0645. From C_4, lay off position Q of target Y at 0645. The own ship's involvement with target Y can be treated as a separate problem from 0645 onwards.

(xiii) Had C_1, C_2 and C_3 been drawn along the course made good, using the speed made good, target X would have appeared stationary on the plotting sheet i.e., its W and A would have coincided. So using this knowledge of course and speed made good, stationary target Y can be made to remain stationary on the plotting sheet as explained below.

(xiv) From C_4, draw a line parallel to AO. This is the course made good from 0645 onwards. Measure off the perpendicular distance from Q. Call the point of contact C_5. This distance, QC_5, is the CPA range of target Y - found to be 1.0 M in this case.

(xv) The speed made good is 12.8 knots. So it is very simple to compute how long the ship will take to go from C_4 to C_5. In this case, own ship will reach C_5 at 0703. The CPA range and time, of target Y, is hence 1.0 M at 0703. This is answer (d).

(xvi) From 0600 till 0645 (i.e., C_1 to C_4), the own ship's course steered and log speed have been drawn. Hence the target X appears to move along WA. Produce WA to P so that P is the predicted position of target X at 0645. In this case WA is 1.95 M in 30 minutes. So AP will be 0.975 M in 15 minutes.

(xvii) At 0645, own ship is at C_4, target X at P and target Y at Q. Since C_4 to C_5 is the course and *speed made good* by own ship, both stationary targets X and Y will remain stationary on the plotting sheet, at P and Q respectively. When own ship reaches C_5 at 0703, targets X and Y will still be at P and Q respectively. At C_5, target Y will be at CPA and the required bearing and range of P can be measured off from C_5. In this case, bearing and range of target X, when target Y is at CPA, is 123°(T) 6.2 M. This is answer (e).

Alternative method

An alternative method, to solve worked example 18, by means of a ground-stabilised true plot, is shown herewith. This method is far simpler than the first method that used a sea-stabilised plot, but the reader's attention is invited to the cautionary note at the end of this alternative method.

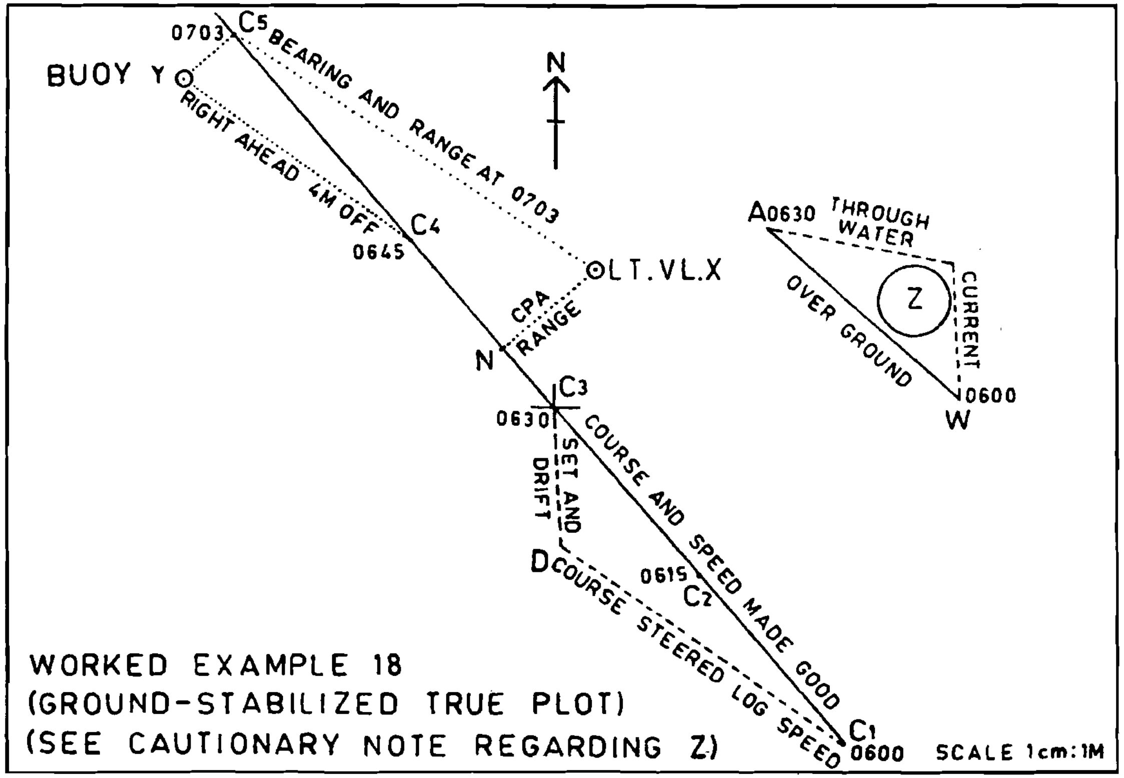
Working by a ground-stabilised true plot.

(i) Take any point on the plotting sheet and call it X, the position of the light-vessel.

(ii) From X, lay off positions C_1, C_2 & C_3 of the own ship at 0600, 0615 and 0630 respectively, using the given ranges and *reversed* bearings. It would be convenient if the position of X on the plotting sheet was so adjusted, in the beginning itself, so as to let C_3 fall in the centre of the plotting sheet.

(iii) Join C_1, C_2 & C_3 and this represents the course and distance *made good* between 0600 & 0630 i.e. movement of own ship over ground. In this case, course & speed made good is 319°(T) 12.8 knots - answer (b).

(iv) From C_1, lay of the given movement through the water between 0600 and 0630 - course 305°(T) 5 M. Call this point reached D, the DR position at 0630. D to C_3 is the set and drift of current between 0600 and 0630, just as is done in chart work. In this case, set is 357°(T), drift 1.95 M in 30 minutes i.e. rate 3.9 knots - answer (a).



WORKED EXAMPLE 18
(GROUND-STABILIZED TRUE PLOT)
(SEE CAUTIONARY NOTE REGARDING Z)

(v) Produce the course made good and, using the speed made good, insert C_4 the 0645 position of own ship. Drop a perpendicular from X to this course made good and call the point of intersection N. Measure off XN, the CPA range. Compute the time of arrival at N, using the speed made good. In this case, CPA range is 1.7 M and time 0635 - answer (c).

(vi) From C_4, lay off the given position of buoy Y, bearing in mind that right ahead is on *course steered*, not on course made good.

(vii) Produce the course made good. Drop a perpendicular from Y to meet this course made good at C_5. YC_5 is the CPA range of Y. Compute the time of arrival at C_5 using the speed made good. In this case CPA range is 1.0 M at 0703 - answer (d).

(viii) Measure off bearing and range of X from C_5 - 123°(T) 6.2 M - answer (e).

CAUTIONARY NOTE

Solving worked example 18 by either method - sea-stabilised or ground-stabilised true plot - showed no difference at all in the answers because both X and Y were stationary objects. If, however, a moving object had also been given, the course and speed of target, obtained by each method would have been different. The reason for this is explained below.

In the sea-stabilised plot, the own ship's course steered and log speeds were used. Because it is assumed that set and rate of current is the same, for all targets in the vicinity, the course and speed of a moving target, obtained from the plot, would be its course and speed through the water (its course steered and log speed). This answer would tally perfectly with that obtained by a relative plot.

In the ground-stabilised plot, the own ship's course and speed *made good* were used. So the course and speed of a moving target, obtained from the plot, would be its course and speed made good. This answer would therefore be somewhat different from that obtained by a relative plot.

The foregoing can be easily illustrated by introducing target Z, in worked example 18, as follows:

Time	Bearing	Range
0600	018° (T)	5.2 M
0630	050° (T)	4.0 M

Required to find the course and speed of target Z.

By the relative plot and the sea-stabilised true plot, the course and speed of target Z is found to be 280°(T) 5.4 knots. This is her course steered and log speed.

By the ground-stabilised true plot, the course and speed of target, indicated by WA, is 312°(T) 7.4 knots. This is her course and speed made good. If the set and drift of current is applied to this, the course steered and log speed can be obtained.

Very important note: The fact that the ground-stabilised true plot gives the target's course and speed *made good* whereas the sea-stabilised true plot and the relative plot give the target's course *steered* and *log speed*, is of great significance. ROR is based on relative bearings that depend on course *steered* and not course *made good*. In cases where the tide/current is strong, and the ships are moving very slowly as in restricted visibility, the course steered and the course made good may vary considerably. A ship underway but stopped and making no way through the water, would appear stationary on a sea-stabilised display but appear to have a course and speed on a ground-stabilised display. ROR decisions made, in restricted visibility, using ground stabilised displays could possibly lead to disaster.

In short, course made good is good for navigation whereas course steered is good for collision avoidance (application of ROR).

40.3 Action taken by target

The fact that a target has taken some action is readily apparent in both, a relative plot and a true plot. What exactly is the action taken by the target is directly obtained from a true plot. In the case of a relative plot, the nature of the action taken by a target can only be obtained by construction of the relative velocity triangle.

The foregoing is clearly illustrated in worked example 19, which is shown here as a true plot. The same problem, worked by a relative plot, is worked example 2 in chapter 37.

Worked example 19

Own course 024°(T) speed 15 knots.

Ship's time	Bearing (T)	Range (M)
0900	345°	7.0
0903	345°	6.4
0906	345½°	5.75
0909	344½°	5.0
0912	337°	3.9
0915	327°	2.9
0918	308°	2.1

Construct a true plot and, from the information available at 0906, find:

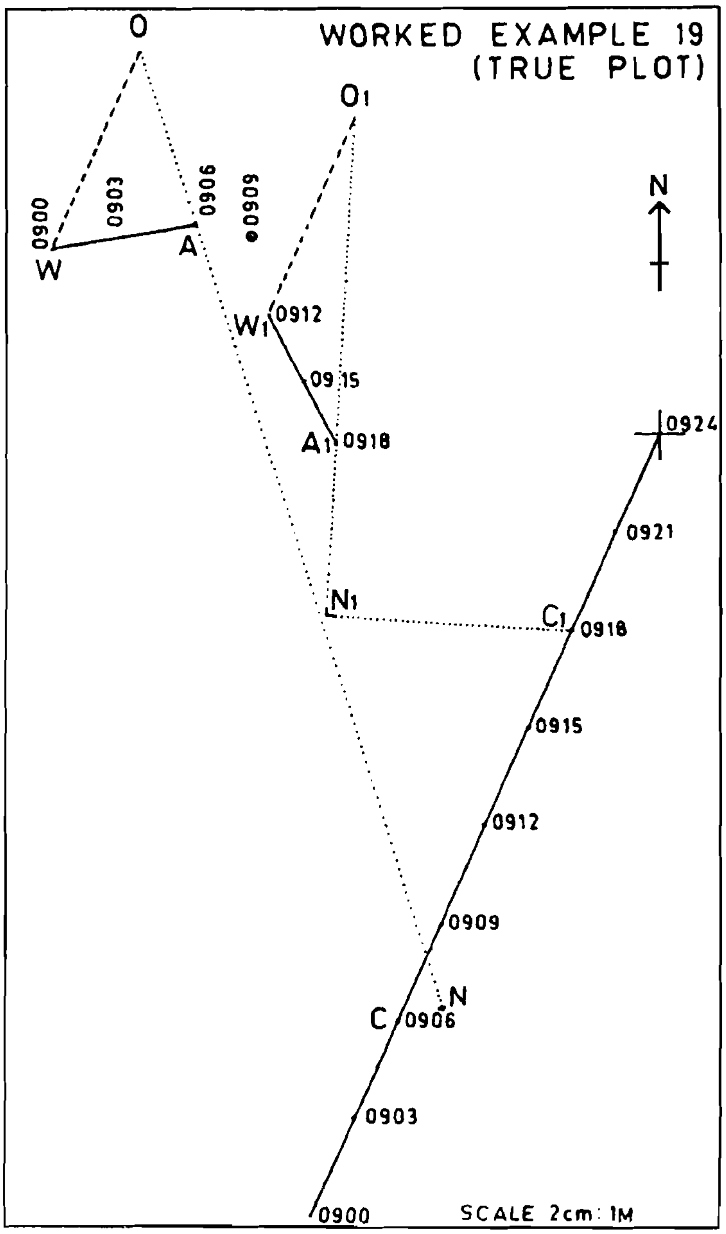
(a) Course and speed of target.
(b) Aspect at 0906.
(c) CPA range and time.

Using all the given information, find:

(d) The action taken, if any, by the target.
(e) The new CPA range and time.

WORKING

(i) On the plotting sheet, draw the course line (024° in this case) and on it mark off the own ship's position at the various times given, at the given speed of 15 knots, using a suitable scale.


WORKED EXAMPLE 19
(TRUE PLOT)
O
O1
W
A
W1
A1
N1
C1
N
C
0900
0903
0906
0909
0912
09 15
0918
0924
0921
0918
0915
0912
0909
0906
0903
0900
SCALE 2cm : 1M

(ii) For each of the given times, lay off the position of the target, from the corresponding position of own ship at that time.

(iii) Starting from the earliest given position of the target (0900 in this case), draw a straight line through as many of the subsequent positions as possible. Call the first position W and last position, on this line, A. WA is the course and speed of target. In this case, the course is 081°(T). The distance WA is 1 M in 6 minutes. So speed of target is 10 knots. Answer (a): 081°(T) 10 knots.

(iv) Compute the aspect as usual.

	Course of target:	081° (T)
	Reversed bearing (0906)	165½°(T)
Answer (b) - Aspect at 0906:		84½° Green

(v) From the last given position of the target, draw a straight line, through as many of the earlier positions as possible. Call the last position A_1 and the earliest position on this line, W_1. W_1A_1 is the new course and speed of target. In this case, new course is 151°(T) 10 knots. By comparing the initial course and speed of target with its new course and speed, the action taken by target is obtained. In this case, target has altered course 70° to starboard but maintained its speed of 10 knots - answer (d). In comparing the initial and final courses and speeds of the target, small alterations in course (less than about 5°) and of speed (less than about 2 knots) may be assumed to be due to inaccuracies inherent in plotting and hence ignored.

It is possible that one or two positions in between may not fall on either of the two course lines of the target (like the 0909 position in this case). This is probably because the action had been commenced, but not completed, by the target, during those observations.

(vi) On WA, complete the relative velocity triangle. Produce OA and measure off the CPA range. Since A is for 0906, CPA range should be measured off from the 0906 position of own ship. Compute the time of CPA as usually done in relative plotting. In this case, CPA range of 0.3 M should occur at 0934 - answer (c).

(vii) On W_1A_1, complete the relative velocity triangle. Produce O_1A_1 and measure off the new CPA range. Since A_1 is for 0918, CPA range should be measured from the 0918 position of own ship. New CPA range of 1.7 M should occur at 0921 - answer (e).

Worked example 20

Own course 044°(T) at 15 knots.

Time	Bearing	Range
1200	005° (T)	7.00 M
1203	005° (T)	6.40 M
1206	005½° (T)	5.75 M

Construct a true plot and thence find:

(a) Course and speed of target.

(b) Aspect at 1206.

(c) Time and range at CPA.

At 1207, the target indicates her intention to take action at 1210 by altering course 30° to starboard and also reducing speed to 6 knots. Find (d) the new CPA range and time.

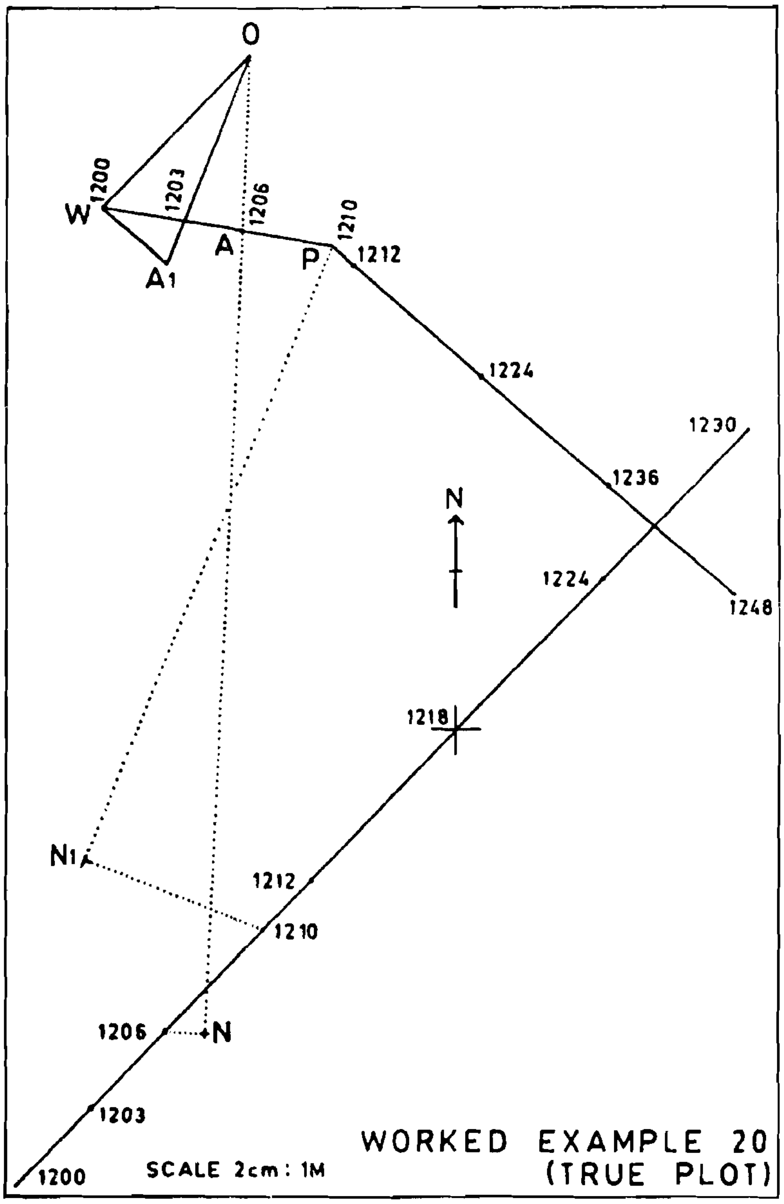
Note: This has been solved earlier, by relative plotting, as worked example 3 in chapter 37.

WORKING

(i) On the plotting sheet, draw the course line (044° in this case) and on it mark off the own ship's position at the given times, at the given speed of 15 knots, using a suitable scale.

(ii) For each of the given times, lay off the position of the target, from the corresponding position of the own ship at that time.

(iii) Join the given positions of the target by a straight line, calling the first position W and the last, A.


O
W
1200
1203
1206
1210
A
P
1212
A1
1224
1230
1236
N
1224
1248
1218
N1
1212
1210
1206
N
1203
1200
SCALE 2cm : 1M
WORKED EXAMPLE 20
(TRUE PLOT)

(iv) WA is the course and speed of target. In this case, course is 101°(T) 10 knots - answer (a).

(v) Compute the aspect as usual.

Course of target	101° (T)
1206 reversed bearing	185½° (T)
Aspect at 1206 - answer (b)	84½° green

(vi) Complete the relative velocity triangle WOA, produce OA and measure off the CPA range. Since A is for 1206, CPA should be measured off from the 1206 position of own ship. Compute the TCPA as usually done in relative plotting. In this case, CPA is 0.3 M at 1234 - answer (c).

(vii) Since the action taken by target is at 1210, predict the positions of the target and own ship for that time, on their respective course lines.

(viii) In relative velocity triangle WOA, lay off WA_1 the new course of target (131° in this case) and the new distance covered by it during the plotting interval (6 minutes at 6 knots is 0.6 M). Join OA_1 and draw a line parallel to it, from the predicted position P, of the target, at 1210. This is the line of approach from 1210 onwards. Measure off the CPA range. Since the action is taken at 1210, the new CPA range must be measured off from the 1210 position of the own ship. Call the new CPA, N_1.

(ix) Time to new CPA from 1210 = $\frac{PN}{OA_1}$ x plotting interval

$$= \frac{4.75}{1.6} \times 6 = 18 \text{ minutes}$$

∴ New CPA time = 1228

New CPA range = 1.35M - answer (d).

40.4 Action taken by own ship

When the own ship takes a specific action at a given time, the result thereof can be found easily, as explained in worked example 21, where a performance delay has also been included.

Worked example 21

Own course 336°(T) speed 12 knots.

Time	Bearing	Range
1100	050° (T)	5.50 M
1106	050° (T)	4.25 M

Construct a true plot and thence find:

(a) Target's course & speed (b) Aspect at 1106 (c) CPA & TCPA

At 1108, Master of own ship orders a course alteration of 30° to starboard and a speed reduction to 8 knots. If the performance delay expected, for both actions simultaneously, is 2 minutes, find (d) the new CPA range and time.

WORKING

(i) Construct a true plot between 1100 and 1106, as described earlier in this chapter, and obtain the course & speed of target, aspect at 1106, CPA and TCPA.

(a) Course and speed of target 281°(T) 15 knots.

(b) Aspect at 1106: red 51°.

(c) Collision at 1126.

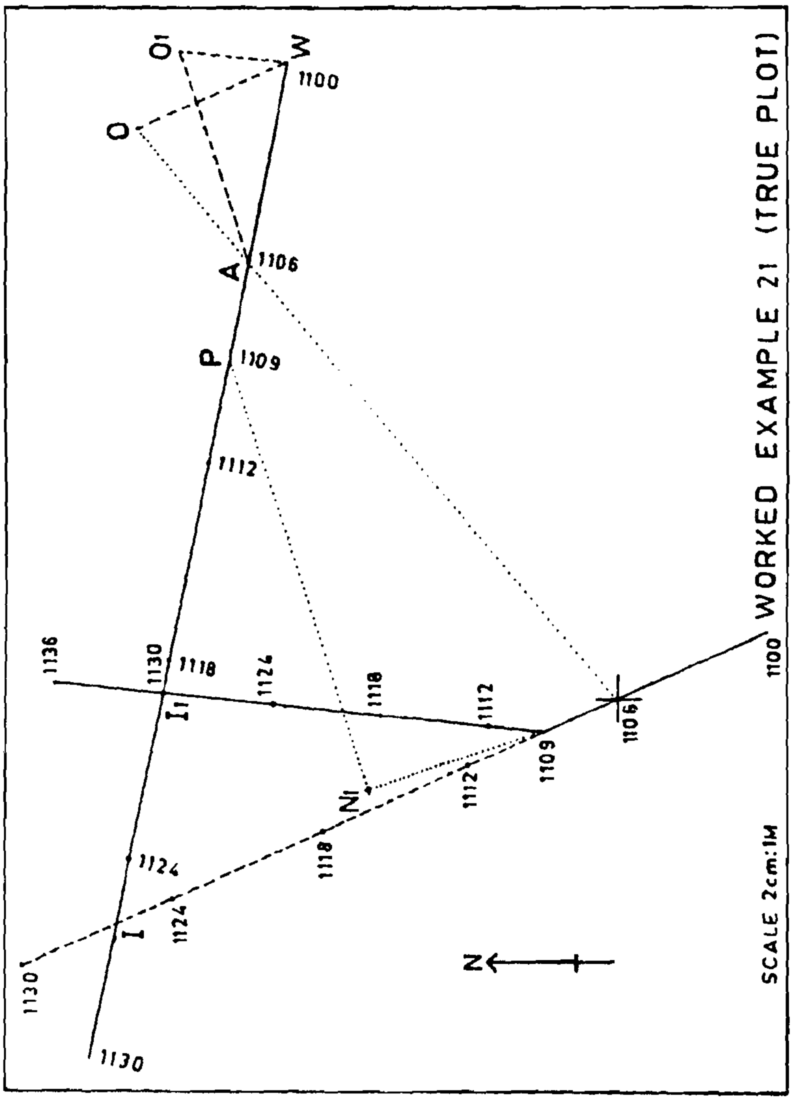
(ii) Since the actions were both commenced at 1108 with a given performance delay of 2 minutes, assume that the actions were taken at 1109 and instantly effective, as explained in 38.2 (i.e., para 2 of chapter 38). Predict position P of target at 1109 on WA produced. Insert own ship's position at 1109 on its own course line.

(iii) In relative velocity triangle WOA, insert WO_1 the new course and new distance covered by own ship in 6 minutes i.e., 006°(T) 0.8 M. Join O_1A and draw a line parallel to it, from P. This is the relative line of approach from 1109. Measure off CPA range from the 1109 position of own ship.

$$\text{Time to new CPA from 1109} = \frac{PN_1}{O_1A} \times \text{plotting interval}$$

$$= \frac{3.35}{1.6} \times 6 = 13 \text{ minutes.}$$

∴ New TCPA = 1122 & New CPA = 1.3 M - answer (d).


WORKED EXAMPLE 21 (TRUE PLOT)
SCALE 2cm:1M
N
O
O1
W
A
P
I
I1
N1
1100
1106
1109
1112
1118
1124
1130
1136

40.5 Head reach

Head reach has been explained earlier in 38.4 (i.e. para 4 of chapter 38). Allowing for head reach is very simple, in a true plot, as illustrated in worked example 22. The same problem was solved, by relative plotting, as worked example 8 in chapter 38.

Worked example 22
In thick fog, while on a course of 040°(T) at 6 knots, a target was observed on the PPI as follows:

Time	Bearing	Range
1600	060° (T)	7.0 M
1612	059½° (T)	5.0 M

Construct a true plot and from it find:

(a) Course and speed of target.
(b) Aspect at 1612.
(c) CPA range and time.

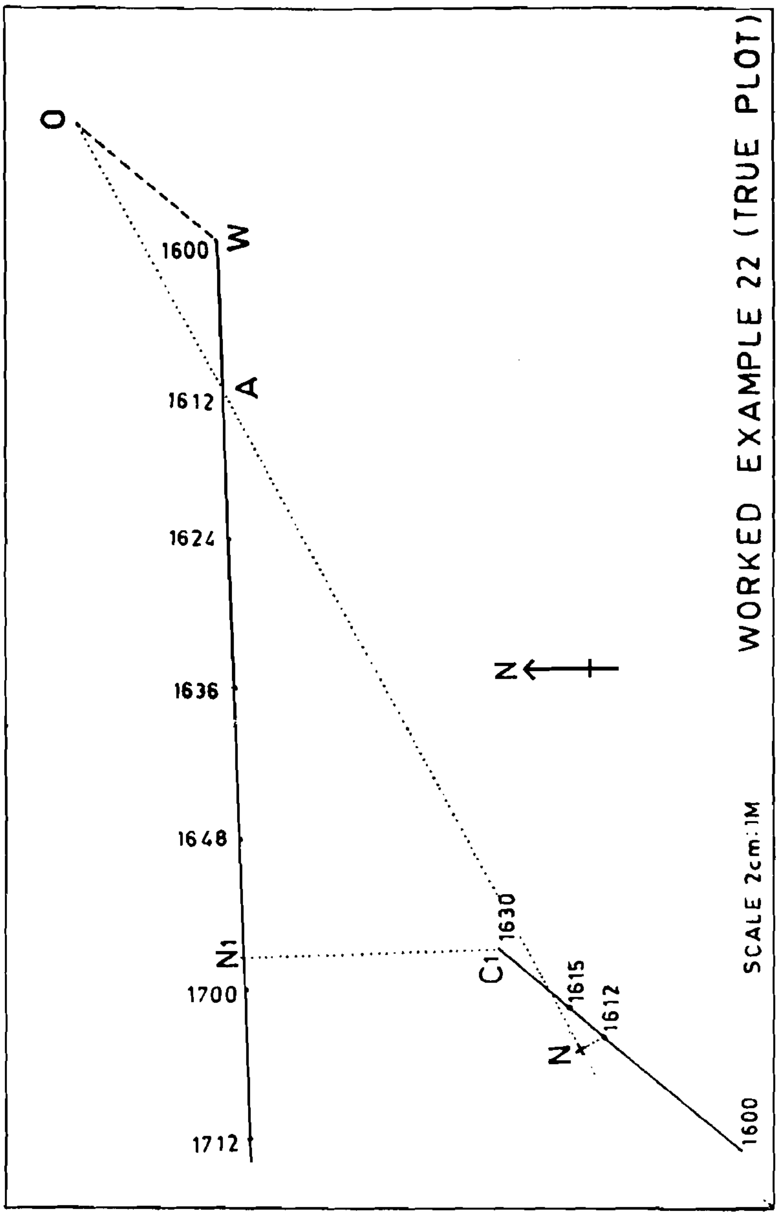
At 1615, own ship's engines were stopped. If the own ship is expected to come to a dead stop in 15 minutes, with a head reach of 0.6 M, predict (d) the new CPA range and time.

WORKING

(i) Construct a true plot between 1600 and 1612, as described earlier in this chapter, and obtain (a) Course and speed of target 268°(T) 5 knots; (b) Aspect at 1106 28½° red; (c) CPA range 0.15 M at 1642. Since A was for 1612, CPA must be measured from the 1612 position of own ship.

(ii) Produce the course line of own ship and insert the 1615 and 1630 positions on it as follows:
From 1612 to 1615 allow given speed - 3 minutes at 6 knots is 0.3 M. From 1615 to 1630, allow the given head reach of 0.6 M. Own ship is, therefore, stationary at this position C_1, from 1630 onwards.

(iii) Drop a perpendicular from the 1630 position of own ship to WA produced and call the point of intersection N_1. This is the new CPA.



WORKED EXAMPLE 22 (TRUE PLOT)

(iv) C_1N_1 is the new CPA range. Using target's speed of WA in 12 minutes, compute the time of arrival of target at N_1 (own ship is stationary at C_1 from 1630 onwards). In this case, new CPA range is 1.7 M at 1658 - answer (d).

40.6 To predict action to take

Prediction of the action to take, to achieve a desired CPA range, can be done in true plotting by the help of the triangle of velocities whereby the relative line of approach is obtained. This is illustrated in worked example 23.

Worked example 23
Own course 055°(T) speed 15 knots.

Time	Bearing	Range
0930	105 ° (T)	14.0 M
0936	105° (T)	11.5 M
0942	104½° (T)	8.9 M

By means of a true plot, find:

(a) Course and speed of target and (b) Aspect at 0942.

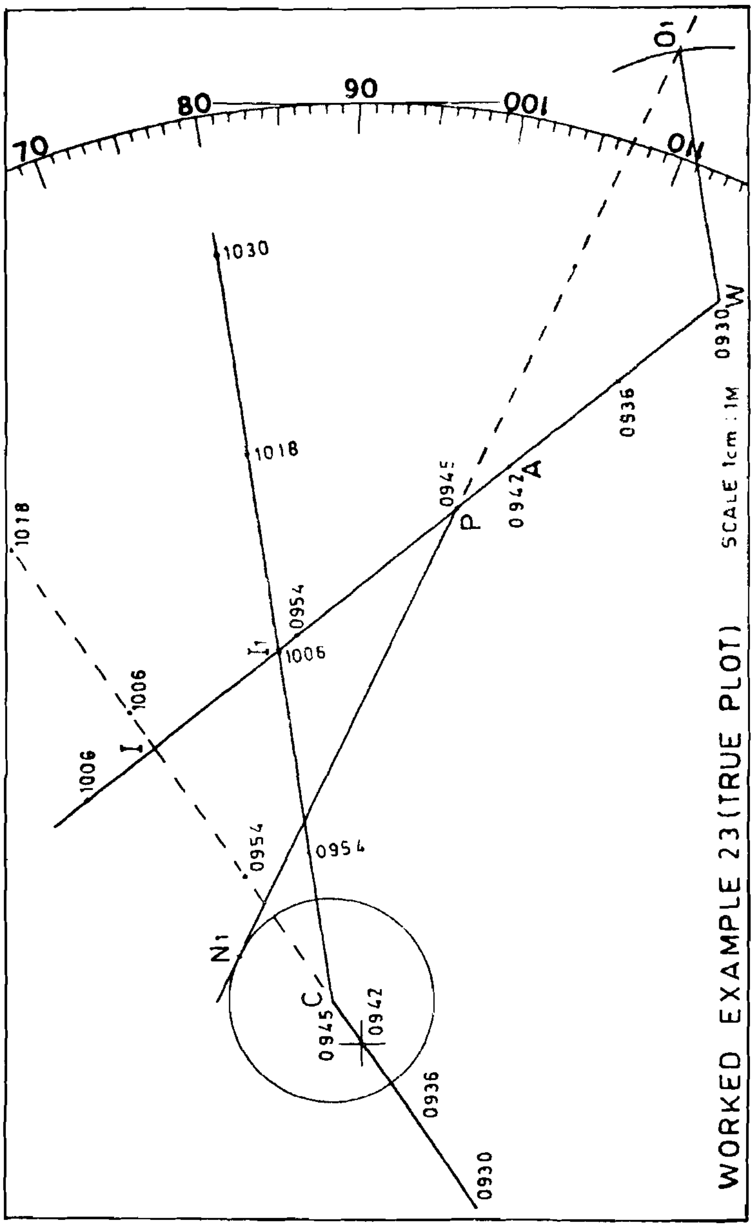
By inspection of the true plot, without constructing a triangle of velocities, state (c) whether a collision or near collision is expected.

The captain of the own ship decides to let the target pass ahead with a CPA range of 1.5 M, by altering course to starboard at 0945. Find (d) the alteration necessary and (e) the new TCPA.

WORKING

(i) Construct a true plot between 0930 and 0942, as described earlier in this chapter, and obtain (a) course and speed of target as 322°(T) 20 knots and (b) aspect at 0942 to be red 37½°.

(ii) Produce the courses of own ship and target and call their point of intersection I. Computing the times of arrival of the own ship and the target at I, at their respective speeds, it is found that they are expected to arrive at I at 1003 and 1002 respectively, indicating that a near-collision situation is imminent - answer (c).


WORKED EXAMPLE 23 (TRUE PLOT)
SCALE 1cm : 1M
70
80
90
100
O1
W
A
P
I
I1
N1
C
1030
1018
1006
0954
0945
0942
0936
0930

(iii) Since the action is required to be taken at 0945, predict the positions of own ship and target for this time and call these points C and P respectively. Since a CPA of 1.5 M is stipulated, the construction of a relative velocity triangle is unavoidable. Since the progress of the target has already been drawn between 0930 and 0945, a 15-minute triangle will be convenient.

(iv) Draw a circle of 1.5 M radius around C. From P, draw a tangent to this circle, ahead of own ship, and call the point of contact N_1. Produce N_1P indefinitely. With centre W, radius equal to 3.75 M (i.e., 15 minutes at 15 knots) cut off O_1 on N_1P produced. WO_1 is the new course to steer from 0945 onwards - 082°(T) i.e., alteration of 27° to starboard - answer (d).

(v) Time to new CPA from 0945 = $\frac{PN_1}{O_1P}$ x plotting interval

$= \frac{7.5}{7.5}$ x 15 = 15 minutes

∴ New CPA time = 1000 answer (e).

40.7 Concluding remarks

By this time, the student of radar plotting should have an extremely competent grasp of both relative plotting and true plotting. Should more practice be desired in true plotting, exercises 1, 2, 3 & 4, though included in relative plotting chapters, may be worked by true plotting and the answers verified.

The student would have, by now, realised that true plotting can be understood properly only after mastering relative plotting. In fact, it is entirely possible for an officer to competently manage a ship, throughout his career, by doing relative plotting only. But, if he is ignorant of true plotting, it is unpardonable. It must be remembered that if the senior officer of the bridge team prefers TM display, the others should not feel uncomfortable or incompetent (or vice versa). The ship's safety depends on the each and every member of the bridge team.

The radar observer must know not only the limitations of the radar set used by him, but also the full scope of its use.

Any problem in radar plotting may be worked on paper, by either relative or true plotting, regardless of the type of presentation in use. However, when using a reflection plotter, a true plot must be done when using a true motion presentation and a relative plot when using a relative motion presentation.

During examinations for certificates of competency, the choice of relative or true plotting is usually left to the candidate. Since most candidates prefer to do the relative plot, the question sometimes specifies a true plot so as to ensure that the candidate has not neglected to study it.

-o0o-

CHAPTER 41

ADVANCED PROBLEMS

IN PLOTTING

Until this chapter, the own ship's involvement has been limited mainly to one target at a time so that the navigator gains competence and confidence steadily, problems by problem, chapter by chapter. However, the final stage has now come where mastery of the subject of radar plotting is to be achieved.

In this chapter, two or more targets are given at a time and the navigator is required to analyse the situation and evaluate the possible actions that the own ship may take under the given circumstances.

Analysing the situation means ascertaining the CPA ranges and times of all the targets with respect to own ship, obtaining the course, speed and aspect of each target and then interpreting the ROR appropriate and applicable to the given circumstances.

Evaluating the possible actions that own ship may take means considering the magnitude and direction of an alteration of course (to starboard or port) or of speed (reduction, which includes stoppage, or increase of speed) and its effect on the CPA ranges of the given targets, bearing in mind the correct application of ROR, the proximity of other dangers, any possible limitations and the observance of good seamanship.

For quick evaluation, the following thumb rule may be useful:

When a close-quarters situation is likely to develop between own ship and two targets (i) at different times, the earlier occurrence is a greater risk than the later one; (ii) at nearly the same time, the one with a closer CPA is the greater risk.

The target that poses a greater risk will generally require an action of greater magnitude by own ship. Hence, during evaluation, try out the possible actions by own ship with respect to the target posing the greater risk and then ascertain whether each such action has a desirable effect with respect to the other target.

In the worked examples that follow, due explanation has been given, where necessary, to ensure proper understanding of the subject.

1. Own course 112° (T) at 9 knots in *reduced visibility.*

	Target X		Target Y	
Time	Bearing	Range	Bearing	Range
1500	126° (T)	10.3 M	149° (T)	8.1 M
1510	125½°(T)	9.2 M	150½°(T)	6.7 M
1520	125° (T)	8.1 M	153½°(T)	5.3 M

For each target, find

(a) CPA range, time and bearing.

(b) Course and speed.

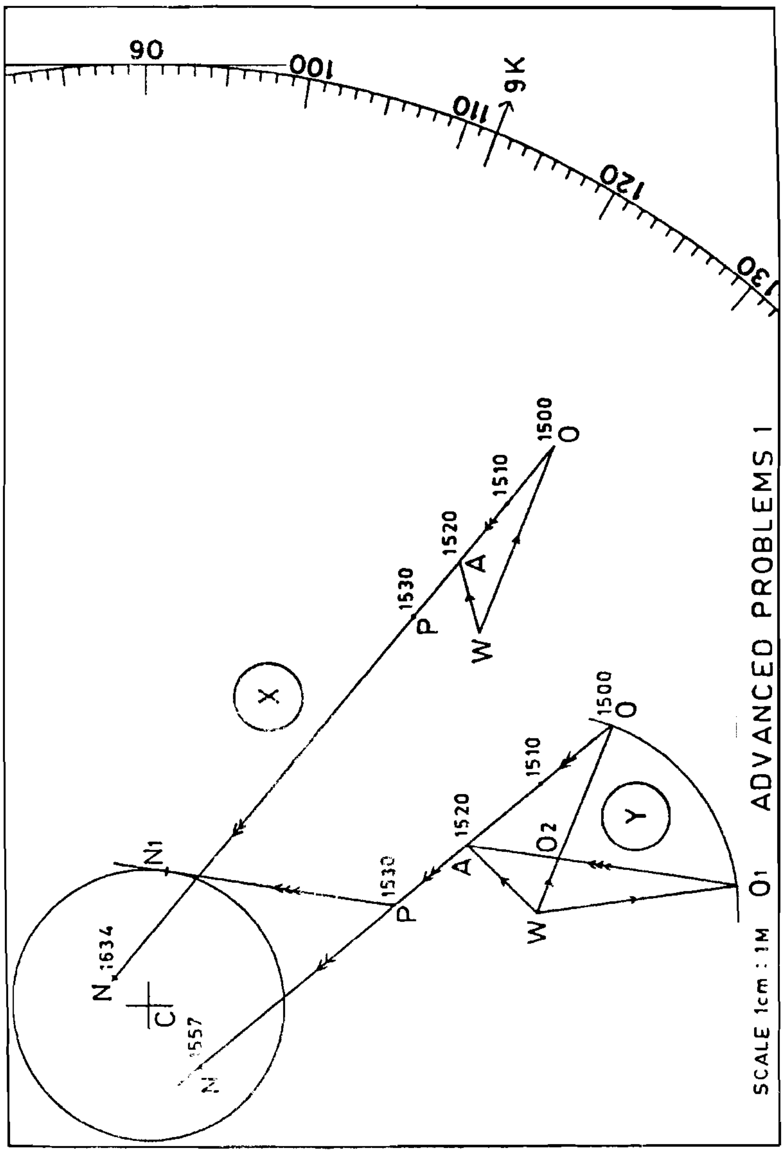
(c) Aspect at 1520.

It is required to take action at 1530 by means of a single action - alteration of course or reduction of speed - so that the CPA of either target will be at least 2.0 M. (d) Evaluate all the possible alternatives and (e) state, with reasons, which of these actions is preferable, under the circumstances.

WORKING

(See attached plotting sheet)

		Target X	Target Y
(a) CPA:	Range	0.6 M	1.2 M
	Time	1634	1557
	Bearing	039°(T)	231°(T)
(b) Target's:	Course	075°(T)	043°(T)
	Speed	3.3 knots	4.5 knots
(c) Aspect at 1520		130° red	70° red.


ADVANCED PROBLEMS 1
SCALE 1cm : 1M
90
100
110
120
130
9K
1500
1510
1520
1530
O
A
P
W
X
Y
O1
O2
N1
N
C
1634
1557

(d) Analysis:

Involvement with target X: Since the aspect is red 130° and the range is decreasing, own ship is overtaking target X. However, since the vessels are *not* in sight of one another, Rule 19 (conduct of vessels in restricted visibility) is applicable. Rule 13 (overtaking) does *not* apply. Own ship should take suitable avoiding action in ample time, to avoid a close-quarters situation. If target X is using radar and is aware of own ship's presence, she should not, as far as possible, alter course to port because own ship is on target X's port quarter.

Involvement with target Y: Own ship and target Y are crossing vessels but, since they are *not* in sight of one another, Rule 19 (conduct of vessels in restricted visibility) is applicable. Rule 15 (crossing vessels) does *not* apply. Own ship may take any suitable action to avoid a close-quarters situation but she should not alter course to port because target Y is forward of her beam. If target Y is using radar and is aware of own ship's presence, she also may take suitable avoiding action but she should not, as far as possible, alter course to port because own ship is forward of her beam.

(e) Evaluation:

In view of the foregoing discussions, own ship may alter course to starboard or reduce speed, under the given circumstances. The starboard alteration must be at least 61° (new course 173°T or more). The new speed, in lieu of a course alteration, must be 2.5 knots or less. Either of these two actions will ensure that (i) the CPA range of target Y will be at least 2.0 M and (ii) the CPA range of target X will be well over 2.0 M. There is little to choose between the two suggested alternatives but in circumstances of reduced visibility, it may be more prudent to reduce speed than to alter course drastically.

In case the predicted new speed of 2.5 knots is below the own ship's steerage way (minimum speed at which she can maintain course under the given circumstances), own vessel may reduce speed to steerage way and alter course accordingly to achieve the same CPA.

2. Own course 240°(T) at 15 knots in *reduced visibility.*

	Target C		Target D	
Time	Brg (T)	Range (M)	Brg (T)	Range (M)
1000	314°	11.9	208½°	10.0
1004	314°	10.7	209°	08.4
1008	314°	09.5	210°	06.8
1012	314°	08.3	211°	05.1

For each target, find:
(a) Range and time at CPA.
(b) Course and speed.
(c) Aspect at 1012.
Master of own ship desires to take action at 1016, by means of a single alteration of course or reduction of speed so that the CPA of either target will be not less than 2.0 M.
(d) Evaluate the possible alternatives.
(e) State which action is most preferable.

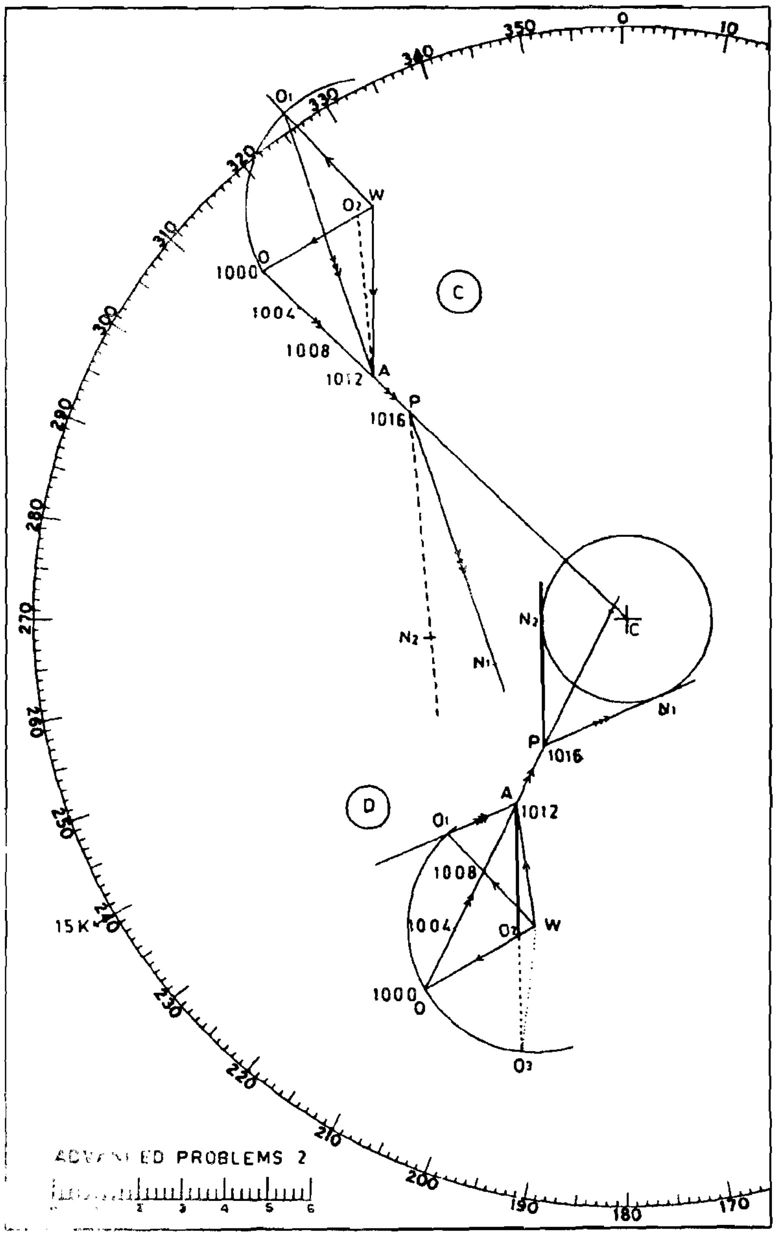
WORKING

(See attached plotting sheet)

(a) CPA range & time: C - collision at 1040; D - 0.4 M at 1024.
(b) Course and speed: C - 180°(T) 20 Kn; D - 351°(T) 15 Kn.
(c) Aspect at 1012: C - 46° red; D - 40° green.
(d) The vessels are not yet in sight of one another, owing to reduced visibility. Hence any of the three ships is free to take any action to avoid a close-quarters situation. However, each ship has the other two forward of her beam and hence none of the three ships is permitted to alter course to port. If either of the two targets is not using radar, she would be unaware of the presence of the other target or of the own ship.

In view of the foregoing points, own ship has only two options - alter course to starboard or reduce speed.

CPA of either target indicates collision or near collision. However, target D will be at CPA 16 minutes before target C. Hence the action required to have CPA of 2.0 M or more will be greater for target D than for target C.



350
0
10
340
330
320
310
300
290
280
270
260
250
240
230
220
210
200
190
180
170
O1
W
O2
O
1000
1004
1008
1012
A
P
1016
C
N2
N1
IC
D
1008
1004
O3
15K
ADVANCED PROBLEMS 2

Inspecting the plotting triangle of target D, it is found that the required 2 M CPA can be made to occur at N_1 or at N_2. The following are the alternatives:

(i) By altering course 77° to starboard (new course 317°), CPA of target D will occur at N_1, at a range of 2 M. By this action, CPA range of target C will be 3.25 M. It is not possible for target D's CPA to be made to occur at N_1, by reducing own ship's speed.

(ii) By reducing speed to 2 knots, CPA of target D can be made to occur at N_2, at a range of 2 M. By this action, CPA range of target C will be 4.6 M.

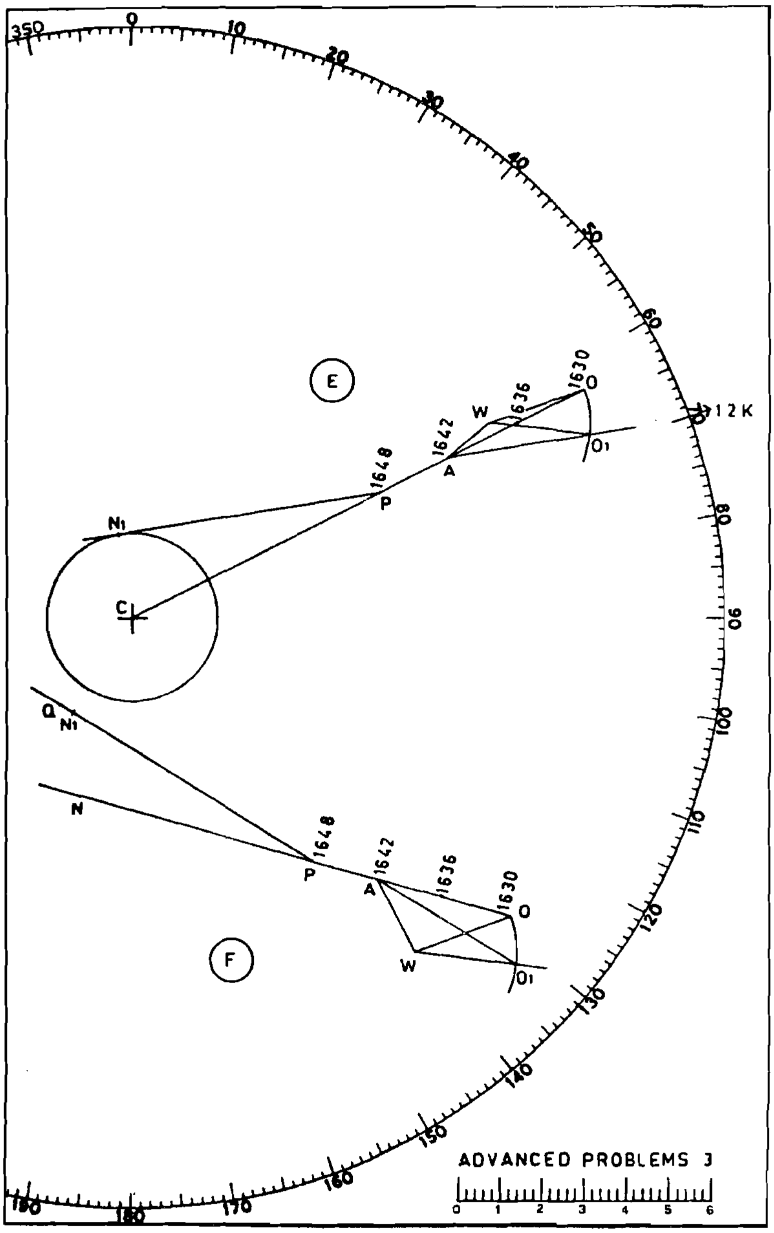
(iii) By altering course 54° to port (new course 186°T), CPA of target D will occur at N_2, at a range of 2 M. However, an alteration of course to port is prohibited by ROR, in this case, as mentioned earlier.

(e) Among the permissible alternatives, (ii) seems preferable. In restricted visibility, it is normally more prudent to reduce speed than to alter course drastically, as much 77°! Such drastic alterations of course not only take longer to execute, but may also result in close-quarters situations with ships that would have otherwise passed clear! Furthermore, such targets may not be shown on the PPI at present but may show up later when the range between them and the own ship decreases.

3. Own course 070°(T) at 12 knots in *restricted visibility*.

	Target E		Target F	
Time	Bearing	Range	Bearing	Range
1630	063° (T)	12.0 M	128½°(T)	11.4 M
1636	063°	10.2	132½°	09.9
1642	063°	08.4	137°	08.5

Analyse the plot and state what alteration of course is to be made at 1648 to ensure that the CPA range of E is 2 M. Having taken this action, what would be the bearing and range of F (from own ship) when E is at its CPA?


ADVANCED PROBLEMS 3
E
F
C
N1
N
P
A
W
O
O1
1630
1636
1642
1648
12 K

WORKING

(See attached plotting sheet)

	Target E	Target F
CPA range	Collision	4.4 M
CPA time	1710	1709
Target's course	230°(T)	333°(T)
Target's speed	6.25 kn	9.75 kn
Aspect at 1642	13° green	16° red

Target E is on a collision course with own ship whereas target F is passing clear. The three vessels are *not yet* in sight of one another. Both, own ship and target E, are free to take any action to avoid a close-quarters situation but neither is allowed by ROR to alter course to port. Own ship is therefore allowed to alter course to starboard or to alter speed. However, an alteration of course is stated in the problem.

Alteration of course

The starboard alteration of course, at 1648, should be 27° (new course 097°). The new CPA range of E will be 2 M at 1710 and of F, 2.65 M at 1709. At 1710 when E is at CPA, F will be at Q. Bearing and range of Q is 219°(T) 2.7 M from own ship.

4. Own course 325°(T) at 6 knots *in reduced visibility*.

	Target G		Target H	
Time	Bearing	Range	Bearing	Range
0840	329½° (T)	11.6 M	019°(T)	14.2 M
0850	332°	10.3	019°	12.0
0900	335°	08.9	019°	09.8
0910	339°	07.6	019°	07.6

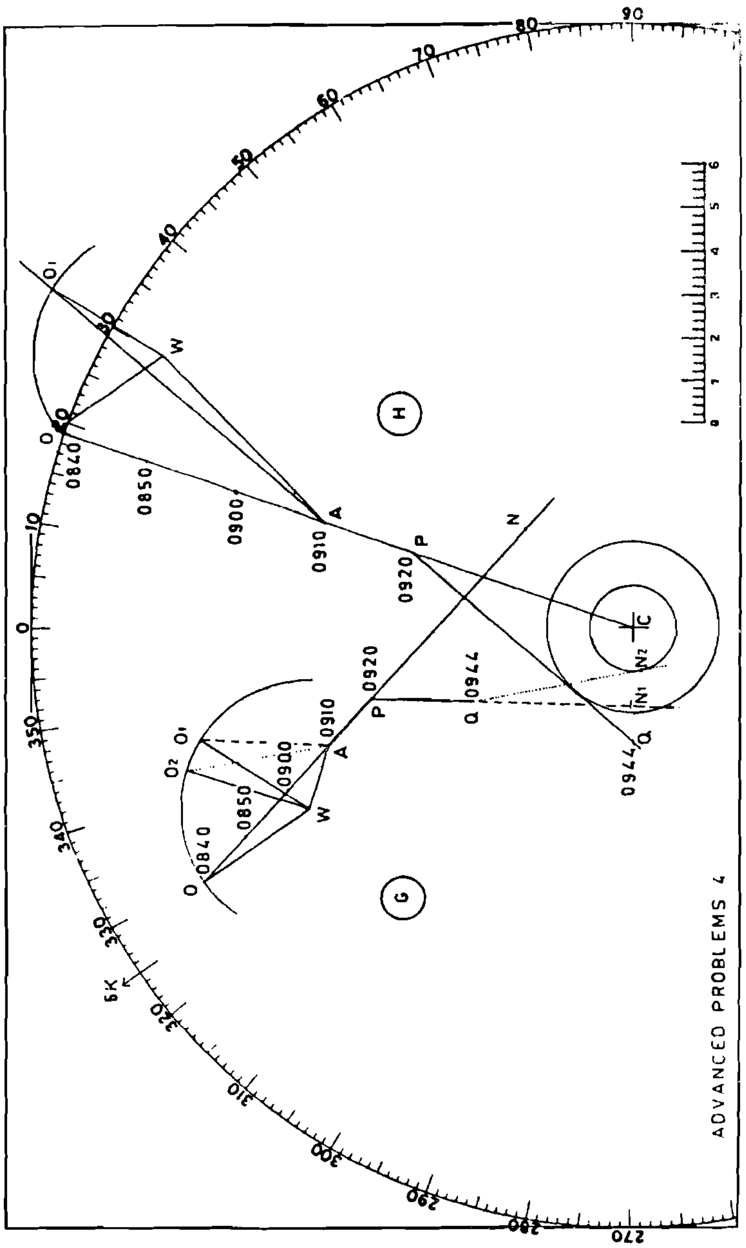
If target G is known to be a light-vessel, find:

(a) Set and rate of current.

(b) Course and speed of target H.

(c) CPA range and time of both targets.

(d) The course alteration to be made at 0920, so that target H will have a CPA of 2.0 M to port of own ship.


ADVANCED PROBLEMS 4

(e) After altering course, when target H bears 270°(T), find what course should be steered to pass target G to port, with a CPA of 1.0 M.
(f) When would target G be at its new CPA of 1.0 M?

WORKING

(See attached plotting sheet)

(a) Set 287°(T) rate 3.2 knots.
(b) Course 226°(T) speed 10.8 knots.
(c) CPA range and time: G – 3.4 M at 0957; H – Collision at 0945.
(d) Alter course 67° to starboard (new course 032°(T).
(e) Target H will bear 270°(T) at 0944, at which time target G will be at Q. New line of approach from 0944 is QN_2. By transferring this into WOA, new course to steer is WO_2 - 017°(T).
(f) Target G will be at N_2 (new CPA 1.0 M off) at 1019.

5. Own course 122°(T) at 15 knots in *reduced visibility*.

	Buoy X		Target Y		Target Z	
Time	Brg (T)	Range (M)	Brg (T)	Range (M)	Brg (T)	Range (M)
0300	113°	8.2	162°	10.2	201°	10.3
0306	111°	6.7	161°	08.8	201°	09.2
0312	108°	5.3	159°	07.4	201°	08.1
0318	102°	3.8	156°	06.0	201°	07.0

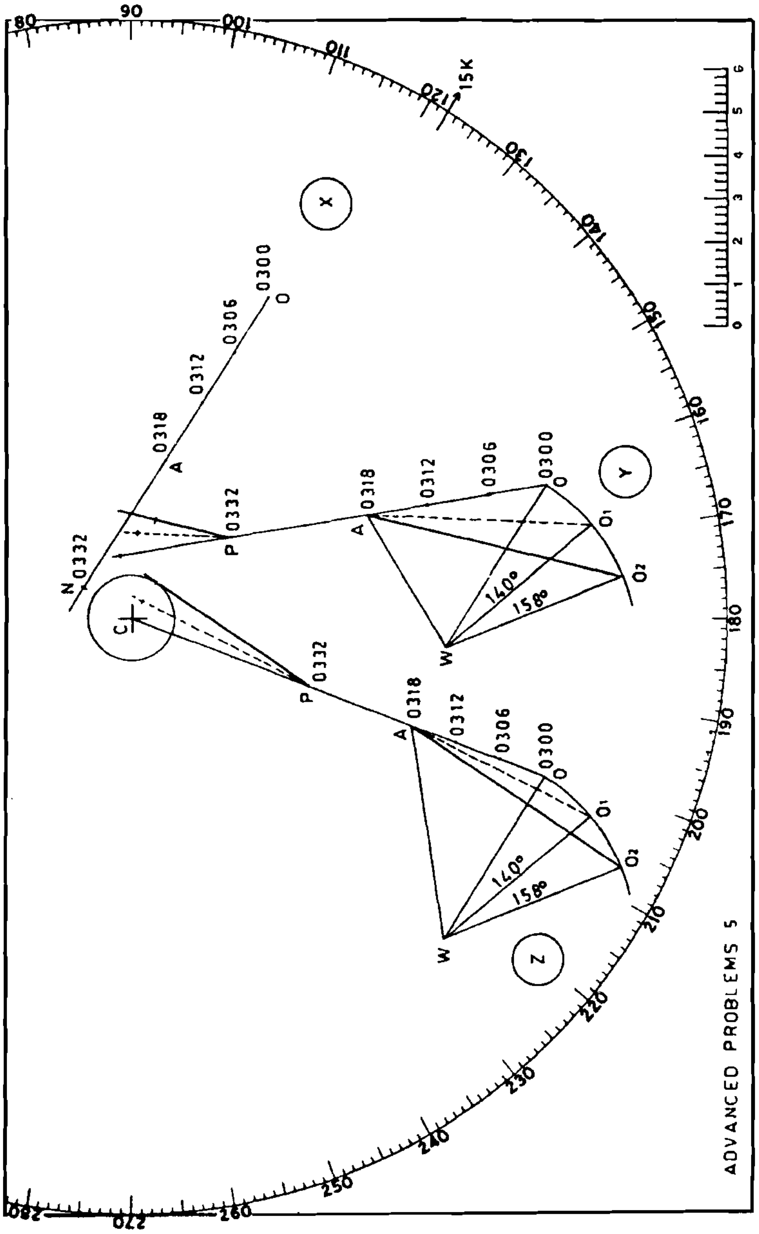
Find (a) CPA range and time of all three targets.

(b) Courses and speeds of targets Y and Z.

(c) When buoy X is abeam, the next course to steer, for navigational purposes, is 140°(T). If own ship's Master does not want any ship to pass less than one mile off, does this alteration of course resolve the situation? If not, what alteration of course would be suitable, both from ROR and navigation points of view?

Assume (i) All actions instantly effective.

(ii) Sufficient depth of water is available all round.


ADVANCED PROBLEMS 5
X
Y
Z
15K
O
0300
0306
0312
0318
A
0332
P
N
C
W
O1
O2
140°
158°
80
90
100
110
120
130
140
150
160
170
180
190
200
210
220
230
240
250
260
270
280
0
1
2
3
4
5
6

WORKING

(See attached plotting sheet)

(a) CPA: X – 1.3 M at 0332; Y – 1.5 M at 0342; Z – Collision at 0356.

(b) Course and speed: Y - 059°(T) 12 kn; Z - 082°(T) 17 kn.

(c) When X is abeam at 0332, Y and Z will be at P, on their respective lines of approach. If own ship alters course to 140°(T) at 0332, Y will remain clear as its CPA will become 2 M. However, by this action, Z will pass ahead of own ship with a CPA of only 0.5 M whereas the Master desires a CPA of 1.0 M. Hence the alteration of 140°(T) at 0332 is not adequate.

The simplest and quickest action to take at 0332, to resolve the situation, would be to alter course to 158°(T) (alter 36° to starboard) which will ensure that Z has a CPA range of 1.0 M and Y, CPA of 2.4 M. After Z reaches its new CPA of 1.0 M at 0345, course of 140°(T) may be set.

6. Own ship, capable of doing 14 knots, is on a course of 202°(T) at 6 knots, in *reduced visibility*, and observes the following on her radar screen:

	Target A		Target B	
Time	Bearing	Range	Bearing	Range
0700	029½° (T)	5.0 M		
0706			315°(T)	11.0 M
0712	027°	4.4		
0718			315°	9.3
0724	024°	3.8		
0730			315°	7.7

Analyse the situation at 0730 and state, with reasons, what would be the most suitable action to take.

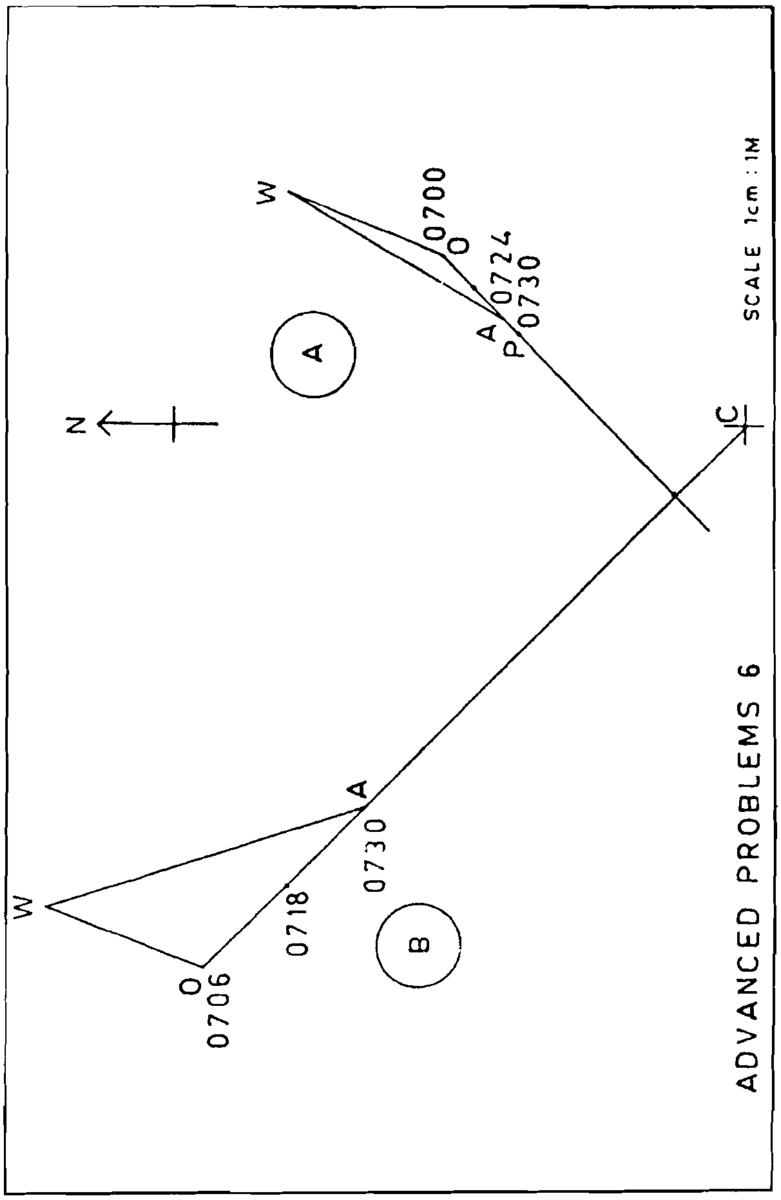
WORKING

(See attached plotting sheet)

CPA: A - 1.45 M at 0829; B - collision at 0826.

Course & speed: A - 210°(T) 9 knots; B - 163°(T) 12 knots.

Aspect at 0730: A - 9° red; B - 28° red.


ADVANCED PROBLEMS 6
SCALE 1cm : 1M
N
A
W
O
0700
0724
0730
A
P
C
B
W
A
0730
0718
O
0706

(i) Involvement with target A

Target A is overtaking own ship but Rule 19 is applicable, *not* Rule 13 (overtaking), because the vessels are *not* in sight of one another in restricted visibility. There is no risk of collision if both maintain their courses and speeds. However, if own ship takes action after 0730 to pass clear of the other two vessels, she should avoid (a) an alteration to starboard as this action contravenes Rule 19(d) (ii) of ROR, with respect to target A and (b) a reduction of speed as this would result in a close-quarters situation with target A.

(ii) Involvement with target B

Target B and own ship are on collision courses. Own ship is being overtaken from the starboard quarter by target B and own ship is thus restrained, by Rule 19(d) (ii) of ROR, from altering course to starboard. Since vessels are not in sight of one another in restricted visibility, Rule 13 (overtaking) is not applicable.

(iii) Summary of possible actions

The summary of possible actions that the own ship may take at 0730 is as follows:

Reduction of speed: Inadvisable, as explained earlier.

Increase of speed: Inadvisable as own vessel, though capable of doing 14 knots, is doing only 6 knots obviously because the Master considers it to be the safe speed under the circumstances. Any increase would mean greater-than-safe speed.

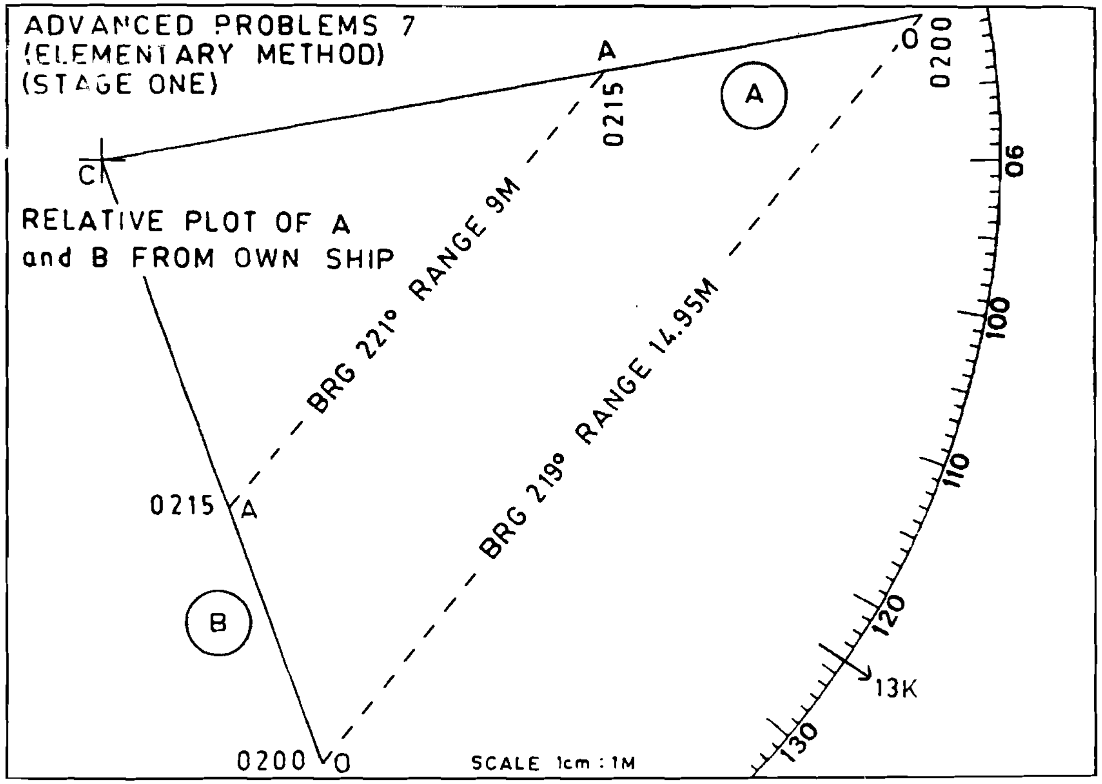
Starboard alteration: Prohibited by ROR as explained earlier

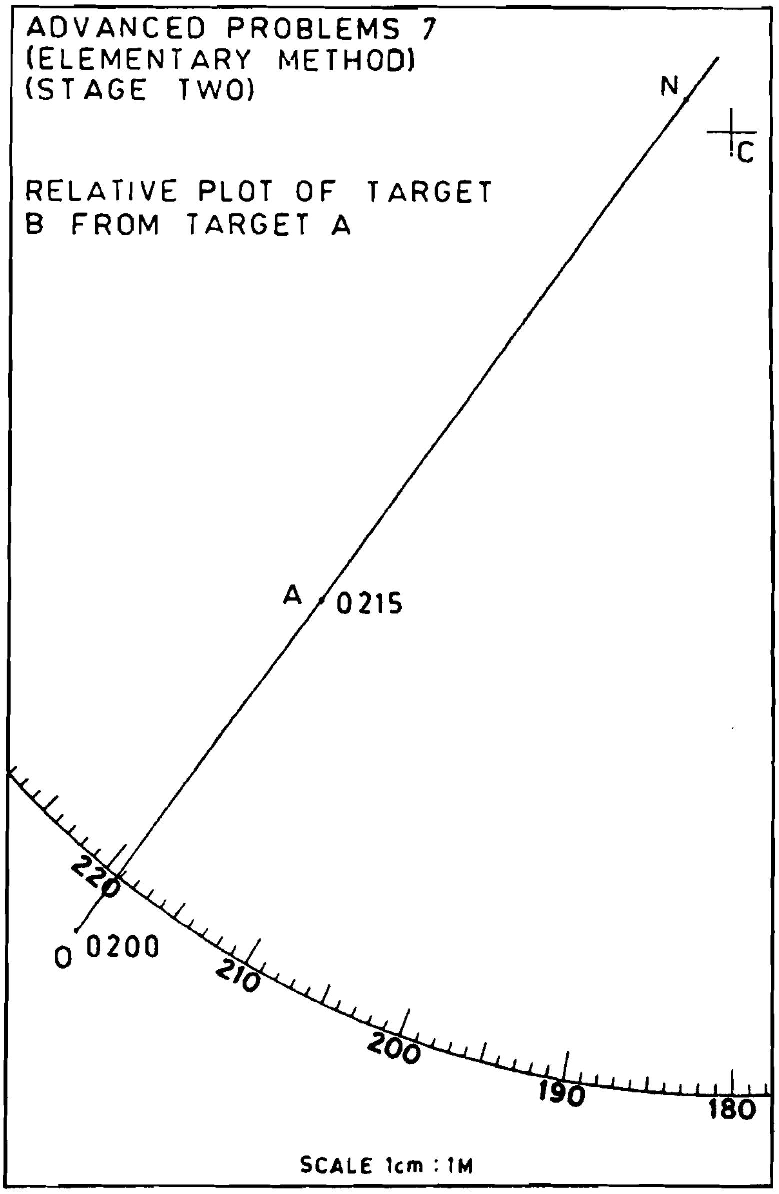
Port alteration: seems to be the best action to take under the circumstances. An alteration of 30° to port would mean that the new CPA ranges of A and B would be 2.6 and 2.5 M respectively, from own ship, at 0754 and 0844.

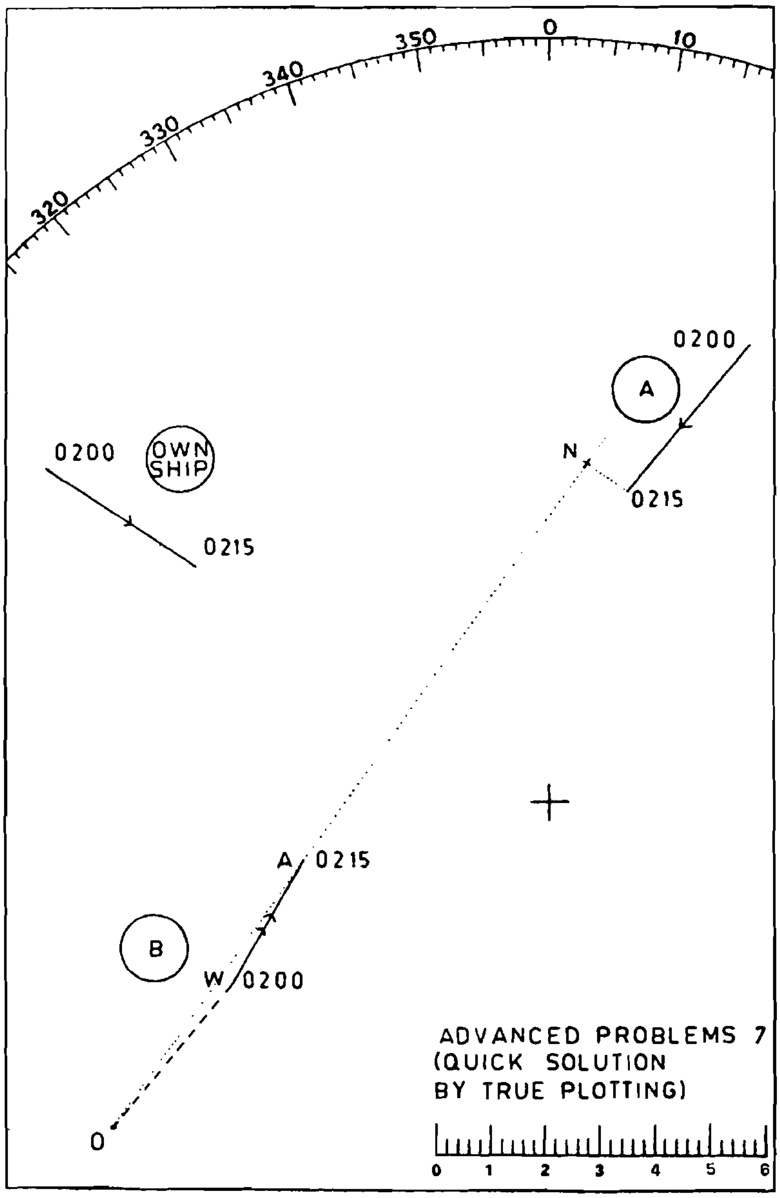
7. Own course 124°(T) at 13 knots. Following seen on PPI:

	Target A		Target B	
Time	Bearing	Range	Bearing	Range
0200	080°(T)	13.0 M	160°(T)	10.0 M
0215	080°(T)	08.0 M	160°(T)	5.75 M

Find the time and range at CPA of target B from target A.


ADVANCED PROBLEMS 7
(ELEMENTARY METHOD)
(STAGE ONE)
RELATIVE PLOT OF A
and B FROM OWN SHIP
C
A
0215
A
O
0200
BRG 221° RANGE 9M
BRG 219° RANGE 14.95M
0215
A
B
0200
O
SCALE 1cm : 1M
90
100
110
120
130
13K


ADVANCED PROBLEMS 7
(ELEMENTARY METHOD)
(STAGE TWO)
RELATIVE PLOT OF TARGET
B FROM TARGET A
N
C
A
0215
220
O
0200
210
200
190
180
SCALE 1cm : 1M



ADVANCED PROBLEMS 7
(QUICK SOLUTION
BY TRUE PLOTTING)

WORKING

(See attached plotting sheets)

There are two methods of solving this problem and both are explained here, separately.

The elementary method

Stage 1

Plot the given bearings and ranges and, from the plot, obtain the bearings and ranges *of* target B *from* target A at 0200 and 0215 [0200 - 219°(T) 14.95 M; 0215 - 221°(T) 9.0 M]. If desired, also find the course and speed of target A (220°T at 14 knots).

Stage 2

Construct a fresh plot of target B from target A, using the information obtained from stage 1:

Time	Bearing	Range
0200	219°(T)	14.95 M
0215	221°(T)	09.00 M

Find the time and range of CPA of target B (from target A) as usual. In this case, this CPA range is 0.8 M at 0237. Though in most cases, both these stages can be easily accommodated on one plotting sheet itself, they have been plotted separately here for the sake of clear illustration.

The quick solution by true plotting

Construct a true plot of the given situation, as explained in chapter 40. Call the 0200 and 0215 positions of target B, W and A respectively. Transfer the movement, of target A, to W and complete the triangle WOA. Produce OA, the line of approach of target B with respect to target A, and measure off the CPA range from the 0215 position of target A. In this case, CPA range of target B from target A will be 0.8 M.

$$\text{Time to CPA from 0215} = \frac{AN}{OA} \times \text{plotting interval}$$

$$= \frac{9}{6} \times 15 = 22.5 \text{ minutes.}$$

∴CPA time of target B from A = 0237.

8. Own course 230°(T) at 15 knots.

	Target X		Target Y		Target Z	
Time	Brg (T)	Range (M)	Brg (T)	Range (M)	Brg (T)	Range (M)
0000	300°	8.9	164°	06.4	182°	10.8
0020	311°	5.5	138°	04.0	174°	06.0

Find the range at CPA of target X, target Z and own ship, from target Y.

WORKING

(See attached plotting sheet)

This problem is worked here by true plotting. It may, if desired, be worked by the elementary method described in the previous problem, but that would take much longer than the true plotting method.

(i) Call any suitable point, on the plotting sheet, the 0000 position of own ship and from it lay off the bearings and ranges of targets X, Y and Z for 0000.

(ii) On a course of 230°(T) at 15 knots, mark off the 0020 position of own ship and from this position, lay off the bearings and ranges of targets X, Y and Z for 0020.

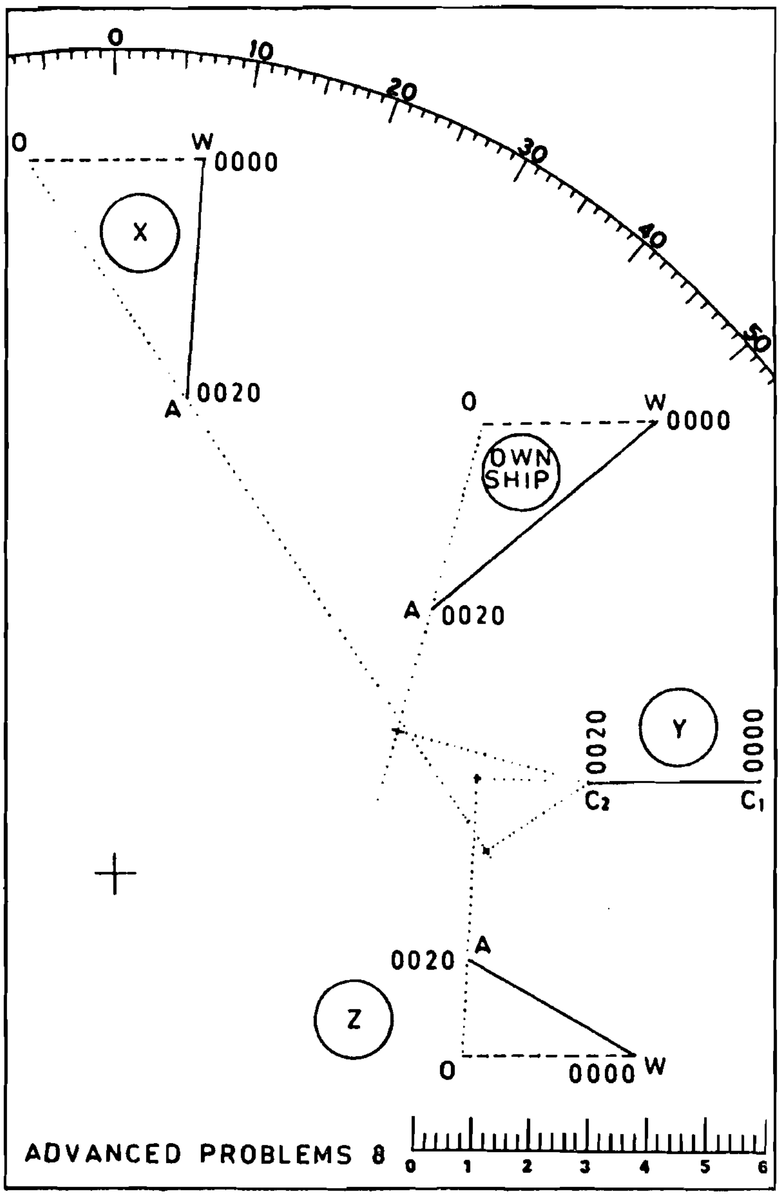
(iii) Join the 0000 and 0020 positions of each target and this line represents its true movement through the water (course and speed of each target).

(iv) Since range at CPA of target X, Z and own ship is required *from* target Y, call the first position of target Y, C_1 and its second position, C_2. Call the first positions of X, Z and own ship, W and the second positions, A.

(v) Transfer C_1C_2, the movement of target Y, to the W of the other three ships, complete their WOA triangles and produce their lines of approach relative to target Y.

(vi) Measure off the range at CPA of each from C_2 and obtain the answers.

CPA range of X	2.10 M
CPA range of Z	1.90 M
CPA range of own ship	3.35 M


0
10
20
30
40
50
O
W
0000
X
A
0020
O
W
0000
OWN SHIP
A
0020
0020
Y
0000
C2
C1
0020
A
Z
O
0000
W
ADVANCED PROBLEMS 8
0
1
2
3
4
5
6

Notes

Part V
PLOTTING

CHAPTER 42

AUTOMATIC RADAR PLOTTING AIDS

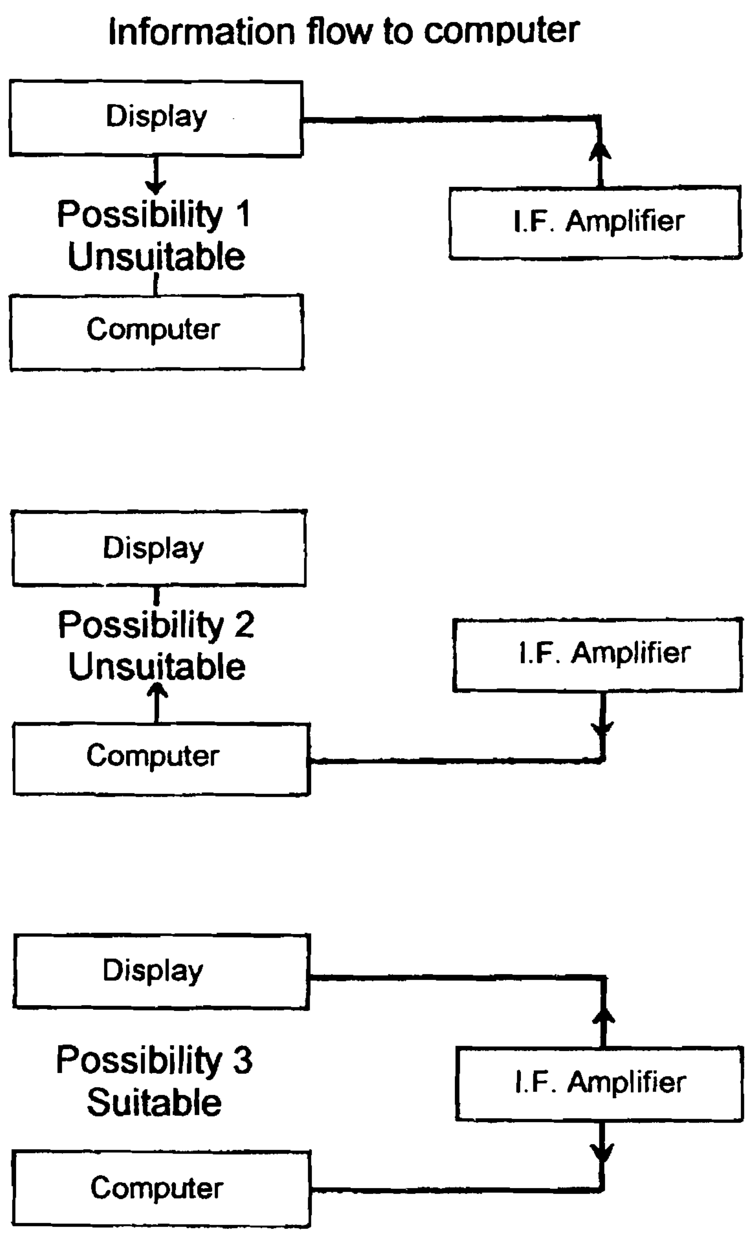
An Automatic Radar Plotting Aid (ARPA) is a computerised addition to basic radar whereby the officer in charge of the watch on the bridge can effectively carry out collision avoidance and navigation without much effort.

In order to use ARPA to full advantage, the user must not only understand its capabilities but also realise its limitations. He must appreciate that ARPA is only an aid and not the ultimate answer to collision avoidance. ARPA can help in assessing the situation by carrying out radar plotting quickly and accurately. However, the application of ROR and decisions regarding the suitable action to avoid collision, in each case, must be made by the duty officer himself.

For an ARPA to function properly, it is necessary that the input of information - own course and speed and the chosen target's bearing and range at each sweep of the scanner - is regular and complete. On the next page, three possibilities of flow of target information are shown. Of these, cases 1 and 2 are unsuitable. Case 3 is suitable. The reasons for the same are as follows:-

Case 1 is not suitable because the input of target information to the computer would be adversely affected by improper setting of the controls of the display, especially gain, sea clutter and rain clutter controls.

Case 2 is not suitable because computer failure or malfunction would deprive the ship of the use of basic radar and hence this is not permitted.


Information flow to computer
Display
I.F. Amplifier
Possibility 1
Unsuitable
Computer
Display
Possibility 2
Unsuitable
I.F. Amplifier
Computer
Display
Possibility 3
Suitable
I.F. Amplifier
Computer

Case 3 is suitable because the flow of target information is made separately available to the display and to the computer. Improper setting of display controls would not affect inputs to the computer and computer malfunction would not interfere with the availability of basic radar to the watch-keeping officer on the bridge. The I.F. (intermediate frequency) amplifier is pre-set for the maximum amplification possible without unacceptable levels of distortion while the video amplifier is controlled by the 'gain' control knob on the display unit.

ARPA FACILITIES

1. Tracking of targets:

A number of targets, chosen by the user, can be tracked (i.e., radar plotting is done in the computer's memory). When desired, the readout of these is available - target's bearing and range, CPA and TCPA, course and speed - one target at a time. Some sets also give 'bow crossing' range and its predicted time. It must be clearly understood that ARPA tracks only targets selected by the user. The computer is unaware of the presence of other targets, on the radar screen, which have not been specifically selected for tracking. Targets being tracked are clearly indicated on the screen by a distinct symbol, such as a cross, circle or square on or around them.

2. Guard zones:

A guard zone can be set up whereby any target entering it (often referred to as an intruder) would set off a visible and also an audible alarm. The visible alarm is usually a flashing symbol that appears around the intruding target. Both these alarms, visible and audible, would continue to operate until acknowledged by the officer on bridge watch. The guard zone may be set at any desired range. The user has the facility to set it up all around or to confine it to specific sectors. Some ARPA's have two guard rings separately adjustable in range but jointly adjustable in directional sectors. The space between them is the guard zone. Any target that enters the guard zone from outside, or appears for the first time on the PPI but in the guard zone, would set off the visible and audible alarms. The extent of the guard zone, when in use, must be clearly indicated on the radar screen.

3. Manual acquisition:

A designator symbol (abbreviated here to DS), which is usually in the form of a circle or a cross, can be made to appear on the PPI when desired and can be moved to any part of the screen by means of a joystick. The DS is positioned over the selected target and an 'acquire' button is pressed. Within 30 seconds, the ARPA would be ready to give readout of that target and a symbol would appear around it indicating that it is being tracked.

4. Automatic acquisition:

In some ARPA's, automatic acquisition of 20 or more targets is possible. A guard zone is set up first and then a button marked 'auto acquisition' is depressed. Thereafter, any target that breaches the guard zone (intruder) would not only set off the audible and visible alarms, but also get acquired automatically.

When in coastal waters, the guard zone should be suitably altered to exclude the possibility of land echoes from intruding into it. Otherwise, land would be acquired in the form of several different targets and would soon saturate the memory of the computer making it unable to acquire any more targets. Such a situation is highly undesirable.

5. CPA/TCPA alarm:

The CPA/TCPA alarm can be put into use whenever desired. The user has to feed in the desired values of CPA and TCPA. If any target, ***which is being tracked***, has CPA and TCPA below the values fed in, this alarm would go off, audibly and visibly, and remain on until acknowledged by the officer of the watch.

6. Vectors:

In ARPA terminology, a vector is a line sticking out of a ***tracked*** target, whose terminal point indicates the predicted position of the target at the end of a specific duration assuming that no alteration of course or speed takes place during the intervening period. The length of the vector is, therefore, expressed in minutes of time and this may be altered, as desired, usually between one minute and sixty. Vectors are of two types - true and relative. It is not possible to switch on both types of vectors - true and relative - at the same time.

A true vector indicates true movement of the target being tracked and is available on both, RM and TM displays.

A relative vector indicates the relative movement of the target being tracked and is available on both, RM and TM displays.

True vectors, when switched on, would appear on all ***moving*** targets that are being tracked and also on the electronic centre (EC) - spot depicting the own ship. They would not appear on stationary targets.

Relative vectors, when switched on, would appear on ***all targets*** that are being tracked regardless of whether they are moving or stationary. They would not appear on own ship or on targets having the same course and speed as own ship.

All vectors on the PPI would be of the same length of time. Any change of this duration, made by the user, would affect all the vectors displayed.

Frequent use of both, true and relative vectors alternately, helps the officer of the watch in getting a pictorial assessment of the current situation, and possible future developments of the same, regardless of whether he is using a True Motion (TM) or a Relative Motion (RM) display.

Relative vectors are very important and useful when using the ARPA in the trial manoeuvre mode, which is described later.

7. Ground stabilisation:

When desired, ground stabilisation of a TM display can be effected by moving the Designator Symbol (DS) over a small target being tracked which has been ***positively identified***, by the user, ***as a fixed target*** and depressing a button marked 'Ground stabilisation' or 'Ground reference'. Thereafter the display would become ground-stabilised. Clear indication would be visible all the time that the display is ground-stabilised. The point chosen for ground reference would be indicated by a distinct symbol.

The computer cannot ground reference on a cluster of targets. Hence it is important that the target chosen for ground reference is a single, small, distinct, isolated target. An end of land, such as a cape, is not suitable. A light vessel, a buoy, a small rock, a building ashore, etc., are ideal targets for this purpose.

It is interesting to understand how the ARPA achieves ground-stabilisation of a TM display. It may be recalled that the movement of a fixed object, on a sea-stabilised TM display, is the reversed set and rate of current. Every two or three rotations of the scanner, the computer calculates the movement of the target chosen for ground reference, reverses it and feeds it as a correction to the inputs to the TM display. The movement of the electronic centre thus corresponds with the ship's movement over the ground. In other words, the chosen point would remain fixed and ***the movement of all objects on the radar screen would be their movement over the ground.***

The display would remain ground-stabilised even if the reference target goes outside the range scale in use.

Ground-stabilisation, when in use, would be cancelled if:-

1. Revoked by the user by releasing the button marked 'Ground-stabilisation' or 'Ground reference'.
2. The set is put on standby
3. The target chosen for ground reference returns poor echoes. The audible and visible alarm marked 'Poor ground reference' would first alert the officer on bridge watch. If not acknowledged and the 'Ground reference' cancelled by him, it would automatically cancel the ground reference.

8. Course Up presentation:

Most ARPA manufacturers offer the built-in facility of Course-Up presentation. Such a form of display is explained in Chapter 26.

9. Trial manoeuvres:

Trial manoeuvre is one of the most important facilities offered by ARPA for both collision avoidance and navigation.

Clear indication must be visible at all times when the 'Trial Mode' is in use.

When used in conjunction with vectors, a pictorial prediction is available. All readouts of targets, in the trial manoeuvre mode, would be the predicted values assuming that the trial manoeuvre fed in has been executed.

When used with relative vectors, it allows the officer of the watch to see what effect specific alterations of course or speed or both, contemplated by him, will have on the relative movement of all the targets being tracked. It can also be used to find out what action would achieve the desired CPA from a specific target and the effect of that action on the relative movement of all the other targets being tracked.

When used with true vectors, it allows the officer of the watch to see what effect specific alterations of course or speed or both, contemplated by him, will have with respect to land targets. It must be remembered that coastlines cannot be tracked, by the computer of the ARPA, as they are not single, well defined targets but are, in fact, similar to a cluster of targets (see remarks under 'Ground-stabilisation' earlier).

When the trial manoeuvre mode is switched on, the computer of the ARPA would require the following information: New course, new speed and the interval after which the contemplated action is to be taken. For the sake of convenience, most manufacturers set in default values - the course and speed already being followed and an interval of 6 minutes. This is explained in greater detail below.

Suppose, when the ship is going 125°(T) at 16 knots, it becomes necessary, for navigational reasons, to make an alteration of course to 155°(T) after an interval of 8 minutes. The duty officer would like to see what effect this alteration would have on the ships in the vicinity, which are being tracked:

First switch on the relative vectors and suitably increase their lengths. Then switch on the trial mode. The new course for trial manoeuvre would read as 125°, the new speed as 16 knots and the interval as 6 minutes. The relative vectors would remain exactly as before, as also the readout of any tracked targets if requested, as no change of course or speed has been fed in as yet. Any of these three inputs may be changed and the corresponding effect would show. In this case, the delay should be changed to 8 minutes and the new course to 155°. The relative vectors of all tracked targets would remain the same as before for 8 minutes and then change direction in accordance with the intended new course of 155°(T). Mere inspection of the new relative vectors would give the duty officer a good idea of the consequential effect of the alteration of course. If the relative vectors are not long enough they may be suitably lengthened now. Any readout of a target would now show the new CPA, TCPA and, if provided, the new bow crossing range and time, assuming that the course alteration had been made as planned.

The readout of any target, while the trial mode is in use, would give the new CPA and TCPA, and, if provided, the bow crossing range and time, assuming that the intended manoeuvre had been executed as planned.

Changing over to true vectors now would remind the duty officer of the course and speed of each target and, because of the true vector on the own ship, give him an idea of the future positions of the own ship with respect to land assuming that the course alteration had been made as planned.

Suppose in open sea, while steering 300°(T) at 12 knots, several targets are being tracked and it is desired to take action after 3 minutes to increase the CPA of a tracked target to 2M:
Set the variable range marker (VRM) to the desired CPA of 2 M.

Switch on the relative vectors and make them suitably long. Then switch on the trial mode. The new course for trial manoeuvre would read as 300°, the new speed as 12 knots and the interval as 6 minutes. The relative vectors would remain exactly as before, and also the readout of any tracked target if requested, as no change of course or speed has been fed in as yet. Any of these three inputs may be changed and the corresponding effect would show. In this case, the delay should be change to 3 minutes and the trial course suitably altered to port or to starboard, in accordance with ROR, so as to make the new relative vector a tangent to the VRM. The new course to steer may then be read off. If necessary the trial speed alone may be altered to achieve the same result and the new speed-read off. It is also possible to try out a combination of course and speed alterations to achieve the desired CPA.

Once the trial manoeuvre to achieve the desired CPA has been successfully made, the effect of that action on the other targets being tracked can be seen by viewing their relative vectors while still in the trial mode. If more precise information is necessary regarding any specific target, while in the trial mode, its readout would give its new CPA and TCPA, assuming the action has been taken.

The foregoing examples are only intended to give an idea of the uses of the trial manoeuvre and are not comprehensive.

10. Map drawing:

Most ARPAs have the facility of map drawing. Maps may be drawn, and stored for later use, long before the ship arrives in a given area. The coastline on the chart is approximated by a series of straight lines whose directions and lengths are noted. In the map drawing mode, the radar screen becomes blank so that the straight lines representing the coastline can be reproduced on it. A single, distinct, radar-conspicuous target on the chart, herein referred to as the MRP (map reference point), is chosen and inserted on the map. The intended safe course of the ship is drawn on the chart and repeated on the map. The map is then stored in the memory of the computer. When the ship arrives in that vicinity, the map may be recalled, aligned so that the MRP on the map coincides with its paint on the PPI and the display ground-stabilised using the MRP for ground reference. Thereafter, a single glance at the PPI would indicate to the user whether the ship is on the course line or not and, if not, how much off and to which side. This simplifies navigation in coastal waters. If the range scale in use is changed, the computer would alter the scale of the map accordingly.

Map drawing, as described above is extensively used by ferries and coasters which call at the same ports very often, and have to keep strict schedules, in some cases at very high speeds. Some owners of such ships have cassette recorders fitted to the ARPAs so that the maps recorded on them may be duplicated and used by other ships of the fleet.

Most officers of large merchant ships, which call at a variety of ports, prefer to use the map drawing facility in a much simpler form. The coastline is not inserted at all. Only a suitable MRP and the lines of the traffic separation scheme are inserted on the map. This can be done in a few minutes, after the ship arrives in that vicinity. After the MRP is aligned with its paint on the radar screen and the display ground-stabilised, a single glance would indicate the position of the ship within the traffic separation scheme.

Where there is no traffic separation scheme, the course line is inserted, sometimes with parallel boundary lines on either side at distances chosen by the officer on watch, to give him an indication of the distance off course when the ship is not exactly on her intended course line.

Using the map facility of the ARPA helps the OOW in:

(a) Letting him know at a glance when the ship is off course.
(b) Deciding how much correction to apply, to the course steered, to bring the ship back on her intended course line.
(c) Carrying out precise navigation of the ship, in coastal waters, by monitoring the progress continuously. This is as effective, but much simpler than, parallel index techniques.

ARPA ALARMS

1. CPA/TCPA alarm:

The CPA/TCPA alarm is a necessary function to be provided on an ARPA. The user has to feed in the desired limits of CPA and TCPA. Once switched on, the audible and visible alarm would get activated if any of the *tracked* targets tends to have CPA and TCPA values less than the limits pre-set by the user. The alarm would continue to remain on until acknowledged by the user. The visible alarm consists of a distinct symbol flashing on/around the target that sets off the alarm and a panel light suitably marked.

The CPA/TCPA alarm is most useful when the ARPA is in the auto-acquisition mode where a number of targets may set off the 'intruder alarm' as and when each breaches the guard zone. Each would get acquired automatically but, within thirty seconds thereafter, only if any of them tends to have CPA and TCPA below the limits pre-set by the user, would this alarm get activated.

Setting high limits of CPA and TCPA for this alarm, in congested waters, would cause it to sound very frequently, creating a nuisance. This can be avoided by suitably reducing the limits fed in.

Setting very low limits of CPA and TCPA for this alarm is dangerous because targets tending to pass closeby fairly soon would not activate this alarm thereby defeating its very purpose.

2. Intruder alarm:

This alarm, also called 'Breach of guard zone alarm', is a necessary feature of an ARPA. It has already been discussed under the ARPA facility called 'Guard zones' earlier. Once a guard zone has been set up, any target entering it, referred to as an intruder, activates this audible and visible alarm which remains on until acknowledged by the officer on bridge watch. The visible alarm consists of a distinct symbol flashing on or around the intruding target and a panel light suitably marked.

3. Poor/lost target alarm:

If a target, which is being tracked, returns echoes of very poor strength, or does not return echoes at every rotation of the scanner, the 'poor/lost target alarm', which is audible and visible, would be activated and it would remain on until acknowledged. The visible alarm consists of a distinct symbol flashing around the last known position of that target and a panel light suitably marked.

4. Poor ground reference alarm:

If the target serving as ground reference for a True Motion display returns echoes of poor strength, or does not return echoes at every rotation of the scanner, this alarm, both audible and visible, would be activated and remain so until acknowledged. The visible alarm would consist of a distinct symbol, flashing around the ground reference target, just like the one denoting poor/lost target, & a panel light marked 'Poor ground reference'.

5. Time for action alarm:

This alarm, both audible and visible, is provided by some manufacturers. When the ARPA is left in the trial mode, at the end of the interval set in by the user, this alarm would be activated and it would remain on until acknowledged. The visible alarm would consist of a panel light marked 'Time for action'. For example, if the trial manoeuvre contemplated was after a delay of four minutes, and the ARPA was left in the trial mode, this alarm would get activated after the lapse of those four minutes. If the trial mode was not left on, this alarm would not get activated.

6. Change of course alarm:

A few manufacturers provide an alarm to indicate a change of course by a *tracked* target. This alarm is both, audible and visible. The visible alarm consists of a distinct symbol flashing on or around the target that activated the alarm and a panel light marked 'Course change'.

7. Wrong order alarm:

In case the user requests the computer to do something with which it cannot comply, the computer would sound a beep and a panel light marked 'Wrong order' would come on. One such request is for readout of a target not being tracked.

8. Equipment malfunction alarm:

The 'Equipment malfunction alarm' is an audible and visible alarm which would come on whenever there is malfunction of the ARPA and/or its related equipment. The audible alarm would be silenced only when the alarm is acknowledged. The visible alarm, which would consist of a panel light marked as such, would remain on until the fault has been rectified. Malfunction of important circuits of the computer, or gyro failure, would cause this alarm to get activated.

9. Memory full alarm:

This audible and visible alarm would get activated as soon as the memory of the computer gets saturated. In other words, as soon as the number of targets acquired equals to the maximum number that the computer has been designed for, this alarm would get activated. The audible alarm would get silenced as soon as it is acknowledged but the visible alarm, consisting of a panel light marked as such, would remain on until at least one acquired target is cancelled, or dropped. Revoking of the order for tracking a target is called 'Drop' or 'Cancel'. Bringing the designator symbol (DS) over the target and pressing a button marked 'Cancel' or 'Drop' does this. As a precaution against inadvertent cancellation of targets, some manufacturers require a button marked 'Select' to be pressed before 'Cancel' - otherwise the computer would not carry out the order to drop the target lying within the DS.

SOME IMPORTANT LIMITATIONS OF ARPA

1. Limitations of radar:

The use of an ARPA is subject to all the limitations of ordinary, shipborne radar. These include minimum detection range, maximum detection range, range accuracy, bearing accuracy, range discrimination, bearing discrimination, blind and shadow sectors, shadow areas, roll/pitch up to ±10° only, etc.

2. Range scale:

The use of ARPA is NOT available on all range scales but limited to a few only such as 3, 6, 12 and 24 M. In practice, however, this is considered quite adequate by most mariners.

3. Gyro stabilisation:

An ARPA works only on gyro-stabilised displays. It is not available for use on unstabilised displays. Whereas this is not important under normal circumstances, it does pose a problem when the gyrocompass is either inoperative or is wandering. The navigator has no choice but to use the Head Up Display but without ARPA.

4. Off when the radar set is on standby:

When the radar set is put on standby, there is no transmission or reception of radio waves. Since the input of information to the computer is interrupted, the ARPA cannot function and goes off.

5. Input errors:

The computer of the ARPA processes the information fed to it. It cannot detect any input errors such as gyro error, log error, etc. Any such errors would most certainly affect the results obtained. The OOW has to watch for this and make due allowances for consequential inaccuracies during the navigation of the ship during his watch. It must be remembered that Doppler logs, when used in the bottom reference mode, give ship's speed *over the ground* whereas the gyro compass feeds in course *through the water* (i.e. course steered). Hence it is important to use such logs in the sea-speed mode while using ARPA.

Failure of the ship's speed-log should cause the 'Equipment failure alarm' to be activated but it is possible that, in some rare cases, it may not do so.

If, due to interruption in the power supply from the ship's mains, the gyrocompass starts to wander, the computer of the ARPA would not be able to detect this. However, failure of the gyrocompass would, most certainly, activate the 'Equipment failure alarm'.

6. Assumptions:

It must be remembered that all predictions obtained by use of an ARPA are made on the assumption that all targets which are being tracked would maintain course and speed during the intervening period. Such predictions include CPA and TCPA, bow crossing range and time, relative and true vectors and trial manoeuvres.

7. Computer tracking capacity:

The computer can keep track of only a limited number of targets. Where only manual acquisition is provided, the minimum capacity is to be at least ten targets and where the auto-acquisition facility is available, the minimum is to be at least twenty. Manufacturers generally give more capacity than the minimum requirements.

8. Maximum speed:

Some ARPAs can track a target only if the target's speed is below 60 knots whereas others can do so up to 99 knots.

9. Target swop:

When two targets, which are being tracked, pass very close to each another, it is possible that the computer exchanges the stored information and subsequent readouts of each would then give the values of the other. This is called target swop or target swap. This is also possible when a target, which is being tracked, passes very close to one which is not, more so if the latter gives stronger echoes than the former.

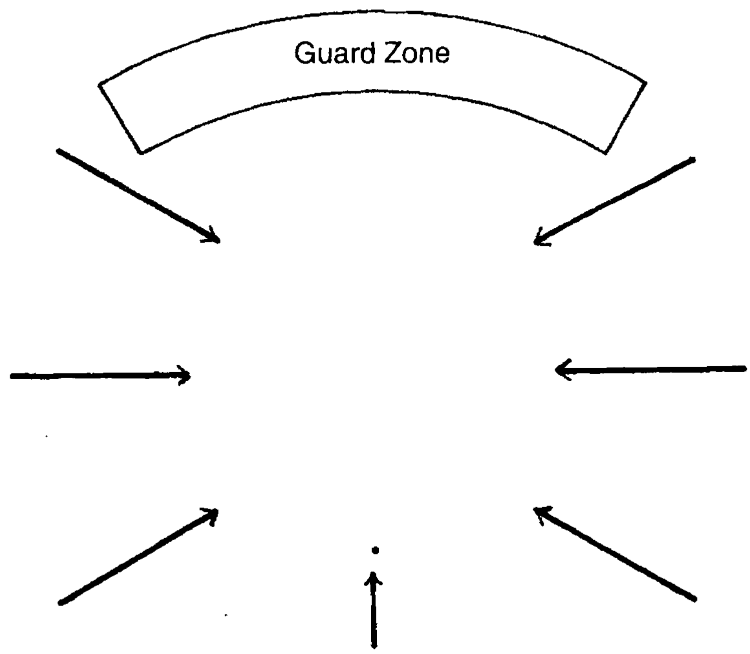
10. Scintillation:

An ARPA makes very accurate calculations but based on the information obtained by it, or supplied to it. It assumes that the position of a target is that position from which the strongest echo is received. It may happen that the strongest echo is returned by different parts of a large ship at different times due to change of aspect as a result of yaw, pitch, roll, etc. This is called 'Target glint' or 'Scintillation' and would cause the computer to assume that the target's position has changed, resulting in slight inaccuracy in the readouts given.

11. Guard zones:

Guard zones are of two types. The first type has a guard ring surrounded by a guard zone having a fixed, radial depth of about 0.5M or 1M. The guard ring may be set at any range desired by the user but the radial width of the guard zone cannot be varied. When set to guard all round the ship, any target which approaches through the guard zone would activate the 'Intruder alarm'. However, if the range of first detection of a target happens to be less than the value of range set for the guard ring, it would pop up inside the guard ring, without passing through the guard zone, and thus not activate the 'Intruder alarm'. For example, an approaching fishing vessel with a maximum detection range of 6 M would appear on the PPI, for the first time, well inside a guard ring set at 10 M. It would <u>not</u> activate the 'Intruder alarm' because it did not pass through the guard zone. If set to guard a particular sector, say between 330° and 030° relative, at a range of 6 M, two arcs separated by 0.5 M (or 1 M) would appear on the PPI, between the said relative bearings. The inner arc is the guard ring (set at 6 M in this case) and the space between them is the guard zone as shown in the following figure.

Any target which pops up inside the guard ring, or which approaches from any direction as shown in the following figure, would <u>not</u> activate the 'Intruder alarm'. Such a situation is dangerous and hence the navigator should be fully aware of this limitation.



The second type of guard zone consists of two guard rings with the guard zone between them. Each of these rings may be set at any desired range separately. In other words, the width of the guard zone may be varied as desired by the user. When set to guard all round the ship, the possibility of a target popping up without activating the 'Intruder alarm' can be minimised by suitably adjusting the width of the guard zone. However, when set to guard only a sector, it is possible for targets to come in, from the directions shown in the foregoing figure, without activating the 'Intruder alarm'.

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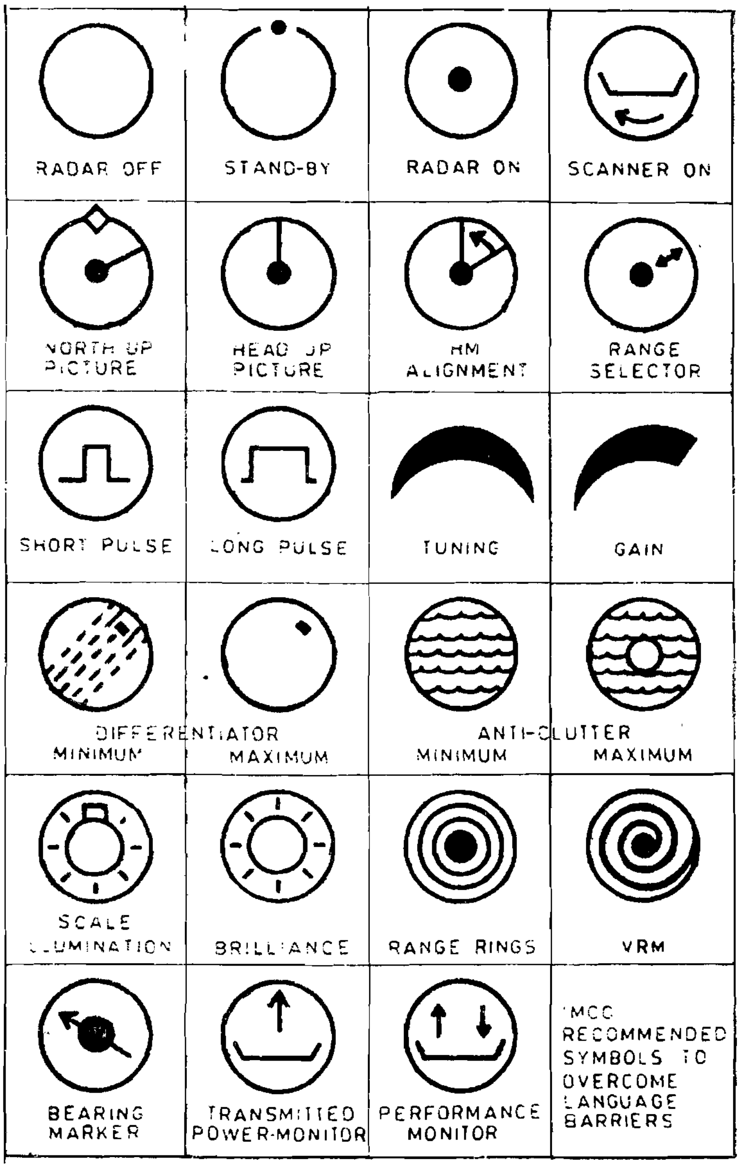
INDEX 1 - RADAR

INDEX 2 - ARPA

-o0o-

Appendix I


RADAR OFF
STAND-BY
RADAR ON
SCANNER ON
NORTH UP PICTURE
HEAD UP PICTURE
HM ALIGNMENT
RANGE SELECTOR
SHORT PULSE
LONG PULSE
TUNING
GAIN
DIFFERENTIATOR
MINIMUM
MAXIMUM
ANTI-CLUTTER
MINIMUM
MAXIMUM
SCALE ILLUMINATION
BRILLIANCE
RANGE RINGS
VRM
BEARING MARKER
TRANSMITTED POWER-MONITOR
PERFORMANCE MONITOR
IMCO RECOMMENDED SYMBOLS TO OVERCOME LANGUAGE BARRIERS

Appendix II

SPEED-TIME-DISTANCE TABLE

PLOTTING INTERVAL (Minutes)

KNOTS	3	4	5	6	9	10	12	15	20
3	.15	.20	.25	.30	.45	.50	.60	.75	1.00
4	.20	.27	.33	.40	.60	.67	.80	1.00	1.33
5	.25	.33	.42	.50	.75	.83	1.00	1.25	1.67
6	.30	.40	.50	.60	.90	1.00	1.20	1.50	2.00
7	.35	.47	.58	.70	1.05	1.17	1.40	1.75	2.33
8	.40	.53	.67	.80	1.20	1.33	1.60	2.00	2.67
9	.45	.60	.75	.90	1.35	1.50	1.80	2.25	3.00
10	.50	.67	.83	1.00	1.50	1.67	2.00	2.50	3.33
11	.55	.73	.92	1.10	1.65	1.83	2.20	2.75	3.67
12	.60	.80	1.00	1.20	1.80	2.00	2.40	3.00	4.00
13	.65	.87	1.08	1.30	1.95	2.17	2.60	3.25	4.33
14	.70	.93	1.17	1.40	2.10	2.33	2.80	3.50	4.67
15	.75	1.00	1.25	1.50	2.25	2.50	3.00	3.75	5.00
16	.80	1.07	1.33	1.60	2.40	2.67	3.20	4.00	5.33
17	.85	1.13	1.42	1.70	2.55	2.83	3.40	4.25	5.67
18	.90	1.20	1.50	1.80	2.70	3.00	3.60	4.50	6.00
19	.95	1.27	1.58	1.90	2.85	3.17	3.80	4.75	6.33
20	1.00	1.33	1.67	2.00	3.00	3.33	4.00	5.00	6.67
21	1.05	1.40	1.75	2.10	3.15	3.50	4.20	5.25	7.00
22	1.10	1.47	1.83	2.20	3.30	3.67	4.40	5.50	7.33
23	1.15	1.53	1.92	2.30	3.45	3.83	4.60	5.75	7.67
24	1.20	1.60	2.00	2.40	3.60	4.00	4.80	6.00	8.00
25	1.25	1.67	2.08	2.50	3.75	4.17	5.00	6.25	8.33
26	1.30	1.73	2.17	2.60	3.90	4.33	5.20	6.50	8.67
27	1.35	1.80	2.25	2.70	4.05	4.50	5.40	6.75	9.00
28	1.40	1.87	2.33	2.80	4.20	4.67	5.60	7.00	9.33
29	1.45	1.93	2.42	2.90	4.35	4.83	5.80	7.25	9.67
30	1.50	2.00	2.50	3.00	4.50	5.00	6.00	7.50	10.00

DISTANCE (Miles)