SEAFARERS TRAINING CENTER INC

RADAR NAVIGATION AT OPERATIONAL LEVEL
RADAR NAVIGATION, RADAR PLOTTING AND USE OF ARPA

IN ACCORDANCE TO INTERNATIONAL CONVENTION ON STANDARDS OF TRAINING, CERTIFICATION AND WATCHKEEPING FOR SEAFARERS (STCW), 1978, AS AMENDED

Aims

This model course aims to meet mandatory minimum standards of competence given in the table under section A-II/1 of the STCW code for ,use of radar and ARPA to maintain safety of navigation . The course includes the theory necessary to understand the systems configuration , principles , performance of shipborne marine radar and ARPA , the factor affecting radar performances, how radar information is obtained , displayed and analyzed , the limitations and accuracy of that information , the correct use of operational controls to obtain an optimal display and use information to maintain safety of navigation .

Objective :

A trainee successfully completing this course and meeting the required performance standards will recognize when radar should be in use, select a suitable mode and range setting fot the circumstances; be able to set the controls for optimal performance; and be aware of the equipment in detecting in detecting in detecting targets and in terms of accuracy .

Entry Standards :

This course is principally intended for candidates for certification as officer in change of a navigational watch . Prior to entering the course , it is recommended the trainees, should have completed a minimum period of six months at sea and preferably have gained some experience of watchkeeping .

Course certification certification, diploma or document may be issued certifying that the holder has completed a course of training which meets or exceeds the level of knowledge and competence specified in table A-II/1 of the STCW Code .

Staff Requirement:

The instructor must have appropriate training in instructional techniques and training methods (Section A-I/6 of the STC code).

Course Outline

Knowledge , understanding and proficiency	Lecture (h)	Demonstration (h)	Practical Training (h)
1. Basic Theory and operational principles of a marine radar system			
1.1 Fundamental principles of radar	2.0		
Demonstration and practical training 1-1		0.5	
Demonstration of radar system configuration and installation location on board			
1.2 Magnetic safe distance	0.05		
1.3 Radiation hazards and precautions	0.05		
1.4 Factors of Radar equipment affecting radar detection	3.0		
1.5 Factors external to radar equipment affecting radar detection	3.8		
1.6 Factors affecting normal radar observation	1.6		
1.7 Performance standards for radar equipment in resolutions MSC.192(79, annex 4 of MSC. 64(67) and	1.0		

A.477(XII)	**11.5**	**0.5**	
2. Radar setting and operation in accordance with manufacture´s instructions			
2.1 Setting up and maintain optimum radar display	4.5		
Demonstration and practical training 2-1		1.0	3.0
Radar setting up and adjustment			
2.2 Accurate measurement of ranges and bearings	1.5		
	6.0	**1.0**	**3.0**
3. Using radar to ensure safe navigations			
3.1 Radar positions -fixing	0.9		
Demonstrations and practical training 3-1		0.2	0.8
Radar position-fixing			
3.2 Radar navigation aids	0.5		
3.3 Parallel index line techniques	0.8		
Demonstration and practical training 3-2		0.4	1.6
Pl line navigation			
3.4 Maps, navigation lines and routes for radar navigation			
Demonstration and practical training 3-3		0.4	1.6
Radar maps, navigation lines and routes navigation			

3.5 Electronic chart overlay on radar picture	0.4		
	3.0	**1.0**	**4.0**
4. Manual Radar Plotting			
4.1 Relative motion triangle	0.5		
4.2 Course, speed and aspect of a target ship	2.0		
4.3 Determination of CPA and TCPA	0.5		
Demonstration and practical 4-1		0.2	0.8
Acquiring motion elements of target ship		0.2	0.8
4.4 Effects of course alteration and speed change	2.5		
Demonstration and practical training 4-2		0.2	0.8
Effects of course alternations on RML			
Demonstration and practical training 4-3		0.2	0.8
Effects of speed changes on RML			
4.5 Report of radar plotting data	0.5		
Demonstration and practical training 4-4		0.2	0.8
Manual radar plotting report			
	6	**0.8**	**3.2**
5. ARPA Systems or radar target tracking (TT) and AIS reporting functions	0.7		
5.1 Display Characteristic of tracked targets	0.2		
5.2 Display characteristic of AIS reported targets	0.3		
5.3 Association of Radar tracked targets with AIS reported targets	0.5		

5.4 IMO performance standards for ARPA or TT and AIS reporting functions	0.5		
5.5 Criteria for acquisition or radar targets and activation of AIS targets	0.5		
5.6 Tracking capabilities and limitations	0.3		
5.7 Delay of target tracking processing and AIS reported information	0.3		
	3.3		
6 Operation of ARPA or radar target tracking (TT) and AIS reporting functions			
6.1 Setting up and maintaining ARPA or TT display	0.7		
6.2 Setting up and maintaining AIS display	0.5		
6.3 Operations of ARPA or TT and AIS reporting to Obtain target information	2.0		
6.4 Errors of interpretation of target data	0.8		
6.5 Causes of errors in displayed data	1.0		
6.6 System operational tests to determine data accuracy	0.5		
6.7 Risk of over-reliance on ARPA or TT and AIS reported information	0.5		
Demonstration and practical training 5 & 6-1		3.0	12.0
Operation of ARPA or TT and AIS reporting functions	**6.0**	**3.0**	**12.0**
7. Application of COLREG´S when using radar			

7.1 Proper use of radar and full and complete interpretation of radar information	0.5		
7.2 Radar related factors affecting safe speed	0.3		
7.3 Methods and characteristic of acquiring sufficient radar information	0.5		
7.4 Actions to avoid Collins based on sufficient radar information and in accordance with COLREG rules	0.5		
7.5 Timing to use radar	0.2		
Demonstration and practical training 7-1		2.0	10.0
Ship handling for integrated collision avoidance	2.0	2.0	10.0
Evaluation	**1**		**0.7**
Total 80.0	**37.8**	**8.3**	**32.9**

1- DESCRIBES THE BASIC THEORY AND OPERATION OF A MARINE RADAR SYSTEM

1.1- Fundamentals principles of radar

The electronic principle on which radar operates is very similar to the principle of sound-wave reflection. If you shout in the direction of a sound-reflecting object (like a rocky canyon or cave), you will hear an echo. If you know the speed of sound in air, you can then estimate the distance and general direction of the object.
The time required for an echo to return can be roughly converted to distance if the speed of sound is known. Radar uses electromagnetic energy pulses in much the same way, as shown in Figure 3. The radio-frequency (RF) energy is transmitted to and reflected from the reflecting object. A small portion of the reflected energy returns to the radar set.
This returned energy is called an ECHO, just as it is in sound terminology. Radar sets use the echo to determine the direction and distance of the reflecting object.

Figure 3: Radar principle

As implied by this contraction, radars are used to detect the presence of an aim (as object of detection) and to determine its location. The contraction implies that the quantity measured is range. While this is correct, modern radars are also used to measure range and angle.
The following figure shows the operating principle of primary radar. The radar antenna illuminates the target with a microwave signal, which is then reflected and picked up by a receiving device. The electrical signal picked up by the receiving antenna is called echo or return. The radar signal is generated by a powerful transmitter and received by a highly sensitive receiver.

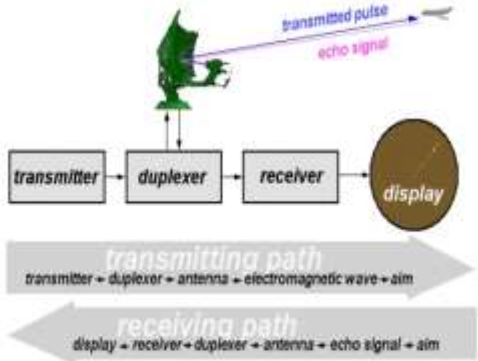


Figure 4: Block diagram of a primary radar with the signal flow

Signal Routing

- The radar transmitter produces short duration high-power RF- pulses of energy.
- The duplexer alternately switches the antenna between the transmitter and receiver so that only one antenna need be used. This switching is necessary because the high-power pulses of the transmitter would destroy the receiver if energy were allowed to enter the receiver.
- The antenna transfers the transmitter energy to signals in space with the required distribution and efficiency. This process is applied in an identical way on reception.
- The transmitted pulses are radiated into space by the antenna as an electromagnetic wave. This wave travels in a straight line with a constant velocity and will be reflected by an aim.
- The antenna receives the back scattered echo signals.
- During reception the duplexer lead the weakly echo signals to the receiver.
- The hypersensitive receiver amplifies and demodulates the received RF-signals. The receiver provides video signals on the output.
- The indicator should present to the observer a continuous, easily understandable, graphic picture of the relative position of radar targets.

All targets produce a diffuse reflection i.e. it is reflected in a wide number of directions. The reflected signal is also called scattering. Backscatter is the term given to reflections in the opposite direction to the incident rays.

Radar signals can be displayed on the traditional plan position indicator (PPI) or other more advanced radar display systems. A PPI has a rotating vector with the radar at the origin, which indicates the pointing direction of the antenna and hence the bearing of targets. It shows a map-like picture of the area covered by the radar beam.

Signal Timing

Most functions of a radar set are time-dependent. Time synchronization between the transmitter and receiver of a radar set is required for range measurement. Radar systems radiate each pulse during transmit time (or Pulse Width τ), wait for returning echoes during listening or rest time, and then radiate the next pulse, as shown in Figure 5.

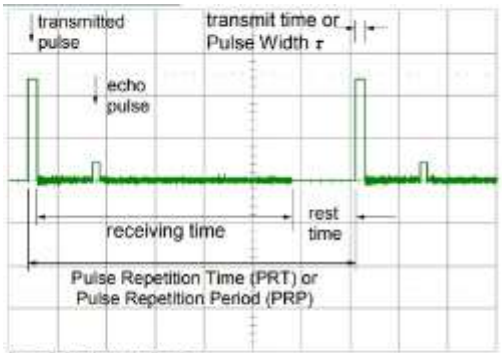


Figure 5. A typical radar time line

A so called synchronizer coordinates the timing for range determination and supplies the synchronizing signals for the radar. It sent simultaneously signals to the transmitter, which sends a new pulse, and to the indicator, and other associated circuits. The time between the beginning of one pulse and the start of the next pulse is called pulse-repetition time (PRT) and is equal to the reciprocal of PRF as follows:

$$PRT = \frac{1}{PRF}$$

The Pulse Repetition Frequency (PRF) of the radar system is the number of pulses that are transmitted per second. The frequency of pulse transmission affects the maximum range that can be displayed, as we shall see later.

Ranging

The distance of the aim is determined from the running time of the high-frequency transmitted signal and the propagation c0. The actual range of a target from the radar is known as slant range. Slant range is the line of sight distance between the radar and the object illuminated. While ground range is the horizontal distance between the emitter and its target and its calculation requires knowledge of the target's elevation. Since the waves travel to a target and back, the round trip time is divided by two in order to obtain the time the wave took to reach the target. Therefore the following formula arises for the slant range:

$$R = \frac{t_{delay} \cdot c_0}{2}$$

R is the slant range

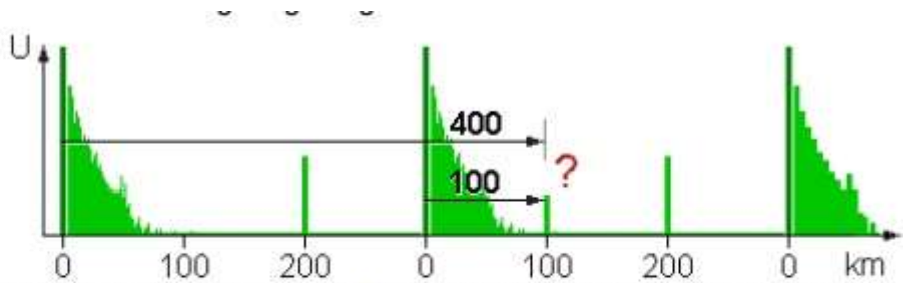
t_{delay} is the time taken for the signal to travel to the target and return

$c0$ is the speed of light (approximately $3 \cdot 10^8$ m/s)

the radar set can be calculated by using this equation.

Maximum Unambiguous Range

A problem with pulsed radars and range measurement is how to unambiguously determine the range to the target if the target returns a strong echo. This problem arises because of the fact that pulsed radars typically transmit a sequence of pulses. The radar receiver measures the time between the leading edges of the last transmitting pulse and the echo pulse. It is possible that an echo will be received from a long range target after the transmission of a second transmitting pulse.



In this case, the

range. The mea

Figure 6: a second-sweep echo in a distance of 400 km assumes a wrong range of 100 km

transmitted pulse and declares a much reduced range for the target. This is called range ambiguity and occurs where there are strong targets at a range in excess of the pulse repetition time. The pulse repetition time defines a maximum unambiguous range. To increase the value of the unambiguous range, it is necessary to increase the PRT, this means: to reduce the PRF.

Echo signals arriving after the reception time are placed either into the

- transmit time where they remain unconsidered since the radar equipment isn't ready to receive during this time, or
- into the following reception time where they lead to measuring failures (ambiguous returns). The maximum unambiguous range for given radar system can be determined by using the formula:

$$R_{unamb} = \left(PRT - \tau\right) \cdot c_0 / 2$$

The pulse repetition time (PRT) of the radar is important when determining the maximum range because target return-times that exceed the PRT of the radar system appear at incorrect locations (ranges) on the radar screen. Returns that appear at these incorrect ranges are referred as ambiguous returns or second time around (second-sweep) echoes. The pulse width (t) in this equation indicates that the complete echo impulse must be received.

Radar Waveforms Minimum Range

The minimum detectable range (or blind distance) is also a consideration. When the leading edge of the echo pulse falls inside the transmitting pulse, it is impossible to determine the "round trip time", which means that the distance cannot be measured. The minimum detectable range Rmin depends on the transmitters pulse with τ, and the recovery time trecovery of the duplexer.

$$R_{min} = \frac{\left(\tau + t_{recovery}\right) \cdot c_0}{2}$$

The receiver does not listen d cause it needs to be disconnected from the transmitter during transmission to avoid damage. In that case, the echo pulse comes from a very close target. Targets at a range equivalent to the pulse width from the radar are not detected. A typical value of 1 µs for the pulse width of short range radar corresponds to a minimum range of about 150 m, which is generally acceptable. However, radars with a longer pulse width suffer a relatively large minimum range, notably pulse compression radars, which can use pulse lengths of the order of tens or even hundreds of microseconds. Typical pulse width τ for

- Air-defense radar: up to 800 µs (R_{min} = 120 km !)
- ATC air surveillance radar: 1.5 µs (R_{min} = 250 m)
- surface movement radar: 100 ns (R_{min} = 25 m)

Cause by the fact that the radar unit measures a slope range, the radar measures different ranges of two airplanes, which exactly one above the other flies (therefore having the same topographical distance to the radar unit exactly).
This false measurement could be corrected by software, or module in modern radar sets with digital signal processing. These software modules then must also especially be adapted on the geographical coordinates of the radar site, however. The calculation is very complicated and also requires some weather data to the correction.

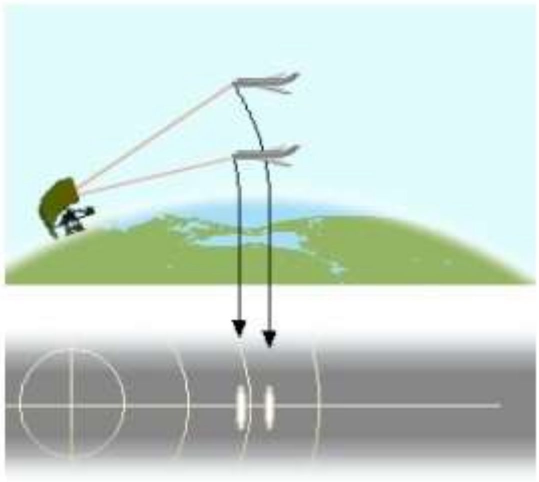


Figure 7: Different height causes a different slant range

.2 States the function and sitting of components

Bearing

The direction to the target is determined by the directivity of the antenna. Directivity, sometimes known as the directive gain, is the ability of the antenna to concentrate the transmitted energy in a particular direction. An antenna with high directivity is also called a directive antenna. By measuring the direction in which the antenna is pointing when the echo is received, both the azimuth and elevation angles from the radar to the object or target can be determined. The ac is determined by the directivity, which is a function of t

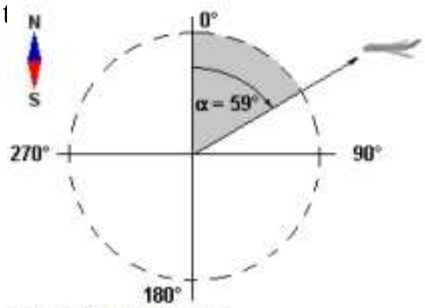


Figure 8: True Bearing

The True Bearing (referenced to t e angle between true north and a line pointed directly at the target. This angle is measured in the horizontal plane and in a clockwise direction from true north. The bearing angle to the radar target

may also be measured in a clockwise direction from the centerline of your own ship or aircraft and is referred to as the relative bearing.
The rapid and accurate transmission of the bearing information between the turntable with the mounted antenna and the scopes can be carried out for

- servo systems and
- counting of azimuth change pulses.

Servo systems are used in older radar antennas and missile launchers and works with help of devices like synchro torque transmitters and synchro torque receivers. In other radar units we find a system of Azimuth-Change-Pulses (ACP). In every rotation of the antenna a coder sends many pulses, these are then counted in the scopes. Some radar sets work completely without or with a partial mechanical motion. These radars employ electronic phase scanning in bearing and/or in elevation (phased-array-antenna).

Elevation Angle
The elevation angle is the angle between the horizontal plane and the line of sight, measured in the vertical plane. The Greek letter Epsilon (ε) describes the elevation angle. The elevation angle is positive above the horizon (0° elevation angle), but negative below the horizon.

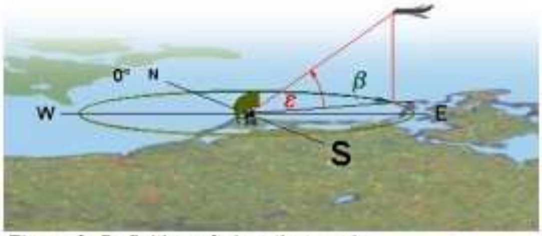


Figure 9: Definition of elevation angle

Height
The height of a target over the earth's surface is called height or altitude. This is denominated by the letter H (like: Height) in the following formulae and figures. True altitude is the actual airplane distance above mean sea level.
The altitude can be calculated with the values of distance R and elevation angle ε, as shown in figure 11, where:

R = aims slant range
ε = measured elevation angle
r_e = earth's equivalent radius (about 6370 km)

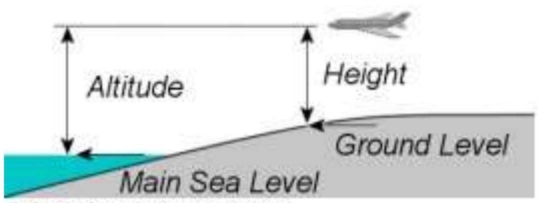


Figure 10: Altitude vs. Height

In practice, however, the propagation of electromagnetic waves is also subject to refraction, this means, the transmitted beam of the radar unit isn't a straight side of this triangle but this side is also bent and it depends on:

- the transmitted wavelength,
- the barometric pressure,
- the air temperature and
- the atmospheric humidity.

Therefore all these equations are an approximation only

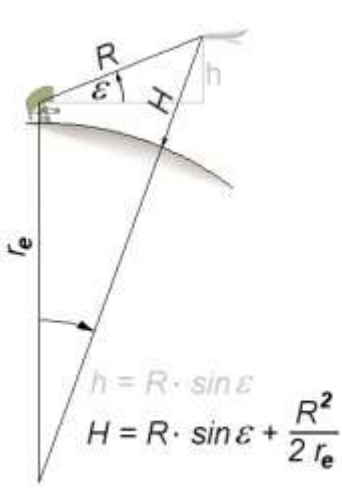


Figure 11: Calculation of height

Accuracy

Accuracy is the degree of conformance between the estimated or measured position and/or the velocity of a platform at a given time and its true position or velocity. Radio navigation performance accuracy is usually presented as a statistical measure of system error.

Accuracy should not be confused with radar resolution.

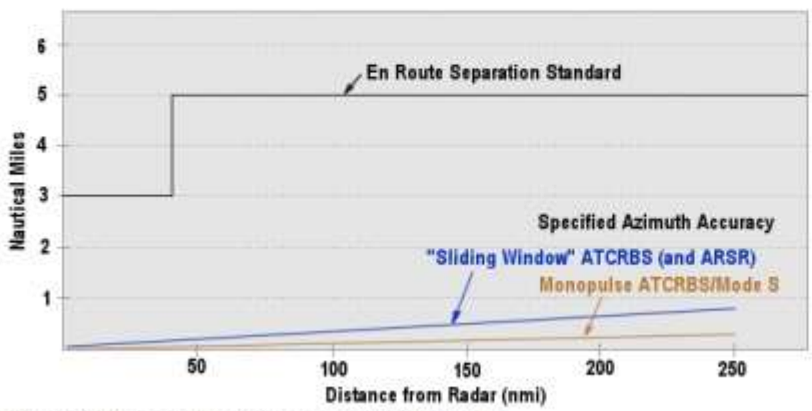


Figure 12: Dependence of the accuracy of the range (Source: MIT Lincoln Laboratory)

The stated value of required accuracy represents the uncertainty of the reported value with respect to the true value and indicates the interval in which the true value lies with a stated probability. The recommended probability level is 95 per cent, which corresponds to 2 standard deviations of the mean for a normal (Gaussian) distribution of the variable. The assumption that all known correction are taken into account implies that the errors in the reported values will have a mean value (or bias) close to zero.
Any residual bias should be small compared with the stated accuracy requirement. The true value is that value which, under operational conditions, characterizes perfectly the variable to be measured or observed over the representative time, area and/or volume interval required, taking into account siting and exposure.

Radar Resolution
The target resolution of radar is its ability to distinguish between targets that are very close in either range or bearing. Weapons-control radar, which requires great precision, should be able to distinguish between targets that are only yards apart. Search radar is usually less precise and only distinguishes between targets that are hundreds of yards or even miles apart. Radar resolution is usually divided into two categories; range resolution and angular (bearing) resolution.

Angular Resolution
Angular resolution is the minimum angular separation at which two equal targets at the same range can be separated. The angular resolution characteristics of a radar are determined by the antenna beam width represented by the -3 dB angle Θ which is defined by the half-power (-3 dB) points. The half-power points of the antenna radiation pattern (i.e. the -3 dB beam width) are normally specified as the limits of the antenna beam width for the purpose of defining angular resolution; two identical targets at the same distance are, therefore, resolved in angle if they are separated by more than the antenna beam width. An important remark has to be made immediately: the smaller the beam width Θ, the higher the directivity of the radar antenna, the better the bearing resolution.

Figure 13: angular resolution

The angular resolution as a distance between two targets depends on the slant-range and can be calculated with help of the following formula:

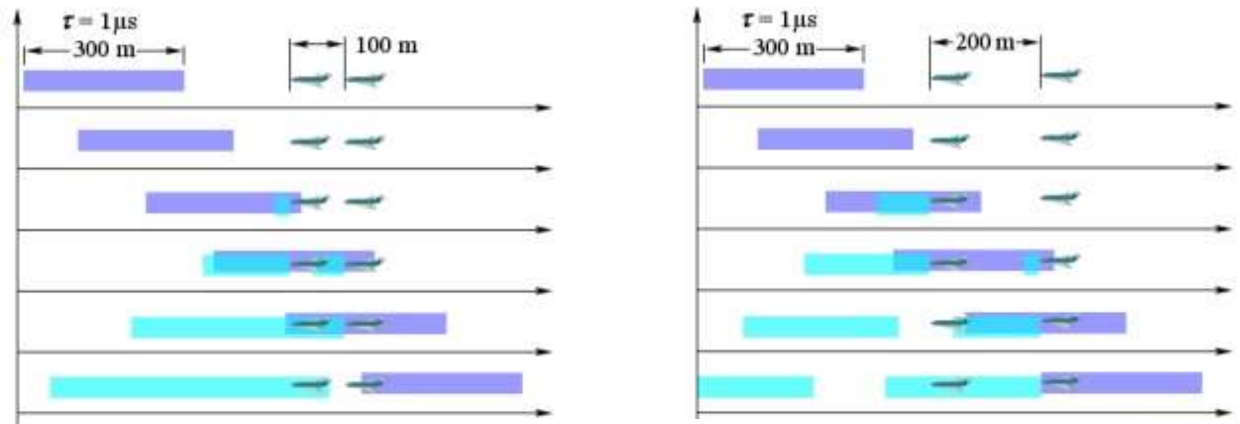
$$S_A \leq 2R \cdot \sin\frac{\Theta}{2} \quad [m]$$

Θ = antenna beam width (Theta)
S_A = angular resolution as a distance between the two targets
R = slant range aims - antenna

Range Resolution
Range resolution is the ability of a radar system to distinguish between two or more targets on the same bearing but at different ranges. The degree of range resolution depends on the width of the transmitted pulse, the types and sizes of targets, and the efficiency of the receiver and indicator. Pulse width is the primary factor in range resolution. A well-designed radar system, with all other factors at maximum efficiency, should be able to distinguish targets separated by one-half the pulse width time. Therefore, the theoretical range resolution of a radar system can be calculated from the following formula:

$$S_r = \frac{c_0 \cdot \tau}{2} \quad [m]$$

c_0 = speed of light
τ = transmitters pulse width
S_r = range resolution as a distance between the two targets



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$$S_r \geq \frac{c_0}{2B_{tx}} \quad [m]$$

c_0 = speed of light
B_{tx} = band width of the transmitted pulse
S_r = range resolution as a distance between the two targets

Resolution Cell
The range and angular resolutions lead to the resolution cell. The meaning of this cell is very clear: unless one can rely on eventual different Doppler shifts it is impossible to distinguish two targets which are located inside the same resolution cell. The shorter the pulse with τ (or the broader the spectrum of the transmitted pulse) and the narrower the aperture angle are, the smaller the resolution cell, and the higher the interference immunity of the radar station is.

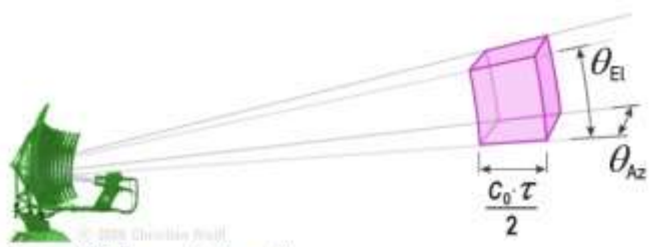


Figure 16: The resolution cell

Theoretical Maximum Range Equation

The radar equation represents the physical dependences of the transmit power, that is the wave propagation up to the receiving of the echo-signals. Furthermore one can assess the performance of the radar with the radar equation. The received energy is an extremely small part of the transmitted energy. How small is it?

$$P_{rx} = P_{tx}\left[\frac{G^2 \cdot \lambda^2 \cdot \sigma_t}{(4\pi)^3 \cdot R^4 \cdot L_s}\right]$$

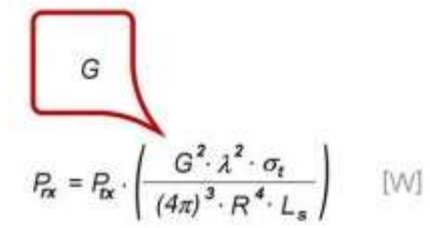
The radar equation relates the important parameters affecting the received signal of radar. The derivation is explained in many texts1 . Now we want to study, what kinds of factors are expressed in this radar equation.

Ptx is the peak power transmitted by the radar. This is a known value of the radar. It is important to know because the power returned is directly related to the transmitted power.

Prx is the power returned to the radar from a target. This is an unknown value of the radar, but it is one that is directly calculated. To detect a target, this power must be greater than the minimum detectable signal of the receiver.

Antenna Gain

The antenna gain of the radar is a known value. This is a measure of the antenna's ability to focus outgoing energy into the directed beam.



$$P_{rx} = P_{tx} \cdot \left(\frac{G^2 \cdot \lambda^2 \cdot \sigma_t}{(4\pi)^3 \cdot R^4 \cdot L_s}\right)$$

$$G = \frac{\textit{maximum radiation intensity}}{\textit{average radiation intensity}}$$

Antenna gain describes the degree to which an antenna concentrates electromagnetic energy in a narrow angular beam. The two parameters associated with the gain of an antenna are the directive gain and directivity. The gain of an antenna serves as a figure of merit relative to an isotropic source with the directivity of an isotropic antenna being equal to 1. The power received from a given target is directly related to the square of the antenna gain, while the antenna is used both for transmitting and receiving.

- The antenna gain increases the transmitted power in one desired direction.
- The reference is an isotropic antenna, which equally transmits in any arbitrary direction.

For example, if the focused beam has 50 times the power of an omni directional antenna with the same transmitter power, the directional antenna has a gain of 50 (or 17 Decibels).

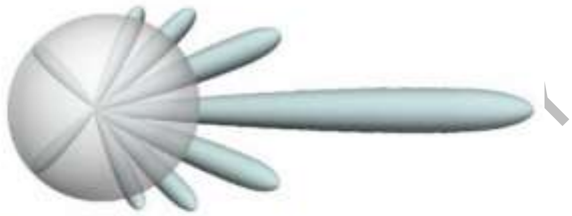


Figure 16: Pattern of a highly directional antenna compared with a ball-shaped isotropic pattern

Radar Cross Section

The size and ability of a target to reflect radar energy can be summarized into a single term, σt , known as the radar crosssection RCS, which has units of m². If absolutely all of the incident radar energy on the target were reflected equally in all directions, then the radar cross section would be equal to the target's cross-sectional area as seen by the transmitter. In practice, some energy is absorbed and the reflected energy is not distributed equally in all directions. Therefore, the radar cross-section is quite difficult to estimate and is normally determined by measurement.

The target radar cross sectional area depends of:

- the airplane’s physical geometry and exterior features,
- the direction of the illuminating radar,
- the radar transmitters frequency,
- used material types of the reflecting surface.

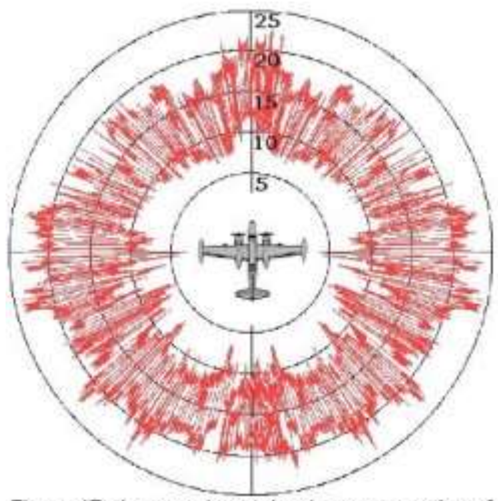


Figure 17: the experimental radar cross section of the B-26 aircraft at 3 GHz frequency as a function of azimuth angle (after Skolnik)

Free-space Path Loss

R is the target range of the term in the equation. This value can be calculated by measuring the time it takes the signal to return. The range is important since the power obtaining a reflecting object is inversely related to the square of its range from the radar.

Free-space path loss is the loss in signal strength of an electromagnetic wave that would result from a line-of-sight path through free space, with no obstacles nearby to cause reflection or diffraction. The power loss is proportional to the square of the distance between the radars transmitter and the reflecting obstacle. The expression for free-space path loss actually encapsulates two effects. Firstly, the spreading out of electromagnetic energy in free space is determined by the inverse square law.

The intensity (or illuminance or irradiance) of linear waves radiating from source (energy per unit of area perpendicular to the source) is inversely proportional to the square of the distance from the source as shown in Figure 18. An area of surface A1 (as of the same size as an area of surface A2) twice as far away, receives only a quarter of the energy SA1. The same is true for both directions: for the transmitted, and the reflected signal. So this quantity is used as squared in the equation

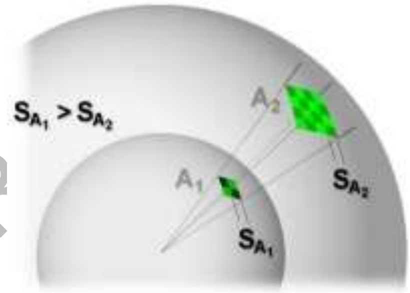


Figure 18: Non-directional power density diminishes as geometric spreading of the beam.

Transmitters Power

The more transmitted power, the more power of range, but: Note this fourth root! To double the maximum range you must increase the transmitted power 16-fold! The inversion of this argument is also permissible: if the transmit power is reduced by 1/16 (e.g. failures into two of 32 transmitter modules), then the change on the maximum range of the radar set is negligible in the practice: 4 4 15 16 0.9375 0.982 2% = = < .

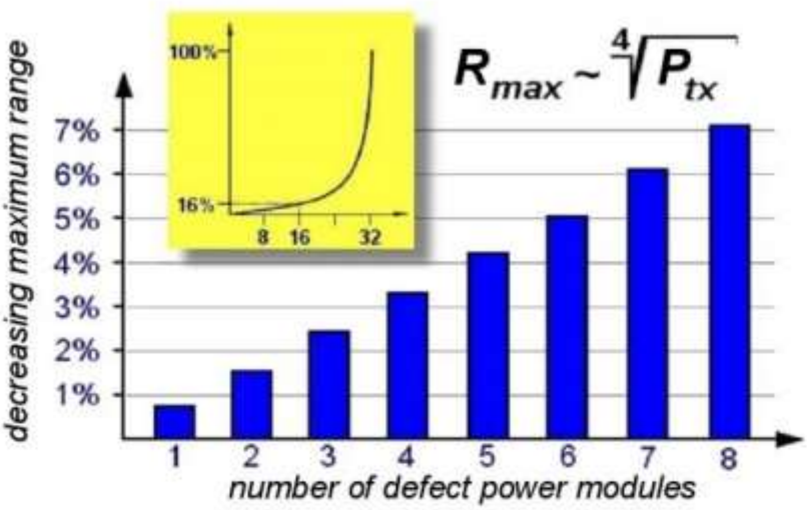


Figure 19: Decreased maximum range by defect or missing power modules in a solid state

1.2- Magnetic Safe Distance

.1- Explain the importance of not storing radar spare nearer to magnetic compasses than the specified safe distance.

Radar is an acronym that stands for Radio Detection And Ranging. It is a system which uses electromagnetic waves – specifically radio waves – to determine the range and direction of both moving and fixed objects in the surrounding area.

A ship's radar equipment has three major components; the generator itself, the monitoring screen, usually on the ship's bridge, and the antenna or scanner, usually mounted high up on the superstructure. The radar antenna transmits pulses of radio waves almost horizontally in a narrow beam as the antenna rotates.

The waves will bounce off any object in their path and a small portion of the wave's energy will return to the antenna for interpretation. When the ship is entering ports the radio waves will encounter dock buildings and equipment such as cranes, gantries etc. The beam will not normally spread down to pick up the ship superstructure or deck.

Type of Radiation

Radiation has a wide range of energies that form the electromagnetic spectrum. The spectrum has two major divisions: non-ionizing radiation and ionizing radiation.

Marine Radar Radiation

Marine radar systems operate in the high radio frequency (RF) and microwave range. Unlike X-rays and nuclear radiation the emissions from marine radar are non-ionizing radiation and do not penetrate the human body but can cause heating of the surface, particularly of the skin and eyes (cornea).

Safe Working Distances

The Canadian Coast Guard has completed calculations on both rotating and fixed scanning antennas which are commonly used in our ports. They concluded that: When a scanning antenna is rotating the safe working distance is: 0.2 meters away from the antenna.

Since a rotating antenna only radiates in a fixed place for a brief moment at a time there is less danger of continuous exposure over a long period. The safe working distance will increase to 6 meters if the radar scanning antenna is transmitting while in a stationary position. However, this will only occur if technicians have intentionally locked the antenna in place. Modern technology prohibits a radar scanning antenna from transmitting while stationary.

It is important that the spares of radar not to be near of the magnetic compass because can interference with the magnetic campus of the magnetic needle causing disorientation and given error in the lectures.

1.3- Radiation Hazards and precautions

.1 state the safety precaution necessary in the vicinity of open equipment and the radiation hazard near antennae and open waveguides.

RADIATION HAZARDS

Much of your radar gear (if labeled correctly) will have radiation hazard (RADHAZ) warnings attached. These labels indicate a radiation hazard producing RF electromagnetic fields intense enough to actuate electro-explosive devices, cause spark ignition of volatile combustibles, or produce harmful biological effects in humans.

You will probably not be able to eliminate the hazards caused by normal operation of your radar equipment. Therefore, you will need to minimize them during certain evolutions. The most effective way to reduce radiation hazards is to shut down equipment when possible or to locate equipment so that radar main beams do not illuminate ordnance, personnel, or fuels.

HAZARDS OF ELECTROMAGNETIC RADIATION TO ORDNANCE

During on-loading or off-loading of ammunition, there is a danger that RF electromagnetic fields could accidentally activate electro-explosive devices (EEDs) or electrically-initiated ordnance. This is a very real hazard to the ordnance, the ship, and the crew.

Usually is required that radars are to be secured. When you are in port and must conduct any radar maintenance requiring rotating the antenna or radiating, always coordinate your actions with Base Operations. Conditions anywhere in the area could be affected by your radar. Even if you just want to radiate a short period for an operational test, check with the OOW.

HERF—HAZARDS OF ELECTROMAGNETIC RADIATION TO FUELS

The HERF program was developed to protect fueling operations. During fueling operations, RF electromagnetic fields with a large enough intensity could produce a spark that could ignite the volatile combustibles. Therefore, certain radars may need to be shut down during fueling operations. Check your HERF publications for specific details.

HERP—HAZARDS OF ELECTROMAGNETIC RADIATION TO PERSONNEL

The HERP program was developed to protect personnel from RF electromagnetic radiation. Anywhere a radar or transmitter is operating, there is a danger that the RF electromagnetic fields may produce harmful biological effects in humans exposed to them. The following paragraphs identify the typical hazards and the steps you can take to minimize them.

SAFE LIMITS.—

Safe limits are based on the power density of the radiation beam and the exposure time of the human body. Table 4-2 identifies safe limits associated with common electronics equipment. It is an example of tables found in NAVSEA

Table 4-2—NAVSEA OP 3565 Volume I, Table B1, Personnel Hazards from Continuous or Intermittent Exposure to Main Beam Radiation

TRANSMITTER	MODE	FIXED BEAM HAZARD			MOVING BEAM		
		DISTANCE		MAX. EXP. TIME(3)	PERSONNEL HAZARD	DISTANCE	
		METERS	FEET			METERS	FEET
SHIPBOARD AND SHORE STATION EQUIPMENT (Continued)							
AN/SPS-37A		14	45	8	NO	-	-
AN/SPS-29		15	50	9	NO	-	-
AN/SPS-39,A		120	400	1	NO	-	-
AN/SPS-40,A,B		18	60	1	NO	-	-
AN/SPS-41		NO HAZARD		6	NO	-	-
AN/SPS-42		55	180	1	NO	-	-
AN/SPS-43		21	70	6	NO	-	-
AN/SPS-43A		14	45	6	NO	-	-
AN/SPS-45		14	46	0	NO	-	-
AN/SPS-46		NO HAZARD		6	NO	-	-
AN/SPS-48**		250	840	0	NO	-	-
AN/SPS-49		61	200	1	NO	-	-
AN/SPS-51		NO HAZARD		6	NO	-	-
AN/SPS-52		120	440	0	NO	-	-
AN/SPS-53,A,E		NO HAZARD		6	NO	-	-
AN/SPS-55		8	25	6	NO	-	-
AN/SPS-57		NO HAZARD		6	NO	-	-
AN/SPS-58		NO HAZARD		6	NO	-	-

RF BURNS.—

Voltages of enough potential to cause a burn injury can be induced on metallic items from nearby transmitting antennas. However, there has to be actual physical contact for the burn to occur. You can help prevent contact by ensuring that warning signs are placed properly and obeyed.

Precautions: During normal operations, personnel can easily avoid most hazards if the hazards are labeled properly. However, during maintenance, some hazards must be eliminated by specific, planned actions, such as those listed below. Using all safety precautions is the personal responsibility of the technician.

Tag- OUT: Hanging a proper tag can save your life. Using tags improperly or not at all will eventually put you, maybe your best buddy, maybe your
whole crew, in a Navy mishap report. Ensure that become familiar with the hazards associated with your required tags are installed properly and observed fully.

MAN-ALOFT CHITS.— Man-Aloft chits protect you from RF hazards when you are working on radar antennas. If the chit is run properly, the operations on your ship and any ship next to you are modified to keep you safe. Heed the requirements and follow the procedures.

EQUIPMENT SAFETY DEVICES.— Devices built into equipment, such as cut-off switches on antennas, are for your safety. A cut-off switch, when set, will keep you out of danger. It will prevent someone from rotating the antenna from a remote location. But, you, the technician, have to set the cut-off switch for it to be of any use. Equipment safety devices are there for your protection. Use them!

Everywhere will be communications and radar equipment that produces an Electromagnetic Radiation Environment (EME). And, there will always be electromagnetic radiation hazards introduced by operating this equipment. To be safe, become familiar with the hazards associated with the equipment.

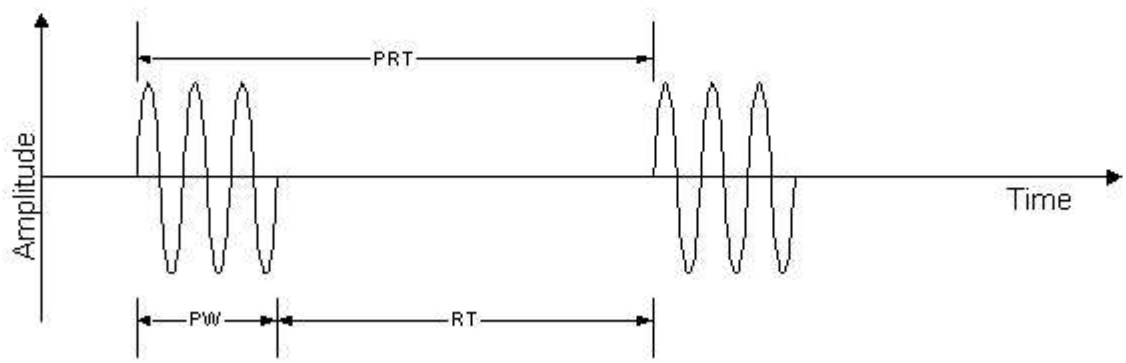
ENERGIZED EQUIPMENT You may have to work on energized equipment on a hectic bridge, in a crowded CIC, or in a cramped radar equipment room. These are not ideal safety environments. As these spaces are maintained by various people, always check the rubber matting around your equipment. Also check other protective equipment, such as rubber gloves and shorting probes before using them.

MAN-ALOFT As we mentioned earlier, when you work aloft on radar antennas, your man-aloft chit protects you from the RF radiation hazards. But, you also need to be protected from falling. Do the required PMS for safety harnesses every time you use the harness. And remember, even a good harness can't save you unless you use it right. When you go up the mast attach your harness properly so you can't free fall to the deck. Attach a line to any tools you carry up, so they are unable to fall freely. Set the cut-off switches for any antennas along your way

1.4 – Factors of Radar equipment affecting radar detection

.1- State the relationship between maximum range and pulse recurrence frequency.

A radar pulse train is a type of amplitude modulation of the radar frequency carrier wave, similar to how carrier waves are modulated in communication systems. In this case, the information signal is quite simple: a single pulse repeated at regular intervals. The common radar carrier modulation, known as the pulse train is shown below.



Minimum Range

The minimum range, R min, is defined by the shortest distance at which, using a scale of 1.5 or 0.75 nm, a target having an echoing area of 10 square meters is still shown separate from the point representing the antenna position. It is mainly dependent on the pulse length, antenna height, and signal processing such as main bang suppression and digital quantization. It is good practice to use a shorter range scale as far as it gives favorable definition or clarity of picture. The IMO Resolution A. 477 (XII) and IEC 936 require the minimum range to be less than 50m.

Maximum Range
The maximum detecting range of the radar, Rmax, varies considerably depending on several factors such as the height of the antenna above the waterline, the height of the target above the sea, the size, shape and material of the target, and the atmospheric conditions. Under normal atmospheric conditions, the maximum range is equal to the radar horizon or a little shorter. The radar horizon is longer than the optical one about 6% because of the diffraction property of the radar signal. It should be noted that the detection range is reduced by precipitation (which absorbs the radar signal).

.2 States the relationship between minimum range and transmitted energy (power and pulse length)

The power supply of a modern radar is critical to its efficient operation. Its job is to take whatever source of direct current (DC) is available from the ship's electrical supply, remove any of the lumps or bumps in it, regulate varying voltage to the optimum for the radar set, and feed the other functions with this source of stable, conditioned power. This allows the ship's power to be higher or lower than the optimal voltage for the radar. It will result in a greater current draw from a lower voltage supply and a lesser current demand from a higher voltage source.
The steady flow of conditioned power is fed into the pulse forming network function of the radar set. Imagine a hydroelectric dam with a river running into it that has a constant steady flow of water. Located at the dam itself there is a floodgate which can be opened and closed to allow a huge surge of water to escape downstream. The flow of water in from the river will determine how much water and how often a surge may be released. The master timer function controls the opening and closing of the floodgate, allowing a lot of water through occasionally or a lesser amount more often, always equalling the input of new water from the river.
That is how the pulse-forming network operates. With its careful design of electrical capacitors and inductors, the network not only accumulates the steady flow of low voltage power, it is able to release it at a high voltage whenever it is commanded by a trigger pulse from the master timer function. A long time between triggers sends an equally long surge of high voltage current to the transmitter, a shorter spaced trigger pulse reduces the length of the surge, but not its sharp shape or high voltage, usually in the range of 25 kilovolts (thousands of volts - kV).
The surge of high voltage power from the pulse-forming network flows directly to the heart of the transmitter function, the magnetron tube. When the proper high voltage of electricity is applied to a magnetron it produces a steady output of radio frequency energy as long as the high voltage pulse of DC power is applied to it. It is this output of RF energy that forms the radar's shout, which is fed directly to the antenna where it is shaped into the narrowest beam possible.

Most of the smaller recreational marine radars transmit a 2 kilowatt (2 kW) pulse, however some are capable of transmitting with 4 kW RF power output. While the focus in this course is with 2 kW of transmitter power, the theory applies equally well to radar sets with 4 kW or more power output.

Characteristics of a radar pulse

There are a number of trade-offs in trying to reach the maximum effectiveness of a radar pulse. The most obvious is cost versus results. Superior results are accompanied by superior costs. However, when the required transmitter output power has been determined, and the antenna design and size selected, there are still two variables which can be used to optimize the transmitted pulse. They are the length of time the transmitter will transmit, called the pulse width (PW) and the number of times per second this will occur, called the pulse repetition frequency (PRF). The following paragraphs discuss the interrelationships between all of these factors.

Pulse Width (PW)

The transmitter delivers its power out at one level, 2kW. The length of time the transmitter generates energy can be increased to ensure "illumination" of a target at maximum range, and help to receive a strong enough echo. This time interval is referred to as the pulse width (PW). Conversely, the amount or pulse width of the energy needed for shorter ranges can be decreased by transmitting more frequently, as the range decreases. In a typical marine radar, you will find three transmitter ranges. One is used for long range surveillance, one for medium ranges and a short range setting for close-in manoeuvring. Note that these are "transmitter" output settings. Most modern displays allow you to select more detailed range display settings within these main transmitter PW groups. Typical PWs for radar ranges up to 48 NM is 0.7µsec. The medium range setting is usually about 0.25 µsec and the short range PW is near 0.08 µsec long.

Pulse Recurrence Frequency (PRF)

The second characteristic of the transmitted signal is the number of these pulses that are transmitted in one second. This is referred to as the Pulse Recurrence Frequency (PRF). The greater the distance that you want a radar to see, the longer the time you have to pause between pulses to allow the receiver to "listen". While this constraint is not a critical factor within the short ranges of a small marine radar, it can influence the differences of available PRFs you might find between smaller range models.

A primary objective in the design of recreational radar is always to obtain the lowest possible power consumption. For any desired transmitter power, the longer the transmitter must transmit, the more DC current has to be supplied to the modulator's pulse forming network. Radar's Pulsed Wave method of operation caters ideally to this need for economy of power consumption. Consider this: for long ranges we need a lot of power, for short ranges we need much less power. We can achieve this by transmitting a long pulse a few times and get a good result over a longer range. Similarly, a shorter pulse transmitted a lot of times will get a better result over shorter ranges.

Both the fewer long pulses and the many short pulses can be obtained from a modest, steady flow of DC current between the power supply and the modulator! This is how a 2

kW radar only consumes about 35 watts to 40 watts of 12v DC power. From the specifications of our theoretical example of a typical radar we find:
a) long range - PW is 0.7 µsec, and PRF is 750 Hz (pulses per sec);
b) medium range - PW is 0.25 µsec, and PRF is 1500 Hz; and,
c) short range - PW is 0.08 µsec, and PRF is 2250 Hz.

.3- State the relationship between minimum range and pulse length

RADAR PULSE CHARACTERISTICS

Radar pulses travel at the speed of light (186,000miles per second). Thus, the distance to a target caneasily be calculated by monitoring a pulse's elapsedtime from transmission un til its return. Half thedistance traveled by the pulse determines the target'srange from the antenna.

Pulse Length

Pulse length (or pulse duration) is themeasurement taken from the leading to trailing edge ofa pulse and is a good indicator of the amount of powercontained within the pulse (fig. 2-7). Generally, longerpulses emitted from a radar return more power, thusincreased target information and data reliability.Longer pulses have the disadvantage in that fine detailswithin the return echo may be lost. Pulse length isusually expressed in microseconds, but is alsomeasured in kilometers. The WSR-88D incorporates avariable pulse length that may be as short as 1.57microseconds (1,545 feet). Important aspects ofaradarpulse include minimum r ange, range resolution, andpulse repetition frequency.

MINIMUM RANGE.—

Pulse length determinesa radar's minimum range or how close a target can getto the antenna without adversely affecting operations.Minimum radar range is defined as any distancegreater than one-half the pulse length. In other words,targets more than one-half pulse length from the antenna can be correctly processed, while approachingtargets that get too close pose serious problems. Iftargets come within one-half pulse length or less of theantenna, the pulse's leading edge will strike the targetand return **before** the radar can switch into its receivemode. Some portion of the return energy is lost and theradar may become confused and discard the pulse.

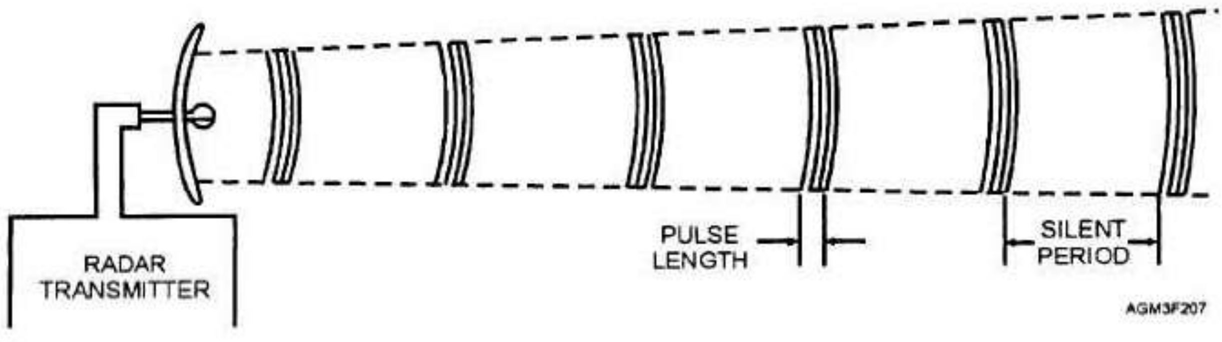


Figure 2-7.—Radar Pulses

RANGE RESOLUTION.

A radar's resolution is its ability to display multiple targets clearly and separately. Range resolution refers to targets oriented along the beam axis as viewed from the antenna's position. Longer pulses have poorer range resolution. Targets too close together lose definition and become blurred. They must be more than one-half pulse length apart or they will occupy the pulse simultaneously and appear as a single target.

.4- Explain the effect on bearing and range accuracy of beam width, heading marker errors, centring error, yawing, parallax, variable range marker, gyro error.

In a marine radar system a single antenna (known as the scanner or aerial) is used for both transmission and reception. It is designed in such a way. As to focus the transmitted energy in a beam which is very narrow in the horizontal plane. The angle within which the energy is constrained is called the horizontal beamwidth.

Beamwidth

It must have a value of not more than 2.5° if it is to comply with IMO Performance Standards for Navigational Radar Equipment. There is an exception for high speed craft in that the horizontal beamwidth can be up to 4° for S-band radar only. However, horizontal beamwidths of less than 2° are commonplace and shipborne civil marine radars are available with values as low as 0.75°. The reception property of the antenna is such that it will only detect energy which has returned from within the angular limits of the horizontal beamwidth. It follows from the directional characteristic of the antenna that only those targets which lie in the direction of the beam will appear on the trace. Thus a single trace represents the ranges of targets lying along a specific line of bearing.

Heading marker error

In general, a bearing is the angle between the direction of a chosen reference and that of an object of interest. On a PPI display the fundamental reference is the instantaneous direction of the observing vessel's head. As the axis of the horizontal beam crosses the ship's fore-and-aft line in the forward direction, a set of contacts is closed, producing a pulse of a few milliseconds duration.

The IMO Performance Standards require that the line be able to be aligned to within 0–1°. Clearly, because both targets and the heading marker are produced by a brightening of the spot, there is a danger that a target may be masked if it lies in the direction of the heading marker. The specification recognizes this danger by requiring that there is a provision for switching the heading marker off. However, the provision must be such that the heading marker cannot be left in the off position. Normally this requirement is complied with by the use of a spring-loaded switch which is biased in the on position. The danger of the heading marker being left in the off position is that, in the absence of the correct reference, an erroneous reference might be used inadvertently. The appearance of the heading marker confirms the orientation of the picture and consequently whether the bearings are relative or true.

Centring error accuracy

In a radial-scan PPI (plan position indicator) display, the spot produces the trace in the form of a radial line whose origin is (normally) placed at the centre of the circular screen.

An echo return from a target is used to produce an increase in the brilliance of the moving spot. To this end, a competent observer will, in setting up the display, adjust the brilliance of the trace so that it is barely visible hence maximizing the probability that small increases in brilliance will be detected. Within certain limits the brightening of the trace by a target return is a function of the strength of the received echo. As with the A-scan display, the origin of the trace coincides with the instant of transmission of the pulse and the duration of the trace is the selected timebase. Thus a target which lies at the maximum range represented by the selected scale will appear at the edge of the screen.

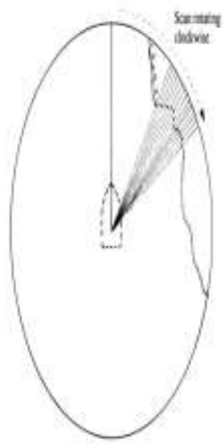
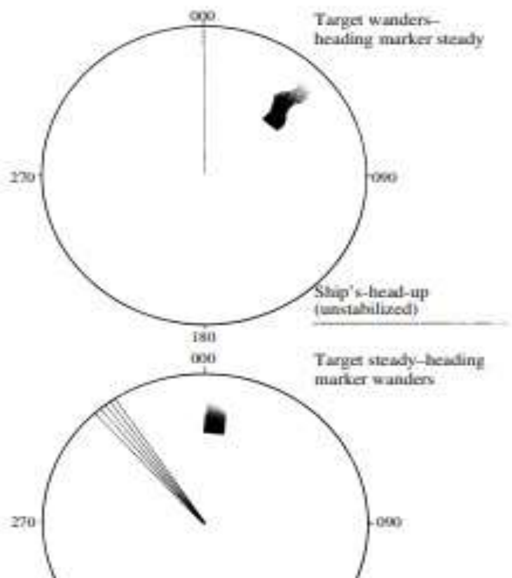


Figure 1.3 The radial-scan PPI display

When the spot has completed the trace, the brilliance is automatically reduced to zero and the spot flies back to the origin to await the incidence of the next transmission. At this event it initiates a further line which, in contrast with the A-scan case, is drawn along a path which is separated from the previous one by a small angle (about one tenth of a degree). In a PPI system the antenna rotates continuously and automatically in a clockwise direction, generating approximately some 3600 lines in one complete rotation

Yawing

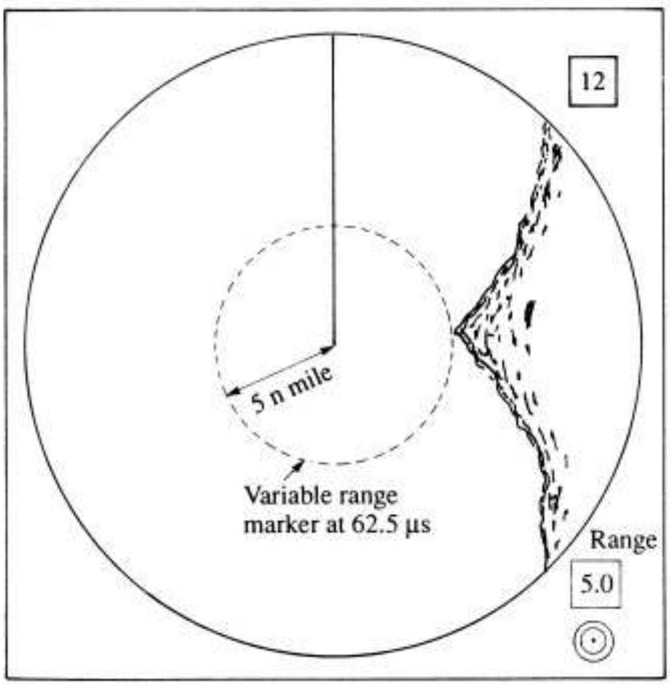
In ideal conditions the ship's heading would coincide at all times with the chosen course; in practice, due to the effect of wind and sea, the ship will 'yaw' about the correct heading. On a display using an un stabilized orientation, this superimposes an angular wander on the movement of all targets (see Figure 1.12) which limits the ease and speed with which bearings can be measured. It becomes



necessary to choose an instant when the target can be intersected with the cursor or electronic bearing line and the vessel's instantaneous heading read off simultaneously, or, alternatively, to wait until the vessel is right on course. The latter is necessary because the bearings read off from this orientation are measured relative to the ship's head and must be converted to true bearings for use in collision avoidance and navigation

Variable range marker

The timing of the calibration marks can be achieved with an extremely high degree of accuracy which in turn becomes implicit in the accuracy with which the range of a target can be measured provided that its echo coincides with a mark. If the echo lies between two marks, some form of interpolation will be necessary. In some circumstances it may be that this can be done by eye, but in other cases an acceptable degree of accuracy will demand electronic assistance.
Interpolation is facilitated by the generation of a single pip, known as a variable range marker, which occurs at a selected elapsed time after transmission. The time is selected by the operation of a manual control which is also connected to some form of numerical read-out. The latter will show the number of miles of time base represented by the selected time.
In conclusion, it is clear that the precision with which the calibration marks are produced is fundamental to the accuracy of range measurement.



The variable range marker

The bearing and range can be used just in heading radar situation if the Gyro compass fail. Because the radar in unavailable to give the real true north .

.5- Explain the effect of bearing and range discrimination of beam with, spot size, plan position indication tube size, pulse length, gain.

Bearing Resolution

Bearing, or azimuth, resolution is the ability of a radar system to separate objects at the same range but at different bearings. The degree of bearing resolution depends on radar beam width and the range of the targets. Range is a factor in bearing resolution because the radar beam spreads out as range increases. A RADAR BEAM is defined in width in terms of HALF-POWER POINTS. All the points off the centerline of the beam that are at one-half the power level at the center are plotted to define beam width. When the half-power points are connected to the antenna by a curve, such as that shown in figure 1-11,the resulting angular width of the curve is called the ANTENNA BEAM WIDTH. The physical size and shape of the antenna determines beam width. Beam width can vary from about 1 degree up to 60 degrees. In figure 1-11, only the target within the half-power points will reflect a useful echo. Two targets at the same range must be separated by at least one beam width to be distinguished as two objects.

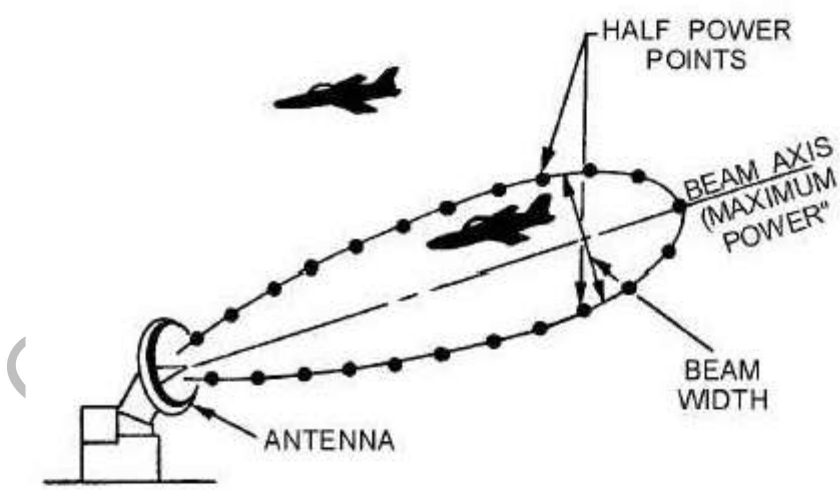


Figure 1-11.—Beam half-power points.

RANGE DISCRIMINATION:

It is the ability of the RADAR set to clearly distinguish two small targets on the same bearing at slightly different ranges. The distance between the two targets is equal to or less than ½ PL .

BEARING DISCRIMINATION:

It is the ability of the radar set to clearly extinguish two targets of the same range and slightly different bearings.Factor affecting bearing discrimination : HBW

MINIMUM RANGE:

THE PULSE LENGTH : The TR circuit prevents the TX of any signal before receiving it. Hence, the theoretical minimum range of detection is repeated by half PL in minutes.

A PL of 0.2 micro would have a range of 30 mtrs.

DEIONISATION DELAY:

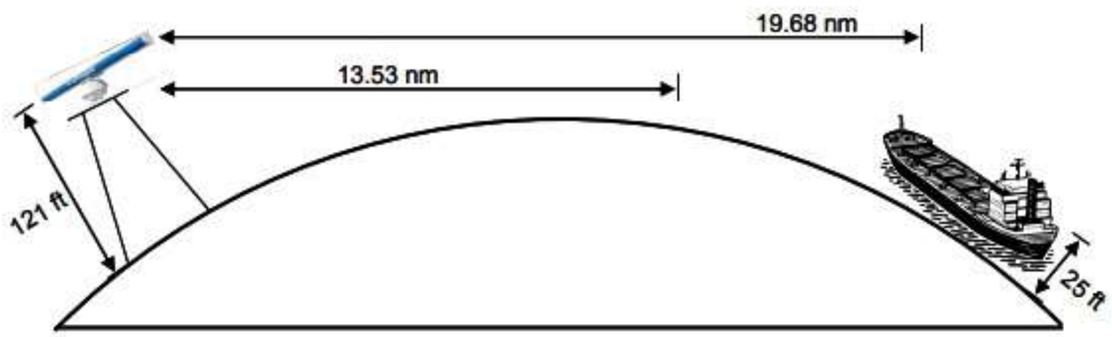
A small delay occurs in the TR cell between the completion of TX & Receiving. A delay of 0.5 microsecond would increase the minimum range a further by 7.5 mtrs.

1.5- Factor External to the radar set affecting radar detection are clearly identify. (

Numerous factors impact the effective detection range of a radar; these include atmospheric conditions, output power, antenna size, target cross section, and the radar horizon.

The radar horizon is essentially line of sight from the radar to the horizon which is limited due to the curvature of the Earth.

The distance to the horizon is calculated by multiplying the root of the antenna height in feet by 1.23 with the result in nautical miles. The maximum range to a target is calculated by adding the root of the antenna to the root of the height of the target and multiplying the result by 1.23.



Distance to the horizon with the antenna height of 121 feet:

$$(\sqrt{121ft}) * 1.23 = 13.53 \text{ nm}$$

Maximum range to detect a target with a height of 25 feet:

$$((\sqrt{121ft}) + (\sqrt{25ft})) * 1.23 = 19.68 \text{ nm}$$

The Radar Horizon is essentially the line of sight from the radar (or VHF radio) to the horizon. The transmission does not penetrate the earth, so the distance a radio can reach is limited by the curvature of the earth.

The distance to the horizon is calculated by multiplying the square root of the antenna's height in feet by 1.23 with the result in nautical miles.

(√antenna height) * 1.23 = radar horizon

In the example taken from the image above we see the ship on the right has an antenna 18ft high so:

(√18ft) * 1.23 = 5.22nm

Therefore, with enough power the antenna can transmit to a station 5.22nm away

But what if we want to make a ship-to-ship transmission?

We then need to take into account the height of both antennas, so we modify the equation like so:

The maximum range to a target is calculated by adding the square root of the height of one antena to the square root of the height of the target and then multiplying the result by 1.23. Don't forget about BEDMAS!

(√18 + √12) * 1.23 = 9.48nm

.2- Explain the effect of variation in refraction on radar detection range (super refraction, sub refraction, surface duct, elevated duct).

SUPERREFRACTION

If the atmosphere’s temperature increases with height (inversion) and/or the water vapor content decreases rapidly with height, the refractivity gradient will decrease from the standard (table 2-1). This situation is known as super refraction, and causes the radar beam to deflect earthward below its normal path (fig. 2-15, view C).Generally, radar ranges are extended when super refractive conditions exist. However, some targets may appear higher on radar than they would under standard atmospheric conditions.

Table 2-1—Refractive Conditions as a Function of N-gradient

Refractive Condition	N-gradient
Ducting	≤-48 N/thousand feet ≥-157 N/thousand meters
Superrefractive	-48 to -24 N/kft -157 to -79 N/km
Standard	-24 to 0 N/kft -79 to 0 N/km

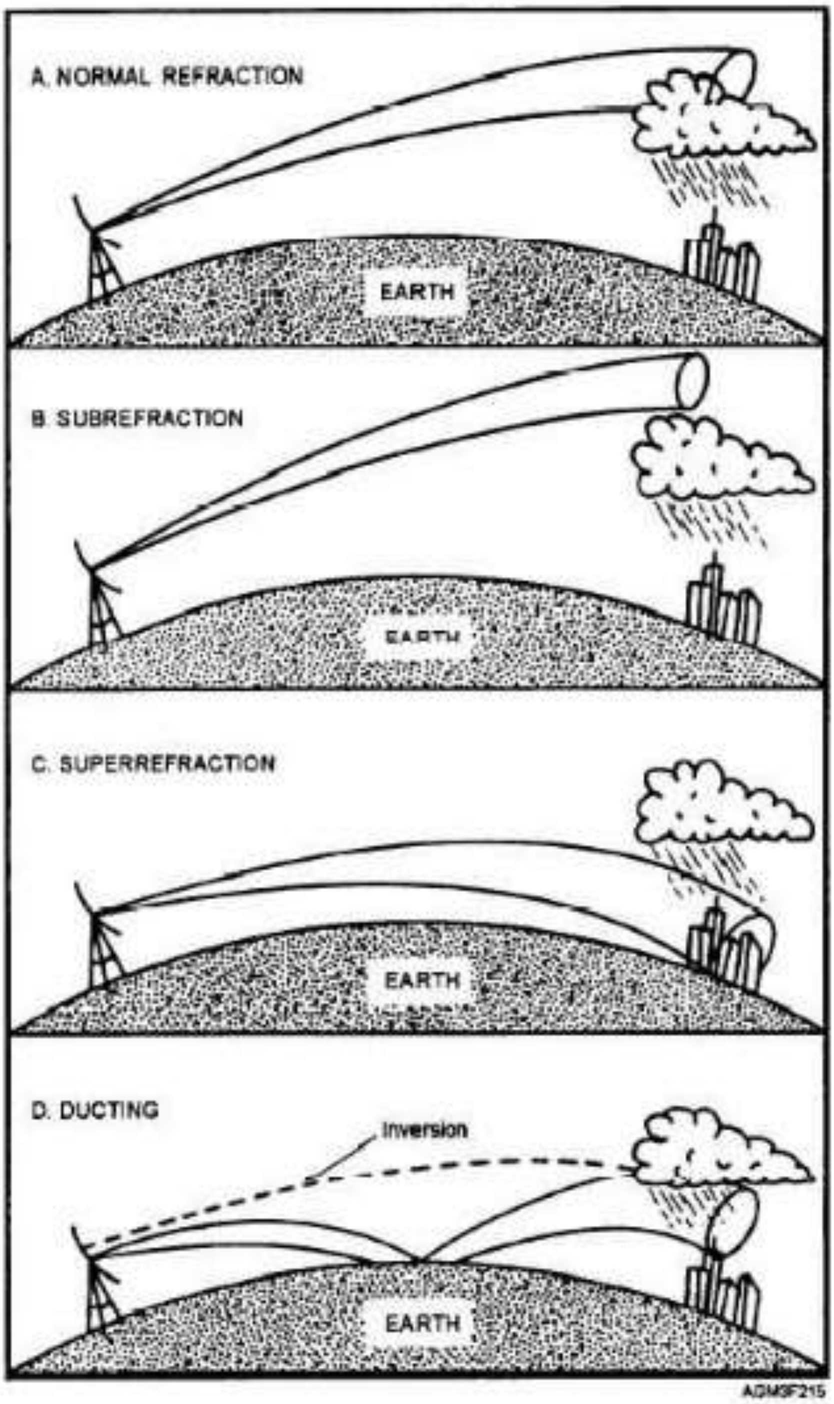


Figure 2-15.—(A) Normal refraction, (B) Subrefraction, (C) Superrefraction, (D) Ducting.

Super refraction occurs under strong inversions, which are typical in subtropical, high-pressure zones.

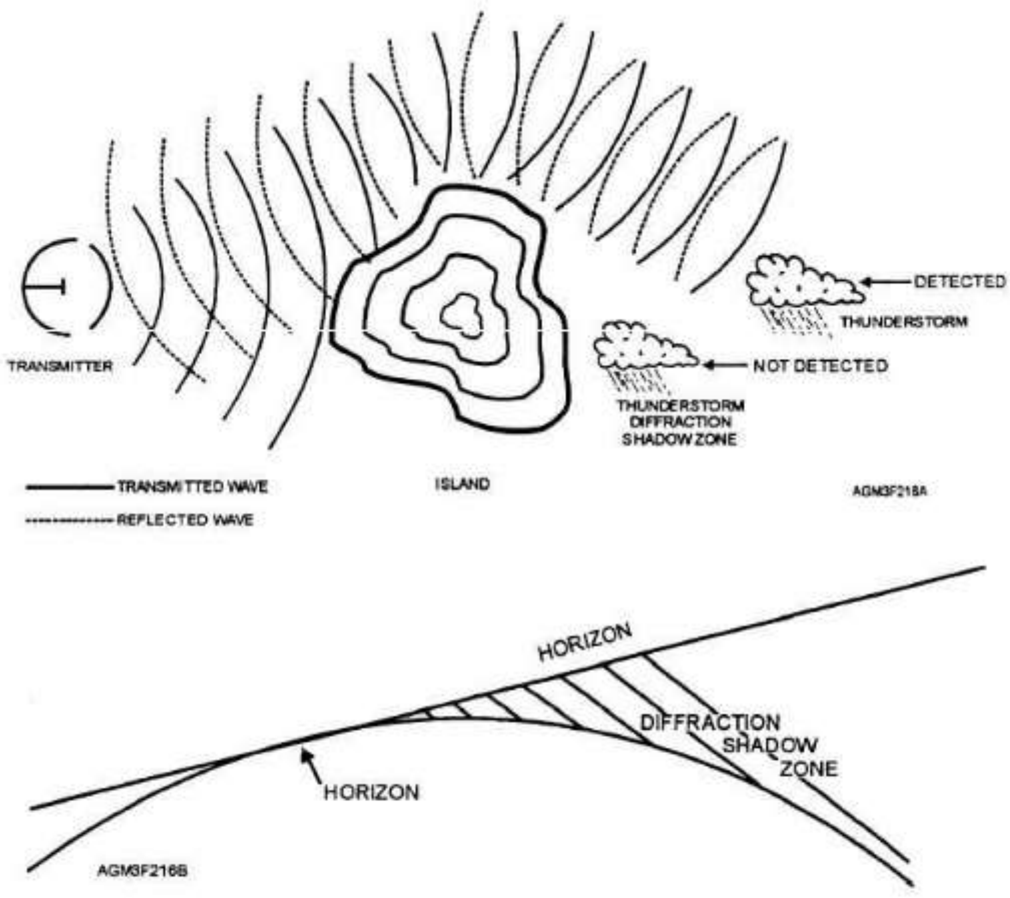
DUCTING.

In extreme cases, a very rapid decrease in the N-gradient will cause radar waves to become trapped in a layer of the atmosphere and travel abnormally long distances (table 2-l). This phenomenon is known as ducting and is a frequent occurrence when strong inversions are present. When ducting occurs, a returning pulse may display low targets from hundreds of miles away-targets that are not normally detected (fig. 2-15, view D).

This may cause an effect similar to range folding. False or exaggerated echoes are plotted where no meteorological targets exist. Keep in mind that ducting is also dependent upon the wavelength of the radar. The larger the wavelength, the deeper the layer has to be before ducting can occur.

DIFFRACTIONE

Electromagnetic waves tend to follow along the curved surface of an object. Diffraction is the process that causes waves traveling in a straight path to bend around an object or obstruction. The direction of propagating energy is changed so that it spreads into a shadow zone, as shown in figure 2-16, view (A). ln the earth-atmosphere system, diffraction occurs where the straight-line distance between the transmitter and receiver is just tangent to the earth's surface as shown figure 2-16, view (B). Generally, the lower the



frequency (
Side lobes ar

Figure 2-16.—(A) Diffraction of a radar wave front around an obstruction. (B) Radar horizon and diffraction region shadow zone.

Another factor affecting radar performance is ground clutter. Ground clutter is an unavoidable form of radar contamination. It occurs when fixed objects, such as buildings, trees, or terrain, obstruct the radar beam and produce non-meteorological echoes. Echoes resulting from ground clutter are usually exaggerated in both size and intensity and may cause radar systems to overestimate precipitation intensity near the radar. Clutter is normally found close to the antenna where the radar beam is nearest to the ground. Further out, the beam points gently skyward and overshoots most obstacles. Under certain circumstances, however, clutter may exist far away. A tall mountain range would be a good example of this. The key to dealing with ground clutter is operator awareness and experience.

.3 States the effect of precipitation on radar detection ranges)rain, hail, snow, fog)

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., and cause varying amounts of attenuation and are discussed below. Attenuation sue to these weather effects causes loss of echo strength and consequent decrease in detection ranges of targets.

Drizzle

Drizzle means small droplets of water, less 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.

Rain

Droop 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 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 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.

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 being usually less than with rain, attenuation due to hail is generally much less than with rain.

Snow

Is 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.

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.

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 reported.

.4- Identify blind areas and shadow areas, permanent blind and shadow sectors and their relationships to the antenna location.

Blind sectors.

You have been told that radar shadow always exists behind objects that reflect radar energy. Naturally then, unless your antenna is higher than any other part of your ship, it is possible that a blind sector may exist on some relative bearing due to the effect of such radar obstacles aboard your own ship as
super-structure, masts, or other antennas. If you have a blind sector you should know exactly where it is.

One way to check for blind sectors is to keep your antenna trained exactly on some steady land target while "swinging ship" through 360 degrees several times. It will be easy if your radar is a true-bearing type, since the antenna will stay on the target as the ship swings. A graph may be made using polar coordinates, showing echo height versus relative bearing of the chosen land contact. It might be useful to attach a temporary scale to the A scope to assist in determining the relative strengths of the echoes. An illustrative graph is shown in figure 3-29.

Such a graph will enable you to estimate which relative bearings are partially blind to your radar. Several graphs should be made before the final pattern is determined. If it is impossible to utilize a land echo, an approximation of the radiation pattern can be obtained by noting the relative strength of sea-return from different bearings. The sea should be fairly calm, since a heavy sea would give a false indication of the pattern; that is, greater reflection would occur from the wave fronts than from the troughs regardless of the actual radiation pattern.

From the foregoing discussion it can be seen that there is more to learning to be a to radar operator than just studying the information in books. It is going to take a lot of actual work on the apparatus itself, but operating time alone means nothing unless you get into the habit of thinking, observing, and remembering, making predictions and checking them, and looking for small details. Radar operating is an art.

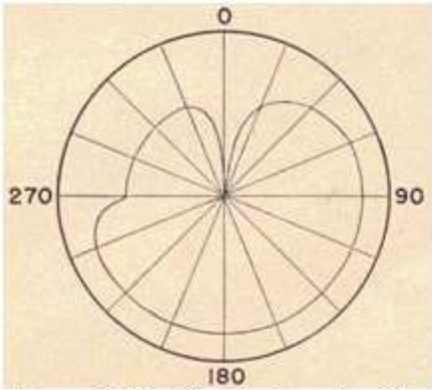


Figure 3-29. Graph showing blind sector.

In order to visualize land nearly as radar "sees" it, imagine yourself looking down on an area from a point high in the sky above it, at about the time of sunset. The beam of light from the low sun illuminates the parts of land that a radar on the same bearing would "see" but of course there will be shadows in the hollows and behind the mountains. These same areas will be in "radar shadows" and therefore not detected by the radar. So much for the points of similarity between these two pictures.

.5- States how characteristics of targets influence their detection range (aspect, shape, composition, size)

Radar Picture and Target Properties The strength of the reflected echo depends not only on the height and size of the target, but also its shape, material composition and angle at which the radio pulse strikes. The size of the target actually has little to do with the reflected echo. If the radio pulse strikes it at a right angle, even a small target will return a strong echo provided that the material is a good reflector of RF energy.

A return echo will be weak if the angle at which the radio wave strikes a target is small. For example, flat surfaces such as sandy beaches, sandbars and mudbanks have almost no area that can reflect energy back to the Radar.

Conical surfaces, such as lighthouses, generate weak return echoes because their shape diffuses most of the radiated energy. Because of their poor reflecting properties, flat or conical surfaces do not return an echo suitable for range determination. Radar sees only the near side of targets. For example, it cannot show you what is behind a sea wall or an island.

The echo of a mountain peak may appear on the Radar display as a peninsula or small island. The Radar image is not always as it seems - you should always exercise caution when interpreting the display.

Target material and reflected echo

Generally, steel objects return a very strong echo while reefs and water return weak echoes. The weakest echoes come from wood and fiberglass objects. In summary, non-metallic objects or those that are flat or conical in shape do not make good Radar targets, and the Radar may display only weak, intermittent echoes - or it may not display them at all.

TARGET CHARACTERISTICS

There are several target characteristics which will enable one target to be detected at a greater range than another, or for one target to produce a stronger echo than another target of similar size.

Height

Since radar wave propagation is almost line of sight, the height of the target is of prime importance. If the target does not rise above the radar horizon, the radar beam cannot be reflected from the target. Because of the interference pattern, the target must rise somewhat above the radar horizon.

Size

Up to certain limits, targets having larger reflecting areas will return stronger echoes than targets having smaller reflecting areas.

Should a target be wider than the horizontal beam width, the strength of the echoes will not be increased on account of the greater width of the target because the area not exposed to the radar beam at any instant cannot, of course, reflect an echo. Since the vertical dimensions of most targets are small compared to the vertical beam width of marine navigational radars, the beam width limitation is not normally applicable to the vertical dimensions. However, there is a vertical dimension limitation in the case of sloping surfaces or stepped surfaces. In this case, only the projected vertical area lying within the distance equivalent of the pulse length can return echoes at any instant.

Aspect

The aspect of a target is its orientation to the axis of the radar beam. With change in aspect, the effective reflecting area may change, depending upon the shape of the target. The nearer the angle between the reflecting area and the beam axis is to 90˚, the greater is the strength of the echo returned to the antenna.

Shape

Targets of identical shape may give echoes of varying strength, depending on aspect. Thus a flat surface at right angles to the radar beam, such as the side of a steel ship or a steep cliff along the shore, will reflect very strong echoes. As the aspect changes, this flat surface will tend to reflect more of the energy of the beam away from the antenna, and may give rather weak echoes. A concave surface will tend to focus the radar beam back to the antenna while a convex surface will tend to scatter the energy. A smooth conical surface will not reflect energy back to the antenna. However, echoes may be reflected to the antenna if the conical surface is rough.

Texture

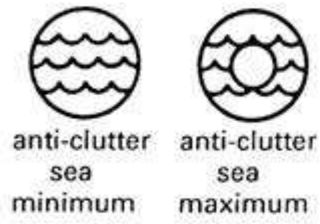
The texture of the target may modify the effects of shape and aspect. A smooth texture tends to increase the reflection qualities, and will increase the strength of the reflection, but unless the aspect and shape of the target are such that the reflection is focused directly back to the antenna, the smooth surface will give a poor radar echo because most of the energy is reflected in another direction. On the other hand, a rough surface will tend to break up the reflection, and will improve the strength of echoes returned from those targets whose shape and aspect normally give weak echoes.

Composition

The ability of various substances to reflect radar pulses depends on the intrinsic electrical properties of those substances. Thus metal and water are good reflectors. Ice is a fair reflector, depending on aspect. Land areas vary in their reflection qualities depending on the amount and type of vegetation and the rock and mineral content. Wood and fiber glass boats are poor reflectors. It must be remembered that all of the characteristics interact with each other to determine the strength of the radar echo, and no factor can be singled out without considering the effects of the others.

.6- Explain how clutter may mask targets (sea clutter, rainclutter)

Sea Clutter Control (STC)

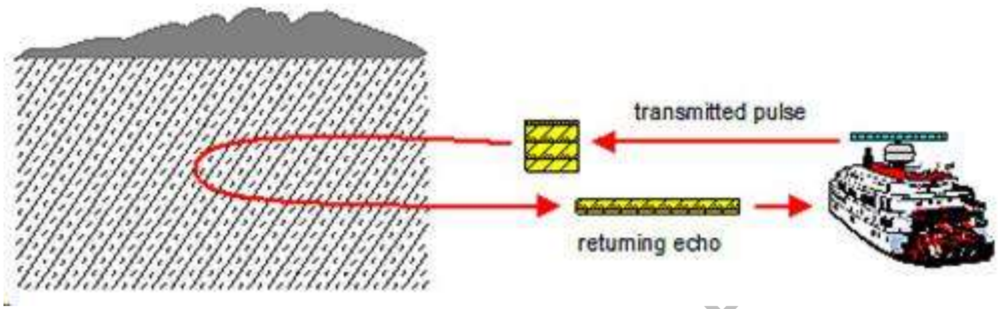


The radar beam will bounce echoes off the sea around the ship, particularly if the weather is a little rough. This result will be a bright sunburst pattern in the middle of the screen which will be more pronounced in the upwind direction. You could reduce this by turning down the gain, the down side to that solution however, is that the echoes of more distant targets will be lost as well.
The solution is the sea clutter control. It works by reducing the receiver gain for a few microseconds after each pulse is transmitted, then gradually restores it to its former level. It works very well, but its use requires care. Too much sea clutter control will result in the loss of close range targets. At sea the sea clutter control must be continually monitored and adjusted.

Rain Clutter Control (FTC)

The rain clutter control will reduce the interference on the screen due to the rain and increase the chance of seeing targets within rain showers. The effect on returning echoes from rain on the screen is usually no more than a transparent smear, looking a little like cotton wool, but it can be dense enough to conceal other echoes within the shower. In a tropical downpour however, the rain can completely block out all echoes, at times requiring the operator to stop the vessel.

The rain clutter control works by making use of the fact that the returning echo from rain is different from the returning echo of a solid object. The returning echo from rain is much longer and very much less dense than the echo from a solid object. The rain clutter circuitry works by passing on to the receiver only the leading edge of a returning echo. This does not affect the returning echo from a solid object like a ship, but drawn out, weak returning echoes from the rain however, will be weakened considerably.



In practice however all returning echoes will be affected, resulting in a reduction in strength from all returning echoes and a reduction in picture quality. Sometimes the sea clutter control may be used to better effect, to see through the rain. However, if you adopt this approach remember that close-in targets will also be lost, which may defeat the purpose.

1.6 –Factors Affecting normal observation

.1- Explain the cause and effect of interference

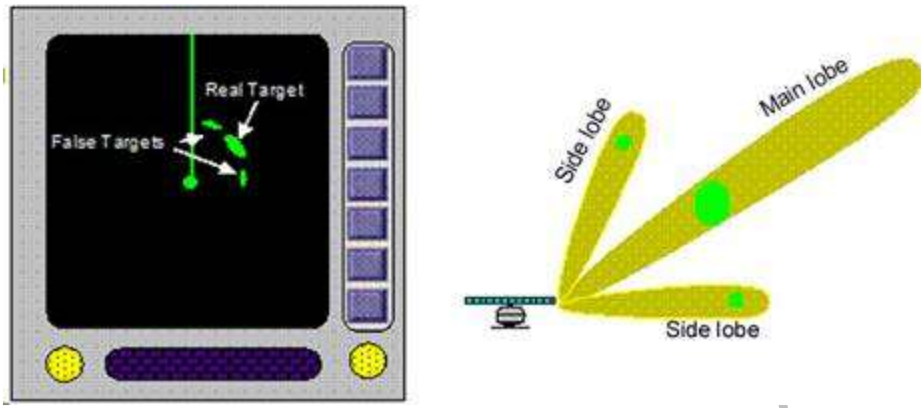
Indirect or false echoes are caused by reflection of the main lobe of the radar beam off ship's structures such as stacks and kingposts. When such reflection does occur, the echo will return from a legitimate radar contact to the antenna by the same indirect path. Consequently, the echo will appear on the PPI at the bearing of the reflecting surface. The indirect echo will appear on the PPI at the same range as the direct echo received, assuming that the additional distance by the indirect path is negligible. Characteristics by which indirect echoes may be recognized are summarized as follows:

1. Indirect echoes will often occur in shadow sectors.
2. They are received on substantially constant bearings, although the true bearing of the radar contact may change appreciably.
3. They appear at the same ranges as the corresponding direct echoes.
4. When plotted, their movements are usually abnormal.
5. Their shapes may indicate that they are not direct echoes.

.2- Explain the cause and effect of side echoes

Side echoes

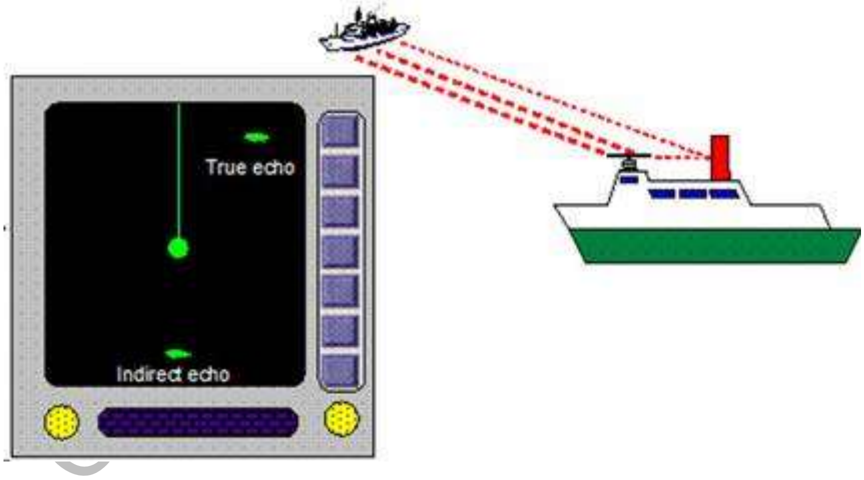
Squeezing a naturally an multi-directional radio wave into a directional radar wave is never fully achieved. Not all of the radar wave can be focused by the radar aerial into the main lobe. Some escapes into what are known as side lobes. Side echoes are caused by reflections from the side lobes of the radar beam. They are likely to appear when a target is a good radar reflector and in range of the weaker side lobes.



The true target will always be the stronger echo in the centre of the pattern. Side echoes can be removed by reducing the gain, or by using the sea clutter control.

.3 – Explain the cause and effect of indirect echoes

Indirect echoes



Indirect echoes are caused when some of the outgoing radar energy is reflected from an object close to the scanner such as a funnel or mast. The echo may return by the same path or directly to the scanner. The false echo will appear (usually intermittently) on the display at the correct range because the additional distance between the scanner and the reflecting object will be negligible, but on the bearing of the obstruction. The true target will also appear on the display at the correct range and bearing.

Indirect echoes usually occur in shadow sectors however, they can appear on bearings where there are no shadow sectors. Indirect echoes are usually associated with funnels and other large objects close to the scanner.

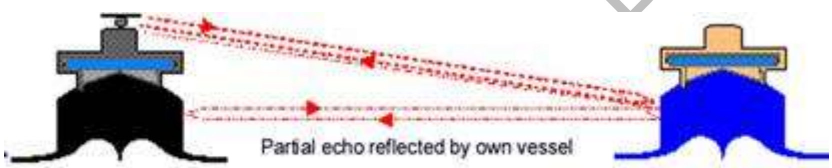
Although the bearing of the real target may change, the bearing of the deflected target will remain constant and may if the range is decreasing, appear to be on a collision course.

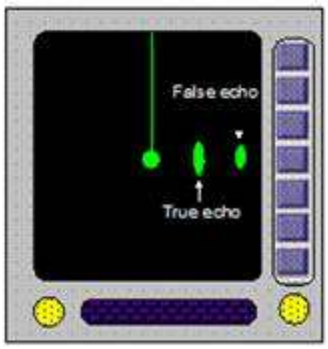
To determine if the target is an indirect echo or not, alter course about 10°, if the relative bearing of the echo remains constant, then the echo is a false one. Alternatively the gain can be reduced, or if the echo appears in a known blind sector it can be ignored.

The other form of reflected or indirect echoes uses strong targets such as buildings, bridges or large ships usually when navigating in rivers or harbours. While some of the radar beam is returned to the scanner, much of it is deflected in other directions but at close range it can produce a beam which will be reflected from the secondary target. This will show on the display on the same bearing as the strong target but at an increased range. It will also show up in its correct position so it should not be too much of a problem.

.4- Explain the cause and effect of multiple echoes.

Multiple echoes





Multiple echoes are caused when a strong echo arrives back at your vessel and bounces off it, effectively retransmitting the signal. For this to occur the other target must be large and close, and both the target, which may be a land target such as a bridge or headland or another vessel, and your ship must be good radar reflectors. The false echoes (which may be any number) will appear at multiples of the true range on the same bearing. Multiple echoes can be removed by reducing the gain.

.5- Explain the cause and effect of second trace echoes

Second trace echoes

Second trace echoes will appear at times during periods of severe super-refraction or ducting. Targets at very long range will appear at a false range on the correct bearing, on the second sweep of the timebase. In other words, an echo may return from a distant target after a second pulse has been transmitted and the receiver is open.

The higher the PRF, the more likely that second trace echoes will occur as more pulses are transmitted and the corresponding silence period is reduced. Second trace returns can usually be made to disappear by changing the range scale in use.

Other causes of false echoes

When navigating in rivers and harbours overhead power cables at close quarters can return an echo from the direction where the cable is at right angles to the radar beam, the effect on the display is a small echo which is closing on a collision course. The echo disappears when the vessel is close to the overhead cable as the radar beam is no longer in contact with the target.

.6- States the effect on radar performance of power lines and bridge crossing rivers and estuaries.

Hour-Glass Effect

Hour-glass effect appears as either a constriction or expansion of the display near the center of the PPI. The expansion effect is similar in appearance to the expanded center display. This effect, which can be caused by a nonlinear time base or the sweep not starting on the indicator at the same instant as the transmission of the pulse, is most apparent when in narrow rivers or close to shore.

.7 Explain the effect of the ship in seaway

Radar antennas are designed to provide the narrowest possible beam-width horizontally and an acceptable width vertically (about 25º). When the antenna itself is not horizontal, the power of the beam is projected downward on the low side and upward on the high side. On a sailboat sailing “on the wind” with a 17º heel (not unusual), a fixed antenna’s beam would be scanning the sky to windward, while it is beaming most of its energy into the water to leeward.

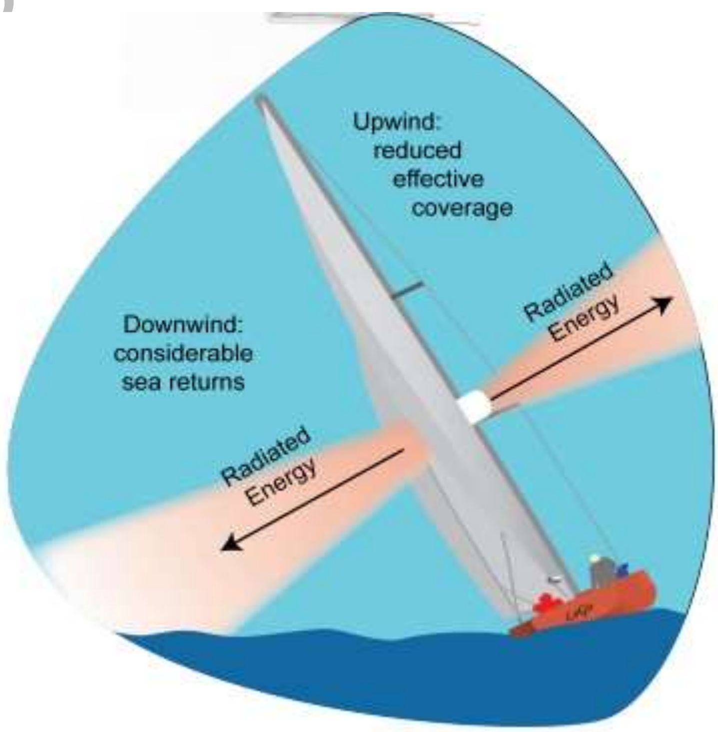


Figure 7.1 Heeling antenna

1.7- Performance Standards for Radar equipment in resolution MSC.192 (79) annex .64(67) and A.44 of MSC A.477 (XII)

ALL RADAR INSTALLATIONS

All radar installations should comply with the following minimum requirements.

3.1 Range performance

The operational requirement under normal propagation conditions, when the radar antenna is mounted at a height of 15 metres above sea level, is that the equipment should in the absence of clutter give a clear indication of:

.1 Coastlines

At 20 nautical miles when the ground rises to 60 metres

At 7 nautiCal miles when the ground rises to 6 metres .

. 2 Surface objects

At 7 nautical miles a ship of 5,000 tons gross tonnage, whatever her aspect.

At 3 nautical miles a small vessel of 10 metres in length.

At 2 nautical miles an object such as a navigational buoy having an effective echoing area of approximately 10 square metres.

3.2 Minimum range

The surface objects specified in 3.1.2 should be clearly displayed from a minimum range of 50 metres up to a range of one nautical mile, without changing the setting of controls other than the range selector.

3.3 Display

3.3.1 The equipment should without external magnification provide a relative plan display in the head-up unstabilized mode with an effective diameter of not less than:

.1 180 millimetres* on ships of 500 tons gross tonnage and more but less than 1,600 tons gross tonnage;

.2 250 millimetres* on ships of 1,600 tons gross tonnage and more but less than 10,000 tons gross tonnage;

.3 340 millimetres* in the case of one display and 250 millimetres in the case of the other on ships of 10,000 tons gross tonnage and upwards.

3.3.2 The equipment should provide one of the two following sets of range scales of display:

.1 1.5, 3, 6, 12 and 24 nautical miles and one range scale of not less than 0.5 and not greater than 0.8 nautical miles; or

.2 1, 2, 4, 8, 16 and 32 nautical miles.

3.3.3 Additional range scales may be provided.

3.3.4 The range scale displayed and the distance between range rings should be clearly indicated at all times.

.2- State require accuracy (range and bearing measurements)

3.4 Range measurement

3.4.1 Fixed electronic range rings should be provided for range measurements as follows:

.1 where range scales are provided in accordance with 3.3.2.1, on the range scale of between 0.5 and 0.8 nautical miles at least two range rings should be provided and on each of the other range scales six range rings should be provided, or

.2 where range scales are provided in accordance with 3.3.2.2, four range rings should be provided on each of the range scales.

3.4.2 A variable electronic range marker should be provided with a numeric readout of range.

3.4.3 The fixed range rings and the variable range marker should enable the range of an object to be measured with an error not exceeding 1.5 per cent of the maximum range of the scale in use, or 70 metres, whichever is the greater.

3.4.4 It should be possible to vary the brilliance of the fixed range rings and the variable range marker and to remove them completely from the display.

3.5 Heading indicator

3.5.1 The heading of the ship should be indicated by a line on the display with a maximum error not greater than plus or minus 1 degree. The thickness of the displayed heading line should not be greater than 0.5 degrees.

3.5.2 Provision should be made to switch off the heading indicator by a device which cannot be left in the "heading marker off" positfon.

3.6 Bearing measurement

3.6.1 Provision should be made to obtain quickly the bearing of any object whose echo appears on the display.

3.6.2 The means provided for obtaining bearings should enable the bearing of a target whose echo appears at the edge of the display to be measured with an accuracy of plus or minus 1 degree or better.

.3- States Required Discrimination (range and bearing)

3.7 Discrimination

3.7.1 The equipment should be capable of displaying as separate indications on a range scale of 2 nautical mi les or less, two small similar targets ata range of between 50 per cent and 100 per cent of the range scale in use, and on the same azimuth, separated by not more than 50 metres in range.

3.7.2 The equipment should be capable of displaying as separate indications two small similar targets both situated at the same range between 50 per cent and 100 per cent of the 1.5 or 2 mile range scales, and separated by not more than 2.5 degrees in azimuth.

2- Radar setting and operation in accordance with manufacture´s

2.1- Setting up and maintaining optimum radar display

The power supply furnishes all AC and DC voltages necessary for the operation of the system components.

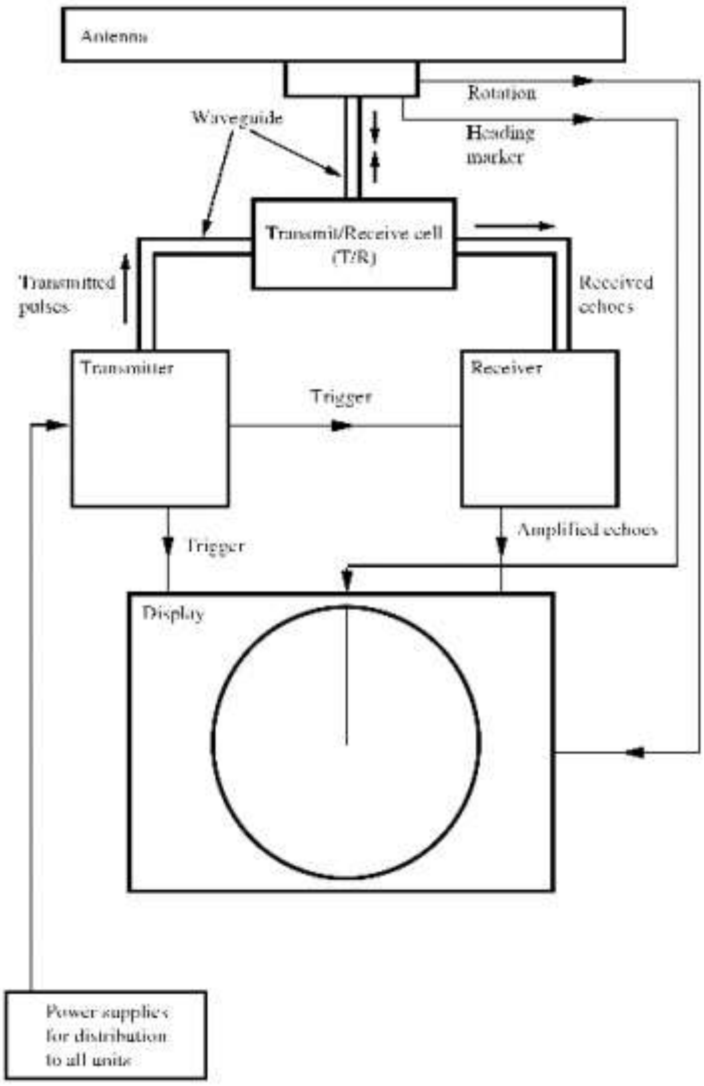


Figure 1.13 - Block diagram of a basic pulse-modulated radar system

In figure 1.13 the power supply is represented as a single block. Functionally, this block is representative. However, it is unlikely that any one supply source could meet all the power requirements of a radar set. The distribution of the physical components of a system may be such as to make it impractical to group the power-supply circuits into a single physical unit.

Different supplies are needed to meet the varying requirements of a system and must be designed accordingly. The power supply function is performed by various types of power supplies distributed among the circuit components of a radar set.

Transmitting and Receiving Antenna System

The function of the antenna system is to take the r-f energy from the transmitter, radiate this energy in a highly directional beam, receive any echoes or reflections of transmitted pulses from targets, and pass these echoes to the receiver.

In carrying out this function the r-f pulses generated in the transmitter are conducted to a FEEDHORN at the focal point of a directional reflector, from which the energy is radiated in a highly directional pattern. The transmitted and reflected energy (returned by the same dual purpose reflector) are conducted by a common path.

This common path is an electrical conductor known as a WAVEGUIDE. A waveguide is hollow copper tubing, usually rectangular in cross section, having dimensions according to the wavelength or the carrier frequency, i.e., the frequency of the oscillations within the transmitted pulse or echo.

Because of this use of a common waveguide, an electronic switch, a TRANSMIT-RECEIVE (TR) TUBE capable of rapidly switching from transmit to receive functions, and vice versa, must be utilized to protect the receiver from damage by the potent energy generated by the transmitter. The TR tube, as shown in figure 1.14 blocks the transmitter pulses from the receiver. During the relatively long periods when the transmitter is inactive, the TR tube permits the returning echoes to pass to the receiver. To prevent any of the very weak echoes from being absorbed by the transmitter, another device known as an ANTI-TR (A-TR) TUBE is used to block the passage of these echoes to the transmitter.

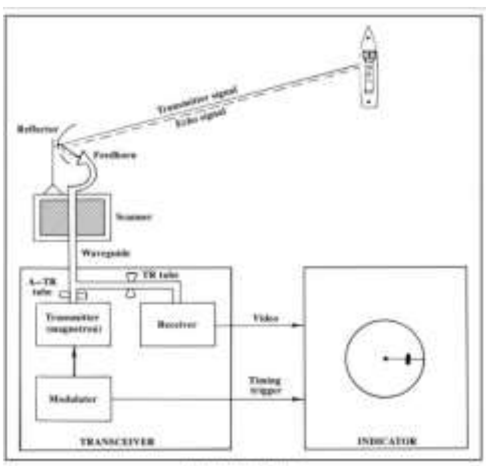


Figure 1.14 - A basic radar system.

. Operates transmitter controls (stand by/transmit, pulse length, PRF)

Operation of the Marine Radars

The operation of the marine radars can be explained as follows:

• There is an antenna on the top of the radar that continuously rotates and flashes

• The flashes actually are frequency beams that are transmitted from the radar to find out whether there any objects present in the path of the ship

• The frequency and the time taken by the flashes to return (reflections) to the radar receiver of the ship helps to find out whether the route of the boat can be continued with or not

• On the display screen, the reflections can be seen so that identifying the actual distance of the objects can be even more easy

Special Switches

Even when the radar set is off, provision may be made for applying power to heaters designed for keeping the set dry. In such case, a special switch is provided for turning this power on and off.

Note: Prior to placing the indicator power switch in the OPERATE position, the brilliance control, the receiver gain control, the sensitivity time control, and the fast time constant switch should be placed at their minimum or off positions. The setting of the brilliance control avoids excessive brilliance harmful to the CRT on applying power. The other settings are required prior to making initial adjustments of the performance controls.

Adjust receiver controls to give an optimal picture (tuning, gain, linear/logarithmic gain, sensitive time control, fast time control)

Brilliance Control

Also referred to as Intensity or Brightness control. The brilliance control, which determines the overall brightness of the PPI display, is first adjusted to make the trace of the rotating sweep visible but not too bright. Then it is adjusted so that the trace just fades. This adjustment should be made with the receiver gain control at its minimum setting because it is difficult to judge the right degree of brilliance when there is a speckled background on the PPI. Figures 2.14, 2.15, and 2.16 illustrate the effects of different brilliance settings, the receiver gain control being set so that the speckled background does not appear on the PPI. With too little brilliance, the PPI display is difficult to see; with excessive brilliance, the display is unfocused.

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Figure 2.14 - Too little brilliance.

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Figure 2.15 - Normal brilliance.

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Figure 2.16 - Excessive brilliance.

The receiver gain control is adjusted until a speckled background just appears on the PPI. Figures 2.17, 2.18, and 2.19 illustrate too little gain, normal gain, and excessive gain, respectively. With too little gain, weak echoes may not be detected; with excessive gain, strong echoes may not be detected because of the poor contrast between echoes and the background of the PPI display.

In adjusting the receiver gain control to obtain the speckled background, the indicator should be set on one of the longer range scales because the speckled background is more apparent on these scales. On shifting to a different range scale, the brightness may change. Generally, the required readjustment may be effected through use of the receiver gain control alone although the brightness of the PPI display is dependent upon the settings of the receiver gain and brilliance controls. In some radar indicator designs, the brilliance control is preset at the factory. Even so, the brilliance control may have to be readjusted at times during the life of the cathode-ray tube. Also the preset brilliance control may have to be readjusted because of large changes in ambient light levels.

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Figure 2.18 - Normal gain.

Tuning Control

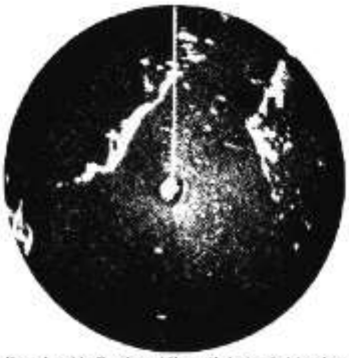

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Figure 2.19 - Excessive gain.

Without ship or land targets, a performance monitor, or a tuning indicator, the receiver may be tuned by adjusting the manual tuning control for maximum sea clutter. An alternative to the use of normal sea clutter which is usually present out to a few hundred yards even when the sea is calm, is the use of echoes from the ship's wake during a turn. When sea clutter is used for manual tuning adjustment, all anti-clutter controls should be either off or placed at their minimum settings. Also, one of the shorter range scales should be used.

Adjust display controls (brilliance, illumination, focus, shift, range selector, range rings, VRM, EBL, mechanical cursor, heading marker, clear scan, anti-clutter)

LIGHTING AND BRIGHTNESS CONTROLS

Reflection Plotter

The illumination levels of the reflection plotter and the bearing dials are adjusted by a control, labeled PLOTTER DIMMER.

The reflection plotter lighting must be turned on in order to see reflected images of the grease pencil plot on the PPI. With yellowish-green fluorescence, yellow and orange grease pencil markings provide the clearest images on the PPI; with orange fluorescence, black grease pencil markings provide the clearest images.

Heading Flash

The brightness of the heading flash is adjusted by a control, labeled FLASHER INTENSITY CONTROL. The brightness should be kept at a low level to avoid masking a small pip on the PPI. The heading flash should be turned off periodically for the same reason.

Electronic Bearing Cursor

The brightness of the electronic bearing cursor is adjusted by a control for this purpose. Unless the electronic bearing cursor appears as a dashed or dotted line, the brightness levels of the electronic bearing cursor and the heading flash should be different to serve as an aid to their identification.

Radar indicators are now equipped with a spring-loaded switch to temporarily disable the flash.

Fixed Range Markers

The brightness of the fixed range markers is adjusted by a control, labeled FIXED RANGE MARK INTENSITY CONTROL. The fixed range markers should be turned off periodically to avoid the possibility of their masking a small pip on the PPI.

Variable Range Marker

The brightness of the variable range marker is adjusted by the control labeled VARIABLE RANGE MARK INTENSITY CONTROL. This control is adjusted so that the ring described by the VRM is sharp and clear but not too bright.

Panel Lighting

The illumination of the panel is adjusted by the control labeled PANEL CONTROL.

MEASUREMENT AND ALIGNMENT CONTROLS

Range

Usually, ranges are measured by means of the variable range marker (VRM). On some radars the VRM can be used to measure ranges up to only 20 miles although the maximum range scale setting is 40 miles. For distances greater than 20 miles, the fixed range rings must be used.

The radar indicators designed for merchant ship installation have range counter readings in miles and tenths of miles. According to the range calibration, the readings may be either statute or nautical miles.

The range counter has three digits, the last or third digit indicating the range in tenths of a mile. As the VRM setting is adjusted, the range is read in steps of tenths of a mile. The VRM control may have coarse and fine settings. The coarse setting permits rapid changes in the range setting of the VRM. The fine setting permits the operator to make small adjustments of the VRM more readily. For accurate range measurements, the circle described by the VRM should be adjusted so that it just touches the inside edge of the pip.

Bearing

On most radar indicators bearings are measured by setting the mechanical bearing cursor to bisect the target pip and reading the bearing on the bearing dial.

With unstabilized Heading-Upward displays, true bearings are read on the outer, rotatable dial which is set either manually or automatically to ship’s true heading.

With stabilized North-Upward displays, true bearings are read on the fixed dial. With loss of compass input to the indicator, the bearings as read on the latter dial are relative. Some radar indicators designed for stabilized North-Upward displays have rotatable relative bearing dials, the zero graduations of which can be set to the heading flash for reading relative bearings.

Some radar indicators, especially those having true motion displays, may have an electronic bearing cursor and associated bearing indicator. The electronic cursor is particularly useful when the display is off-centered

Range Calibration

The range calibration of the indicator should be checked at least once each watch, before any event requiring high accuracy, and more often if there is any reason to doubt the accuracy of the calibration. A calibration check made within a few minutes after a radar set has been turned on should be checked again 30 minutes later, or after the set has warmed up thoroughly.

The calibration check is simply the comparison of VRM and fixed range ring ranges at various range scale settings. In this check the assumptions are that the calibration of the fixed range rings is more accurate than that of the VRM, and that the calibration of the fixed range rings is relatively stable.

One indication of the accuracy of the range ring calibration is the linearity of the sweep or time base. Since range rings are produced by brightening the electron beam at regular intervals during the radial sweep of this beam, equal spacing of the range rings is indicative of the linearity of the time base.

Representative maximum errors in calibrated fixed range rings are 75 yards or 1.5 percent of the maximum range of the range scale in use, whichever is greater. Thus, on a 6-mile range scale setting the error in the range of a pip just touching a range ring may be about 180 yards or about 0.1 nautical mile. Since fixed range rings are the most accurate means generally available for determining range when the leading edge of the target pip is at the range ring, it follows that ranging by radar is less accurate than many may assume. One should not expect the accuracy of navigational radar to be better than plus or minus 50 yards under the best conditions.

Each range calibration check is made by setting the VRM to the leading edge of a fixed range ring and comparing the VRM range counter reading with the range represented by the fixed range ring. The VRM reading should not differ from the fixed range ring value by more than 1 percent of the maximum range of the scale in use. For example, with the radar indicator set on the 40-mile range scale and the VRM set at the 20-mile range ring, the VRM range counter reading should be between 19.6 and 20.4 miles.

Demonstrate correct order of making adjustments and states the criteria for optimum setting of the controls

When setting up a radar, remember to consider and work through all of the following points:

- Set the screen brilliance
- Set the control panel brilliance
- Select day or night display
- Align radar with the true heading using the gyro compass and apply the gyro error, if any.
- Do not align with a gyro repeater
- Ensure the radar heading marker is aligned with the fore and aft line of the vessel
- Check that the radar scanner is not obstructed and is free to turn
- Ensure that no one is working on or near the radar scanner
- Turn on the power to the radar scanner
- Once the radar has warmed up, switch from standby to transmit
- Set display mode to either relative or true motion
- Select picture orientation: North-up, head-up or course-up Select an appropriate range scale for the prevailing circumstances and conditions

- Offset the screen centre if deemed appropriate to the prevailing circumstances and conditions
- Set the gain
- Tune the radar either manually or automatically
- Adjust the manual rain and sea clutter controls, or switch on automatic anti-clutter
- Set the pulse length; short, medium or long – longer pulse length for higher range scales
- Set the interference rejection level as required
- Switch enhanced video/echo stretch/target expansion on or off as required
- Switch echo averaging on or off as required
- Switch the range rings on or off as required
- Switch the VRMs on or off as required
- Switch the EBLs on or off as required
- Switch target AIS data on or off as required
- Check the performance of the radar using the performance monitor

State that small or poor echoes may scape detection

Sea state and Wind

It is difficult to measure experimentally the effect of the wind and sea state on radar echo. Such measurements require a substantial period of time to obtain a wide variation of sea and wind conditions. Since the sea state depends on the wind it is not always easy to determine which is the more important factor affecting the radar echo from the sea. Generally at the higher microwave frequencies (X band or above) and low grazing angles, the wind is found to be a significant parameter with which to correlate radar sea echo. At the lower frequencies and higher grazing angles the wave characteristics are probably more significant than the wind velocity.

Describe the effect of saturation by receiver noise

Methods of detecting inaccurate speed settings on true-motion controls; the effects of receiver noise limiting the ability to display weak echo returns, and the effects of saturation by receiver noise, etc.; the adjustment of operational controls; criteria which indicate optimum points of adjustment; the importance of proper adjustment sequence, and the effects of maladjusted controls; the detection of maladjustments and corrections of:

- controls affecting detection ranges; and
- controls affecting accuracy;

State the importance of frequent changes in range scale

CHOICE OF RANGE SCALE:

Appropriate range scales should be used depending on the prevailing circumstances and conditions of the environment the ship is in. Where two radars are used, one radar can be kept on a longer range scale to obtain advance warning of the approach of other vessels, changes in traffic density, or proximity to the coastline. The other radar can use a short range scale, which helps to detect smaller targets easily. Use the RANGE key in the keyboard to select the range desired. The '+' key increases the range whereas the '-' key decreases the range.

Identifies different types mode (true motion, relative motion – un stabilized relative motion – stabilized, north up, course up, head up.)

Relative motion

There are two basic displays used to portray target position and motion on the PPI's of navigational radars. The relative motion display portrays the motion of a target relative to the motion of the observing ship.

True motion

The true motion display portrays the actual or true motions of the target and the observing ship.

Depending upon the type of PPI display used, navigational radars are classified as either relative motion or true motion radars. However, true motion radars can be operated with a relative motion display. In fact, radars classified as true motion radars must be operated in their relative motion mode at the longer range scale settings. Some radars classified as relative motion radars are fitted with special adapters enabling operation with a true motion display. These radars do not have certain features normally associated with true motion radars, such as high persistence CRT screens.

Un stabilized relative motion

There are two basic orientations used for the display of relative motion on PPI's. In the HEADING-UPWARD display, the target pips are painted at their measured distances in direction *relative* to own ship's heading. In the NORTH-UPWARD display, target pips are painted at their measured distances in true directions from own ship, north being upward or at the top of the PPI.

In figure 2.1 own ship on a heading of 270° detects a target bearing 315° true. The target pip is painted 045° relative to ship's heading on this Heading-Upward display. In figure 2.2 the same target is painted at 315° true on a North-Upward display. While the target pip is painted 045° relative to the heading flash on each display, the Heading-Upward display provides a more immediate indication as to whether the target lies to port or starboard.

Figure 2.1 - Unstabilized Heading-Upward display.

Relative motion (stabilized and unstabilized)

Stabilization

The North-Upward display in which the orientation of the display is fixed to an unchanging reference (north) is called a STABILIZED display. The Heading-Upward display in which the orientation changes with changes in own ship's heading is called an UNSTABILIZED display. Some radar indicator designs have displays which are both stabilized and Heading- Upward. In these displays, the cathode-ray tubes must be rotated as own ship changes heading in order to maintain ship's heading upward or at the top of the PPI.

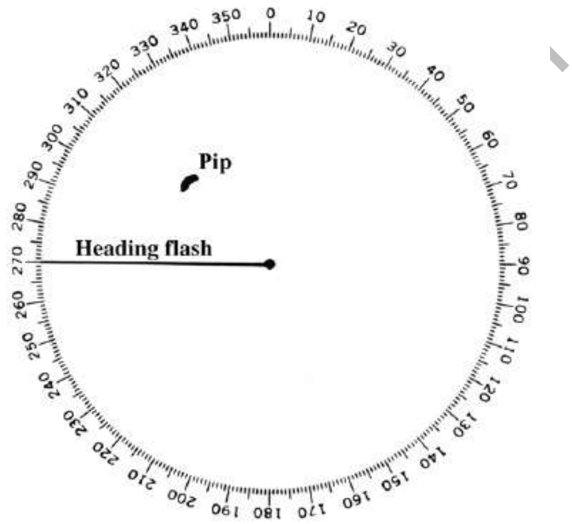


Figure 2.2 - Stabilized North-Upward display.

True motion radar displays own ship and moving objects in their true motion. Unlike relative motion radar, own ship's position is not fixed on the PPI. Own ship and other moving objects move on the PPI in accordance with their true courses and speeds. Also unlike relative motion radar, fixed objects such as landmasses are stationary, or nearly so, on the PPI. Thus, one observes own ship and other ships moving with respect to landmasses.

True motion is displayed on modern indicators through the use of a microprocessor computing target true motion rather than depending on an extremely long persistence phosphor to leave "trails".

Stabilization

Usually, the true motion radar display is stabilized with North-Upward. With this stabilization, the display is similar to a plot on the navigational chart. On some models the display orientation is Heading-Upward. Because the true motion display must be stabilized to an unchanging reference, the cathode-ray tube must be rotated to place the heading at the top or upward.

PRESENTATION MODES

This radar has the following presentation modes:

Relative Motion (RM)

Head-up: Unstabilized

Head-up TB: Head-up with compass-stabilized bearing scale (True Bearing)

Course-up: Compass-stabilized relative to ship's intended course

North-up: Compass-stabilized with reference to north)

True Motion (TM)

North-up: Ground or sea stabilized with compass and speed inputs

Explain the advantages and limitations of different types of display mode.

SELECTING PRESENTATION MODE

Press the MODE key on the mode panel. Each time the MODE key is pressed, the presentation mode and mode indication at the upper-left corner of the screen change cyclically.

Loss of Gyro Signal: When the gyro signal is lost, the presentation mode automatically becomes head-up and the GYRO readout at the screen top shows asterisks(*****.***). The message SET HDG appears at the upper of the screen. This warning stays on when the gyro signal is restored, to warn the operator that the readout may be unreadable. Press the MODE key to select another presentation mode (the asterisks are erased at this point). Then, align the GYRO readout with the gyrocompass reading and press the CANCEL key to erase the message SET HDG.

Explain the need for compass error on stabilized display, and compass and log input for true motion display

Types of True Motion Display

While fixed objects such as landmasses are stationary, or nearly so, on true motion displays, fixed objects will be stationary on the PPI only if there is no current or if the set and drift are compensated for by controls for this purpose. Dependent upon set design, current compensation may be effected through set and drift controls or by speed and course-made-good controls.

When using true motion radar primarily for collision avoidance purposes, the *sea-stabilized* display is preferred generally. The latter type of display differs from the *ground-stabilized* display only in that there is no compensation for current. Assuming that own ship and a radar contact are affected by the same current, the sea-stabilized display indicates true courses and speeds through the water. If own ship has leeway or is being affected by current, the echoes of stationary objects will move on the sea-stabilized display. Small echo trails will be formed in a direction opposite to the leeway or set. If the echo from a small rock appears to move due north at 2 knots, then the ship is being set due south at 2 knots. The usable afterglow of the CRT screen, which lasts from about 11/2 to 3 minutes, determines the minimum rate of movement which can be detected on the display. The minimum rate of movement has been found to be about 11/2 knots on the 6- mile range scale and proportional on other scales.

The *ground-stabilized* display provides the means for stopping the small movements of the echoes from stationary objects. This display may be used to obtain a clearer PPI presentation or to determine leeway or the effects of current on own ship.

In the *ground-stabilized* display own ship moves on the display in accordance with its course and speed over the ground. Thus, the movements of target echoes on the display indicate the true courses and speeds of the targets over the ground. Ground-stabilization is effected as follows:

(1) The speed control is adjusted to eliminate any movements of the echoes from stationary targets dead ahead or dead astern. If the echoes from stationary targets dead ahead are moving towards own ship, the speed setting is increased; otherwise the speed setting is decreased.

(2) The course-made-good control is adjusted to eliminate any remaining movement at right angles to own ship's heading. The course-made-good control should be adjusted in a direction counter to the echo movement.

Therefore, by trial and error procedures, the display can be groundstabilized rapidly. However, the display should be considered only as an approximation of the course and speed made good over the ground. Among other factors, the accuracy of the ground-stabilization is dependent upon the minimum amount of movement which can be detected on the display. Small errors in speed and compass course inputs and other effects associated with any radar set may cause small false movements to appear on the true motion display. The information displayed should be interpreted with due regard to these factors. During a turn when compass errors will be greater and when speed estimation is more difficult, the radar observer should recognize that the accuracy of the ground stabilization may be degraded appreciably.

The varying effects of current, wind, and other factors make it unlikely that the display will remain ground stabilized for long periods. Consequently, the display must be readjusted periodically. Such readjustments should be carried out only when they do not detract from the primary duties of the radar observer.

While in rivers or estuaries, the only detectable movement may be the movement along own ship's heading. The movements of echoes of stationary objects at right angles to own ship's heading are usually small in these circumstances. Thus, in rivers and estuaries adjustment of the speed control is the only adjustment normally required to obtain ground stabilization of reasonable accuracy in these confined waters.

Identifies effects of transmitting compass error on stabilized and true motion display

Compass Errors If targets are being tracked, a compass error will cause affected target tote data to change from green to red. The affected data being TBRG, CPA, TCPA, COG (or CSE), SOG (or STW), BCR and BCT. After 1 minute all tracked targets will be cancelled; auto acquisition zones, mapping facilities, the constant radius turn and plots will be switched off and it will not be possible to use these facilities, or select a stabilised mode, until a valid compass heading is available. The system will reset to the H-Up presentation mode.

Identifies effect of transmitting log errors on true motion display, manual speed input error

Be sure not to select LOG when a speed log is not connected. If the log signal is not provided, the ship speed readout at the top of the screen will be blank. In the event of a log error, you can continue plotting by entering a manual speed.

If a log signal interval becomes more than 30 seconds with the ship's speed 5 knots or more, the radar regards the speed log is in trouble and LOG FAIL appears, reading xx.xKT. For R-type, if no speed input is present for 3 minutes at below 0.1 knots, the radar regards the log is in failure.

Operates special control (presentation, speed, re-set, course made good correction, compass repeater)

TRUE MOTION CONTROLS

The following controls are representative of those additional controls used in the true motion mode of operation. If the true motion radar set design includes provision for ground stabilization of the display, this stabilization may be effected through use of either set and drift or speed and coursemade- good controls.

Operating Mode

Since true motion radars are designed for operation in true motion and relative motion modes, there is a control on the indicator panel for selecting the desired mode.

Normal Reset Control

Since own ship is not fixed at the center of the PPI in the true motion mode, own ship's position must be reset periodically on the PPI. Own ship's position may be reset manually or automatically. Automatic reset is performed at definite distances from the PPI center, according to the radar set design. With the normal reset control actuated, reset may be performed automatically when own ship has reached a position beyond the PPI center about two thirds the radius of the PPI. Whether own ship's position is reset automatically or manually, own ship's position is reset to an off-center position on the PPI, usually at a position from which the heading flash passes through the center of the PPI. This off-center position provides more time before resetting is required than would be the case if own ship's position were reset to the center of the PPI.

Delayed Reset Control

With the delayed reset control actuated, reset is performed automatically when own ship has reached a position closer to the edge of the PPI than with normal reset.With either the normal or delayed reset control actuated, there is an alarm signal which gives about 10 seconds forewarning of automatic resetting.

Manual Reset Control

The manual reset control permits the resetting of own ship's position at any desired time.

Manual Override Control

The manual override control when actuated prevents automatic resetting of own ship's position. This control is particularly useful if a critical situation should develop just prior to the time of automatic resetting. Shifting from normal to delayed reset can also provide more time for evaluating a situation before resetting occurs.

Ship's Speed Input Selector Control

Own ship's speed and course being necessary inputs to the true motion radar computer, the ship's speed input selector control permits either manual input of ship's speed or automatic input of speed from a speed log. With the control in the manual position, ship's speed in knots and tenths of knots can be set in steps of tenths of knots.

Set and Drift Controls

Set and drift controls, or their equivalent, provide means for ground stabilization of the true motion display. When there is accurate compensation for set and drift, there is no movement of stationary objects on the PPI.

Without such compensation, slight movements of stationary objects may be detected on the PPI. The set control may be labeled DRIFT DIRECTION; the drift control may be labeled DRIFT SPEED.

Speed and Course Made Good Controls

The radar set design may include speed and course made good controls in lieu of set and drift controls to effect ground stabilization of the true motion display. The course made good control permits the input of a correction, within limits of about 25° to the course input to the radar set. The speed control permits the input of a correction to the speed input from the underwater speed log or from an artificial (dummy) log.

Zero Speed Control

In the ZERO position, the zero speed control stops the movement of own ship on the PPI; in the TRUE position own ship moves on the PPI at a rate set by the speed input.

Identifies maladjusted controls and explain their effects and dangers

Preparing the display. This involves the setting of the controls directly associated with the CRT so as to prepare the tube to display a marine radar picture; they should be adjusted in the sequential order set out below. In modern systems some of these controls may be preset. Nevertheless it is important to check that the preset control is having the desired effect, since they have no automatic correcting action. If they go wrong, they will stay wrong.

Setting the brilliance

The brilliance control sets the no signal level of the spot brightness. Since the presence of an echo is indicated by a temporary increase in that brightness, the setting of this control is fundamental to successful echo detection. The brilliance control should be set so that the rotating trace is barely visible. If the brilliance is set lower than this, weak echoes may be missed because a small increase in electron beam strength may be insufficient to make the spot visible. Conversely, if the setting is too high, echoes may be missed, not because they are not displayed, but because a small increase in spot brightness may be difficult to see against an already bright background. The latter effect is sometimes described as lack of contrast.

Excessive brilliance will tend to de-focus the spot, resulting in a reduction in discrimination and the accuracy with which ranges and bearings can be measured

Setting the focus

This control, by adjusting the position to which the electron beam is converged, determines the spot size. As the latter is one of the factors which affects the area of echo paint, the control must be set to produce the smallest possible spot diameter. To set the focus control, switch on the range rings and adjust the control until the range rings appear as sharp as possible. Choose a ring half-way between the centre and the edge of the screen, as it is difficult to achieve perfect focus over the whole screen. Poor focus is evidenced by the ring appearing thick and woolly. In modern marine equipment the focus is invariably preset and no user control is provided. When the check has been completed the rings should be switched off. Where focus adjustment is necessary, it is important that it is carried out after the brilliance has been correctly set because an excessive brilliance setting will tend to defocus the spot.

Centring the origin

A pair of centring or shift controls allow the observer to make small adjustments to the position of the origin of the rotating trace. As its name suggests, the horizontal shift (or centring) control produces horizontal movement of the origin, i.e. movement parallel to the 090/270 axis of the graduated circular bearing scale which surrounds the tube, while the vertical shift produces movement at right angles to this direction

The centre of the Perspex cursor disk is normally marked by a cross formed by the intersection of the main cursor line, which is engraved along a diameter, and a short line which bisects it at right angles. To centre the origin, the cursor should be aligned to the 000/180 direction on the bearing scale and the horizontal shift control should be adjusted to place the origin below the engraved diameter. The vertical shift control should then be adjusted to place the origin below the cross at the centre of the Perspex cursor disk and thus (assuming that there has been no mechanical damage to the mounting of the disk), at the geometrical centre of the bearing scale

Orientating the picture

The picture must be correctly orientated by rotating it so that the heading marker intersects the correct graduation on the circular bearing scale surrounding the tube. In many older systems it was necessary to rotate the picture manually, whereas in more modern systems auto-alignment takes place provided that the compass repeater has been correctly set to the vessel’s heading. The procedure will thus depend on the preferred orientation and can be set out as follows:

Ship’s-head-up (unstabilized). The ship’s-head-up orientation should be selected. Where a manual alignment control is provided, the heading marker should be rotated to align it with the 000 graduation on the bearing scale. In the case of an auto-aligned system, the display should be observed to ensure that the heading marker has aligned correctly.

True-north-up (stabilized). It is expedient to start by selecting the ship’s-head-up (unstabilized) orientation as this ensures that the heading marker will not yaw in sympathy with the azimuth stabilizing signal until the observer is ready to switch in the latter

The display compass repeater should be correctly aligned to the vessel’s instantaneous true heading. The alignment control which adjusts the repeater normally operates in association with a clutch mechanism. When the control is pressed in against a spring, the gyro repeater card is disconnected from the gyro follow-up system and it can be freely rotated to the desired reading by turning the alignment control. On release of the control, the clutch re-engages the repeater card to the gyro follow-up system and the alignment control can be rotated freely. The repeater should be aligned to the true course and, at an instant when the vessel is right on course, the alignment control should be released. A check should then be made to ensure that the repeater does follow variations in the ship's heading

Course-up (stabilized) It is expedient to start by selecting the ship's-head-up (unstabilized) orientation as this ensures that the heading marker will not yaw in sympathy with the azimuth stabilizing signal until the observer is ready to switch in the latter (see Section 2.6.3).

The display compass repeater should be correctly aligned to the vessel's instantaneous true heading in the same way as described for the north-up orientation.

Where a manual alignment control is provided, the heading marker should be rotated to align it with the 000 graduation on the bearing scale. At an instant when the vessel is right on course, the course-up orientation should be selected.

In the case of an auto-aligned system, course-up should be selected and the display should then be observed to ensure that the heading marker has aligned correctly.

In both cases, after the heading marker has been aligned, the display should be observed for a short period to ensure that the heading marker is following variations in the ship's heading.

In the particular case of course-up orientation, it will be necessary to reset the reference course each time the vessel makes a sustained alteration of course. In older systems this will have to be done manually, while in more modern systems it is merely necessary to press some form of reset control when the vessel is steady on the new course.

Detect and correct maladjusted

When an echo is maladjusted and is detected , we must to correct them given an Optimum picture that is obtained by setting the receiver controls to maximize the detection of weak echoes. This involves the adjustment of, firstly, the gain control and, secondly, the tuning control.

Setting the gain control

The gain control, which is sometimes referred to as the sensitivity control, adjusts the amounts by which all received echoes and receiver noise are amplified. It should be advanced until a low level, close-grained speckling can be seen all over the screen. The speckling is the visual indication of the phenomenon known as thermal or receiver noise. The problem is analogous to attempting to listen for the fog signal of another vessel against the background of audible noise from the engine and other sources on board the observing vessel. Because it determines the minimum level of detectable signal, the amplitude of displayed noise, and thus the setting of the gain, is of critical importance. Noise is a fluctuating signal and if the gain is set too low the peaks will not be displayed and genuine echoes close to noise level may well escape detection (see Figure 6.1.) If the gain is set too high, again weak

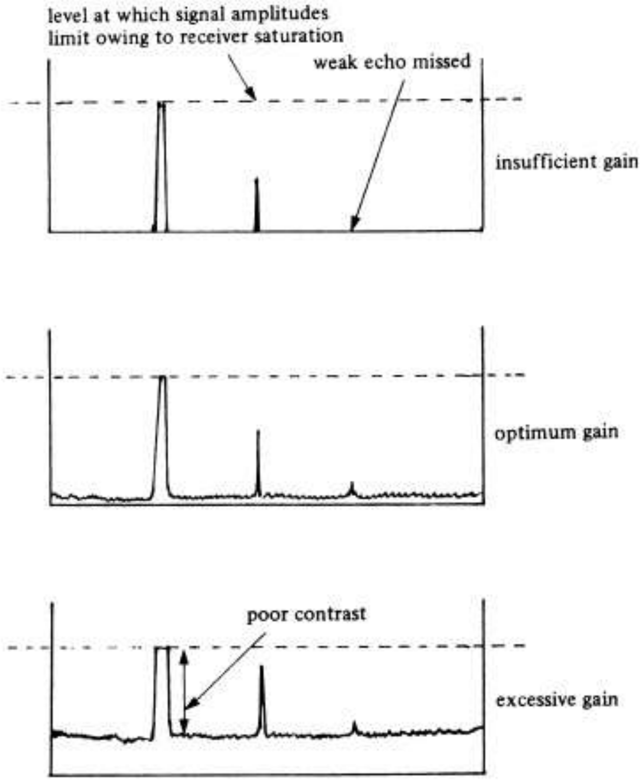


Figure 6.1 Setting the gain control

echoes may be lost, not because they are not displayed but because, as a result of poor contrast, they may not be obvious against the background of the noise (see Figure 6.1). Further, excessive noise may also make it difficult to detect even strong echoes. If strong signals saturate the receiver, additional gain will not increase their brightness but will increase the amplitude of the noise echoes and hence reduce the contrast which is related to the signal-to-noise ratio. Excessive gain may cause defocusing of the spot, resulting in loss of discrimination and measurement accuracy.

Setting the tuning control

The function of the tuning control is to adjust the frequency of the receiver so that it coincides with that of the transmitter, rather in the same way as one might tune a broadcast receiver to listen for a distant station.

If the receiver is only slightly mistuned, the extent of the bandwidth may still allow stronger echoes to be displayed even to the level of saturation. It is important not to be misled by this because weak echoes will most certainly be lost. It is thus important to establish criteria against which it is possible to make a sensitive assessment of the setting of the tuning control.

One of the most sensitive criteria is the response of a weak echo from land (see Figure 6.2). The tuning control should be adjusted while carefully watching such a response. As the correct frequency is approached, the brightness of the displayed echo response will increase. It will peak at the correct setting and decay after that setting has been passed. By adjusting the control to achieve the maximum displayed brightness of such a target, the correct setting may be easily and reliably found. As the correct setting is approached it will be necessary to adjust the control in progressively smaller steps. It is important to appreciate that after each small adjustment is made, it is necessary to wait until the echo is re-painted in order to judge what effect an adjustment has had. If the coarse tuning has been set correctly by service personnel, the correct setting for the display tuning control should lie close to the centre of its range of travel. If the correct position is found to approach either end of the range of travel, the coarse tuning control (which will be located inside the transceiver) should be readjusted by qualified service personnel.

States effect of incorrect speed setting and CMG(course made good) correction on true motion display

In the ground-stabilized display own ship moves on the display in accordance with its course and speed over the ground. Thus, the movements of target echoes on the display indicate the true courses and speeds of the targets over the ground. Ground-stabilization is effected as follows:

(1) The speed control is adjusted to eliminate any movements of the echoes from stationary targets dead ahead or dead astern. If the echoes from stationary targets dead ahead are moving towards own ship, the speed setting is increased; otherwise the speed setting is decreased.

(2) The course-made-good control is adjusted to eliminate any remaining movement at right angles to own ship's heading. The course-made-good control should be adjusted in a direction counter to the echo movement.

Describes the purpose and use of the performance monitor

Performance check procedure

It must be remembered that the length of the monitor signals (or the status of other indicators) is influenced by the position in which the operational controls have been set. When carrying out a performance check it is vital that controls are set as instructed in the maker's manual – otherwise comparison with the calibration level is meaningless.

It cannot be stressed too strongly that the way in which the performance signals are displayed, and the extent to which they monitor the performance, vary considerably from manufacturer to manufacturer and even with different types made by the same company. Thus the important basic rule for carrying out a performance check is: *Consult the maker's manual and follow exactly the instructions given therein*.

A performance check should be carried out as soon as practicable after setting up and thereafter at regular intervals. In the United Kingdom, it is a requirement that a check should be carried out before sailing and at least every four hours when a radar watch is kept. This should be regarded as a minimum.

Record radar data: (performance monitor reading, modifications, blinds and shadow sector diagram)

A Radar Log is a very useful record book to have on the bridge of a ship. It is of value for the ship's owner so that he will be able to assess the benefits of the radar installation; it can also be useful for the manufacturer of the installation so that improvements can be made in the equipment, if required! Last but not least a radar log will assist the navigator himself. Its record will give a picture of the particular characteristics and limitations of a radar set and will teach him to be critical in the interpretation of the display. The log will also be of great value when new officers or relief officers come on board. It provides the history of a radar set and its behaviour under different conditions and circumstances, and offers details which cannot be discussed in a short time.

Explain how propagation conditions can affect target detection.

Summary of distortions in accordance with conditions

Figure 4.3 illustrates the distortion effects of radar shadow, beam width, and pulse length. View A shows the actual shape of the shoreline and the land behind it. Note the steel tower on the low sand beach and the two ships at anchor close to shore. The heavy line in view B represents the shoreline on the PPI. The dotted lines represent the actual position and shape of all targets. Note in particular:

(a) The low sand beach is not detected by the radar.

(b) The tower on the low beach is detected, but it looks like a ship in a cove. At closer range the land would be detected and the cove-shaped area would begin to fill in; then the tower could not be seen without reducing the receiver gain.

(c) The radar shadow behind both mountains. Distortion owing to radar shadows is responsible for more confusion than any other cause. The small island does not appear because it is in the radar shadow.

(d) The spreading of the land in bearing caused by beam width distortion. Look at the upper shore of the peninsula. The shoreline distortion is greater to the west because the angle between the radar beam and the shore is smaller as the beam seeks out the more westerly shore.

(e) Ship No. 1 appears as a small peninsula. Her pip has merged with the land because of the beam width distortion.

(f) Ship No. 2 also merges with the shoreline and forms a bump. This bump is caused by pulse length and beam width distortion. Reducing receiver gain might cause the ship to separate from land, provided the ship is not too close to the shore. The FTC could also be used to attempt to separate the ship from land.

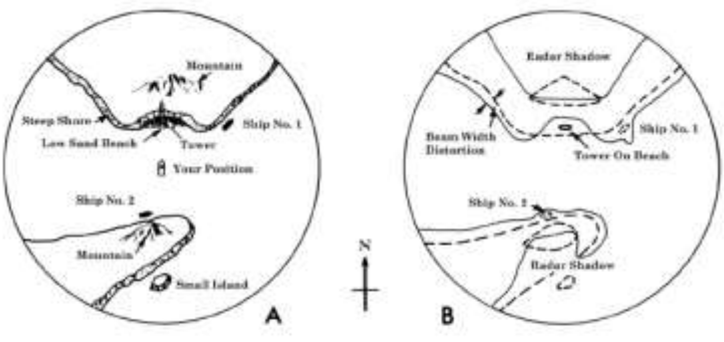


Figure 4.3 - Distortion effects of radar shadow, beam width, and pulse length.

2.2- Accurate measurement of ranges and bearing

States methods and accuracy of measuring ranges (fixed ranges markers, VRM)

A wide range of facilities are provided to enable the observer to measure the range and bearing of targets.
Some arrangements measure range and bearing while others measure one quantity or the other. In older systems the facilities are associated with rotary controls and mechanical scales, whereas more modern equipments employ a joystick/tracker ball and graphic read-out. There is considerable variation in the precise detail of facilities provided by different manufacturers but the principle is essentially the same in each case.
The new IMO Performance Standards also require that all radar displays are fitted with compensation for an offset antenna so that all positional data is relative to a consistent common reference point (normally the conning position). This could be very useful for multiple antenna installations.

Fixed range rings

The IMO Performance Standard requires that fixed rings should be provided. The number of rings required depends on the range scale selected; six rings are typical for range scales above 1 n mile, but this can be reduced to two rings for range scales below 1 n mile. There is also a requirement that the range scale displayed and the interval between the range rings should be clearly indicated at all times.
The fixed range rings take the form of a pattern of equally spaced circles concentric with the electronic origin of the picture. The pattern is generated by subdividing the time base into equal intervals of time and rotating the trace through 360. In a radial-scan display the rings should appear as perfect circles because all elements of a ring will be displayed at the same distance from the origin.
The IMO Performance Standards require that the fixed range rings should enable the range of an object to be measured with an error not exceeding 1 per cent of the maximum range of the scale in use or 30 metre, whichever is greater. Thus, when using the range rings to measure the range of a target, the most open range scale appropriate should be selected so as to maximize the inherent accuracy of the measurement.
The only situation in which an observer can conveniently fix the vessel’s position with a sufficient degree of precision to be able to check the accuracy of the rings is when the vessel is alongside a berth. It is possible for an observer to check the accuracy of the rings by observing the echo of an known small, isolated and steep-sided target when secure in a known charted position.

Variable range marker (VRM)

The new IMO Performance Standards require that two electronic range markers with a numerical read-out of range be provided.
It also requires that arrangements are made so that it is possible to vary the brilliance of each marker and to remove it completely from the screen.
The accuracy requirement, i.e. 1 per cent of the maximum range of the scale in use or 30 metres (whichever is greater) is also the same as that required for the fixed range rings.

The VRM is a variable-radius ring generated at a selected elapsed time after the instant of trigger for radial scan displays.

The elapsed time, and hence the radius of the ring, can be varied by the observer over a continuous set of values from zero to the limit of the maximum range of the scale in use. The radius of the VRM was traditionally set by a rotary control which also drove a mechanical three or four digit scale. In modern systems *increase* and *decrease* push-button controls or a joy stick/tracker ball will be employed and the read-out may form part of the graphics on a raster-scan display.
In the raster-scan case, the VRM will be similarly liable to exhibit the staircase effect described for the fixed range rings.

Although the electronic circuitry which generated the traditional VRM was simple and reliable, errors frequently arose due to its association with controls, scales and read-outs which were of a mechanical nature. For this reason it was essential to check the accuracy of the VRM regularly by placing it over a ring and comparing the read-out value with that of the ring. To maximize the inherent accuracy of any range measurement made with the VRM, the most open range scale appropriate should be selected.

The VRM brilliance should be adjusted to obtain the finest possible line and the range should be taken to the nearer edge of the echo.
More modern systems are less likely to suffer this kind of error, but it is prudent to check the VRM anyway.

Measures ranges with emphasis on accuracy

Range accuracy

The IMO Performance Standards require that the fixed range rings and the variable range marker enable the range of a target to be measured with an error not exceeding 1 per cent of the maximum range of the scale in use or 30 metres, whichever is greater. Where appropriate in the preceding descriptions of the various facilities available for range measurement, mention was made of procedures for ensuring that the potential accuracy is realized. For ease of reference it is appropriate to summarize these procedures in this section.

1 Adjust the brilliance of the VRM, or ERBL to obtain the finest possible line.

2 Measure the range to the nearer edge of the displayed echo.

3 Use the rings when the target is on or close to a ring.

4 Use the VRM, ERBL or joystick marker to interpolate between the rings.

5 Regularly check the VRM, ERBL or joystick marker against the rings.

6 Use the most open scale appropriate.

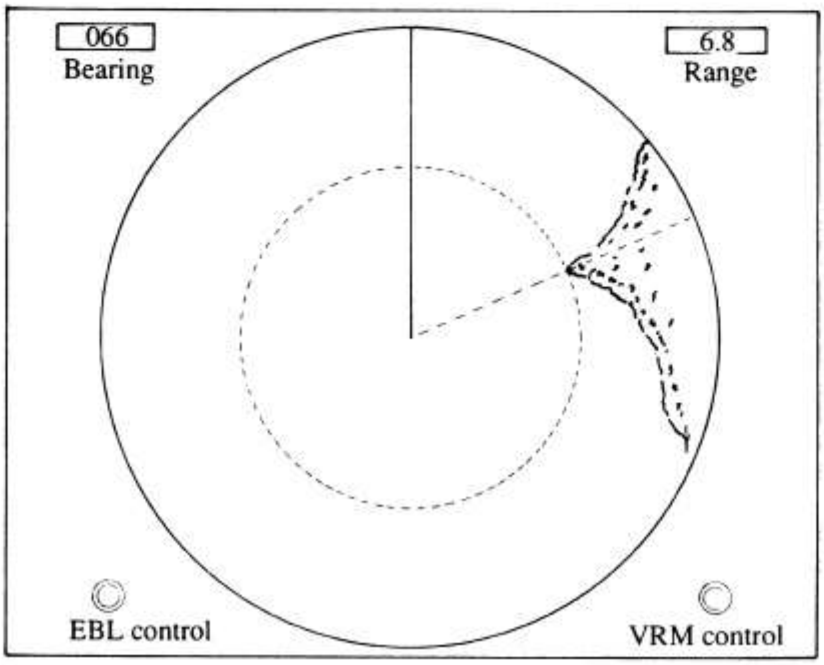
7 When it is not necessary to display the rings, good practice dictates that they should be switched off in order to prolong the life of the phosphor area on which they paint.

Explain the methods and accuracies of measuring bearings (rotatable cursor, EBL)

The electronic bearing line (EBL)

This may also be referred to as the electronic bearing indicator (EBI) or electronic bearing marker (EBM). It takes the form of a continuous or dashed line which is generated electronically (see Figure 6.13(a)). Because it emanates from the electronic origin it can be used even if the origin is not centred. In radial-scan displays the brilliance of the line will normally be continuously variable, from 'off ' to 'maximum', under the control of the observer. In raster-scan displays the levels may be restricted to on/off or possibly to off/low/high, though the EBL brilliance will be indirectly affected by the setting of the screen brilliance control.

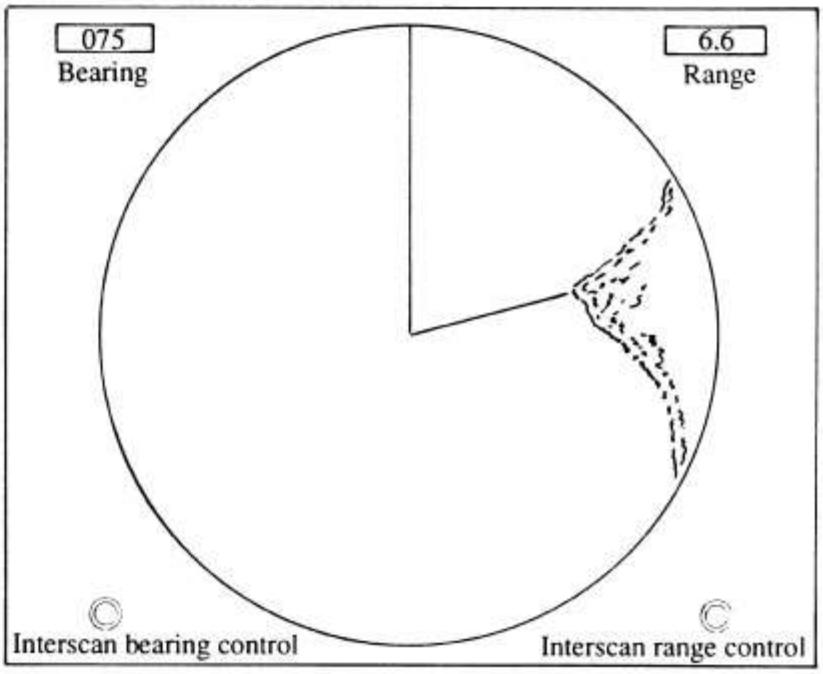
In older radial-scan systems it is produced by the closing of a mechanical contact once per rotation of the scan coils. The angular position of the contact with respect to the scan coils is adjusted by a rotary control which also drives some form of circular or three-digit remote mechanical read-out. When adjusting the position of this type of EBL, the observer may have to wait for a period



(a) EBL and VRM

of up to one aerial revolution to see whether or not the desired target has been intersected and hence it is somewhat slower than other methods of bearing measurement.

In radial synthetic systems the EBL can be made visible continuously by brightening it once per trace rather than once per revolution. This is achieved by using the spot to write the EBL in the rest period between timebases . For this reason, such an EBL is sometimes referred to as an *interscan cursor*. The cursor position is adjusted by a rotary mechanical control which also drives a mechanical or electronic read-out. The bearing measurement function may be combined with that of range measurement by making it possible to vary the length of the interscan cursor, in which case it may be referred to as an electronic range and bearing line (ERBL) (see Figure 6.13(b)). Alternatively, the continuous line may be retained and a variable range indication given by generating a mark of some sort at an adjustable point somewhere along the line.



(b) Interscan cursor

Figure 6.13 Electronic bearing line, VRM and interscan cursor

Measures bearing with emphasis in accuracy

Bearing accuracy

The IMO Performance Standards require that the means provided for measuring bearings should enable the bearing of a target whose echo appears at the edge of the display to be measured with an accuracy of ±1_ or better.

It is essential to appreciate that the permitted error of ±1_ refers only to the measurement of the angle (whose accuracy will depend on the correctness of the alignment of scanner and trace/digital bearing word and the graduation accuracy of the measuring device).
It does not take into account the accuracy of the heading marker from which the angle is measured or of the accuracy of the gyro signal used where azimuth stabilization is provided.

The Performance Standards specify an accuracy of ±1_ for the heading marker and ±0_5_ for the gyro input. If these error sources are aggregated, a bearing measured from the display could be in error by 2_5_ without the provisions of the Standards being contravened.
However, it must be said that each error will have a component which is substantially constant throughout the period of taking a series of bearings.
For example, only in the case of mechanical fault would one expect the error from the heading marker source to change from +1_ to −1_ during the taking of a series of bearings.
The significance of the aggregate error will depend on whether the bearings are being used for radar plotting or for position-fixing.

Where appropriate in the preceding descriptions of the various facilities available for bearing measurement, mention was made of procedures for ensuring that the potential accuracy is realized.

It is important to check regularly that the heading marker accurately represents the ship's fore-and-aft line. The procedure for carrying out this check is as follows:

(a) On radial displays adjust accurately the centre of the trace. On all displays switch off azimuth stabilization and ensure heading marker is aligned with 0_ on bearing scale.

(b) Select an object which is conspicuous but small visually and whose echo is small and lies near as possible to the maximum range scale in use. Measure simultaneously the relative visual bearing of this object and the bearing on the PPI relative to the bearing scale. It is important that the visual bearing is taken from a position near the radar antenna in plan.

Repeat at least twice and calculate the mean difference between bearings obtained visually and by radar.

(c) If an error exists, adjust the heading marker contacts to remove the error. Traditionally, the adjustment was in the antenna unit, but modern systems allow adjustment to be done in the processing unit.

(d) Repeat (b) above to check accuracy of the adjustment.

2 Ensure that centring has been carried out before using the Perspex cursor on radial sets.
3 Ensure that the picture is correctly orientated.
4 Use an appropriate range scale with the target as near to the edge of the screen as possible.
5 Take care to avoid parallax when using the Perspex cursor or parallel index lines on radial sets.
6 If using a ship's-head-up unstabilized orientation, the ship's head must be read at the instant of taking the bearing.
7 Check the EBL, ERBL or joystick marker by superimposing them on the heading marker, at which time the bearing and heading should agree.
Any error should be noted, applied to bearings and the cause investigated.
8 For a small isolated target align the cursor, EBL, ERBL or marker with the centre of the target.
9 Temporarily reduce the gain if it will give a more clearly defined echo.

In general it should be borne in mind that radar range position circles have a much higher inherent accuracy than is obtainable from position lines derived from radar bearings. Further, radar bearings are not as accurate as visual bearings

.5- Check and correct error in range and bearings

Range Accuracy

The range accuracy depends on:
(a) The uniformity and rectilinearity of the time-base or sweep.
(b) The size of the spot, especially on long range scales.
(c) The curvature of the screen (especially near the tube edge).
d) The height of the scanner which can introduce parallax when the scanner is high and objects are near and low-lying.

The range accuracy of the fixed range rings is generally such that the maximum error does not exceed l~% (1982 Specification) of the maximum range of the scale in use. The range accuracy of the rings should be determined in port or when anchored in a roadstead by comparing the true range with the recorded radar range of a radar conspicuous object. It CHARACTERISTIC OF SET 37 can be done sometimes on a moving vessel by measuring the difference in radar ranges between two radar conspicuous objects which lie on the same or opposite bearings and comparing them with the chart distances.

Alternatively parallel index lines engraved on a rotating bearing mask at intervals of the fixed range rings can be used to measure the radar range between two objects. Even a pair of rubber-tipped dividers could be employed to measure the radar range between two fixed objects. After measurement take the radar range off along the radius of the rings and compare with the chart.

For interpolation between the fixed range rings it may be advisable to use the variable range marker or strobe. Generally the accuracy of the variable range marker is slightly less than that of the range rings. The error may vary for different range scales and also at different ranges on the same range scale.

The variable range marker must be checked and calibrated against the fixed range rings. It should be done fairly frequently because it sometimes happens that small drifts are introduced in the error. The method of calibration is as follows:

Bring range rings and range marker simultaneously on the screen. Let the range marker coincide with the range ring concerned. Then take the reading of the variable range marker and compare it with the range indicated by the particular fixed range ring. Always measure the range of the leading edge of the echo. A radar pulse cannot "feel" the off side of a target. When taking a range with the range marker, the outer edge of the range marker should touch the inner edge of the echo.

3- USING RADAR TO ENSURE SAFE NAVIGATION

3.1 Radar Position -Fixing

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The provision for continuous manning of the radar by a designated and competent observer does not necessarily mean that other responsible navigational personnel should not observe the radarscope from time to time.
In fact the observations by other navigational personnel are highly desirable.
According to the navigational plan, the designated observer may be relieved by a more experienced and proficient observer in the event that radar must be used as the primary means of insuring the safety of the vessel at some point during the transit. In such event the observer who has been manning the radar should be able to brief his relief rapidly and reliably with respect to the radar situation. Assuming that the previous observer has made optimum range settings according to plan at various points on the track, the new observer should be able to make effective use of the radar almost immediately. If this more proficient observer has been making frequent observations of the radarscope, aided by comment of the observer continuously manning the radar, any briefing requirements on actually relieving the other observer should be minimal.
If radar is to be used effectively in hazardous waters, it is essential that provisions be made for the radar observer and other responsible navigational personnel to be able to inspect the chart in the immediate vicinity of the radar indicator. The practice of leaving a radar indicator installed in the wheelhouse to inspect the chart in the chartroom is highly unsatisfactory in situations requiring prompt and reliable radarscope interpretation. The

radar observer must be able to make frequent inspections of the chart without undue delays between such inspections and subsequent radar observations.
A continuous correlation of the chart and the PPI display is required for reliable radarscope interpretation.
If the navigational plot is maintained on a chart other than that used by the radar observer for radarscope interpretation, the observer's chart should include the basic planning data, such as the intended track, turning bearings, danger bearings, turning ranges, etc.
In planning for the effective use of radar, it is advisable to have a definite procedure and standardized terminology for making verbal reports of radar and visual observations. At points on the track where simultaneous visual and radar observations are to be made, the lack of an adequate reporting procedure will make the required coordination unduly difficult. Reports of radar observations can be simplified through the use of appropriate annotations on the chart and PPI. For example, a charted rock which is identified on the PPI can be designated as "A"; another radar-conspicuous object can be designated as "B," etc.With the chart similarly annotated, the various objects can be reported in accordance with their letter designations.

.2- states the characteristics of object which give poor radar response

Target characteristics

There are several target characteristics which will enable one target to be detected at a greater range than another, or for one target to produce a stronger echo than another target of similar size.

Height

Since radar wave propagation is almost line of sight, the height of the target is of prime importance. If the target does not rise above the radar horizon, the radar beam cannot be reflected from the target. Because of the interference pattern, the target must rise somewhat above the radar horizon.

Size

Up to certain limits, targets having larger reflecting areas will return stronger echoes than targets having smaller reflecting areas. Should a target be wider than the horizontal beam width, the strength of the echoes will not be increased on account of the greater width of the target because the area not exposed to the radar beam at any instant cannot, of course, reflect an echo. Since the vertical dimensions of most targets are small compared to the vertical beam width of marine navigational radars, the beam width limitation is not normally applicable to the vertical dimensions. However, there is a vertical dimension limitation in the case of sloping surfaces or stepped surfaces. In this case, only the projected vertical area lying within the distance equivalent of the pulse length can return echoes at any instant.

Aspect

The aspect of a target is its orientation to the axis of the radar beam. With change in aspect, the effective reflecting area may change, depending upon the shape of the target. The nearer the angle between the reflecting area and the beam axis is to 90°, the greater is the strength of the echo returned to the antenna.

Shape

Targets of identical shape may give echoes of varying strength, depending on aspect. Thus a flat surface at right angles to the radar beam, such as the side of a steel ship or a steep cliff along the shore, will reflect very strong\ echoes. As the aspect changes, this flat surface will tend to reflect more of the energy of the beam away from the antenna, and may give rather weak echoes. A concave surface will tend to focus the radar beam back to the antenna while a convex surface will tend to scatter the energy. A smooth conical surface will not reflect energy back to the antenna. However, echoes may be reflected to the antenna if the conical surface is rough.

Texture

The texture of the target may modify the effects of shape and aspect. A smooth texture tends to increase the reflection qualities, and will increase the strength of the reflection, but unless the aspect and shape of the target are such that the reflection is focused directly back to the antenna, the smooth surface will give a poor radar echo because most of the energy is reflected in another direction. On the other hand, a rough surface will tend to break up the reflection, and will improve the strength of echoes returned from those targets whose shape and aspect normally give weak echoes.

Composition

The ability of various substances to reflect radar pulses depends on the intrinsic electrical properties of those substances. Thus metal and water are good reflectors. Ice is a fair reflector, depending on aspect. Land areas vary in their reflection qualities depending on the amount and type of vegetation and the rock and mineral content. Wood and fiber glass boats are poor reflectors. It must be remembered that all of the characteristics interact with each other to determine the strength of the radar echo, and no factor can be singled out without considering the effects of the others.

.3- Fixes the position fixing based on radar bearing and radar ranges

Radar fixing methods

Range and bearing to a single object

Preferably, radar fixes obtained through measuring the range and bearing to a single object should be limited to small, isolated fixed objects which can be identified with reasonable certainty. In many situations, this method may be the only reliable method which can be employed. If possible, the fix should be based upon a radar range and visual gyro bearing because radar bearings are less accurate than visual gyro bearings. A primary advantage of the method is the rapidity with which a fix can be obtained. A disadvantage is that the fix is based upon only two intersecting position lines, a bearing line and a range arc, obtained from observations of the same object.
Identification mistakes can lead to disaster.

Two or more bearings

Generally, fixes obtained from radar bearings are less accurate than those obtained from intersecting range arcs. The accuracy of fixing by this method is greater when the center bearings of small, isolated, radar-conspicuous objects can be observed.
Because of the rapidity of the method, the method affords a means for initially determining an approximate position for subsequent use in more reliable identification of objects for fixing by means of two or more ranges.

TANGENT BEARINGS

Fixing by tangent bearings is one of the least accurate methods. The use of tangent bearings with a range measurement can provide a fix of reasonably good accuracy.
As illustrated in figure 4.19, the tangent bearing lines intersect at a range from the island observed less than the range as measured because of beam width distortion. Right tangent bearings should be decreased by an estimate of half the horizontal beam width. Left tangent bearings should be increased by the same amount. The fix is taken as that point on the range arc midway between the bearing lines.
It is frequently quite difficult to correlate the left and right extremities of the island as charted with the island image on the PPI. Therefore, even with compensation for half of the beam width, the bearing lines usually will not intersect at the range arc.

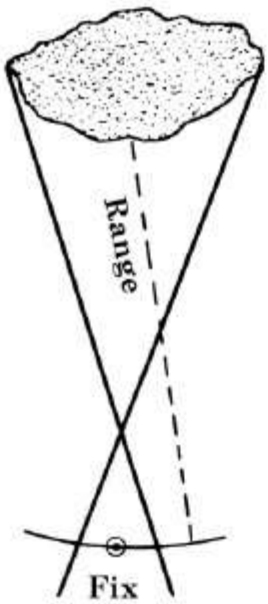


Figure 4.19 - Fixing by tangent bearings and radar range.

In many situations, the more accurate radar fixes are determined from nearly simultaneous measurements of the ranges to two or more fixed objects. Preferably, at least three ranges should be used for the fix. The number of ranges which it is feasible to use in a particular situation is dependent upon the time required for identification and range measurements. In many situations, the use of more than three range arcs for the fix may introduce excessive error because of the time lag between measurements.
If the most rapidly changing range is measured first, the plot will indicate less progress along the intended track than if it were measured last. Thus, less lag in the radar plot from the ship's actual position is obtained through measuring the most rapidly changing ranges last.
Similar to a visual cross-bearing fix, the accuracy of the radar fix is dependent upon the angles of cut of the intersecting position lines (range arcs). For greater accuracy, the objects selected should provide range arcs with angles of cut as close to 90° as is possible.
In cases where two identifiable objects lie in opposite or nearly opposite directions, their range arcs, even though they may intersect at a small angle of cut or may not actually

intersect, in combination with another range arc intersecting them at an angle approaching 90°, may provide a fix of high accuracy (see figure 4.20). The near tangency of the two range arcs indicates accurate measurements and good reliability of the fix with respect to the distance off the land to port and starboard.

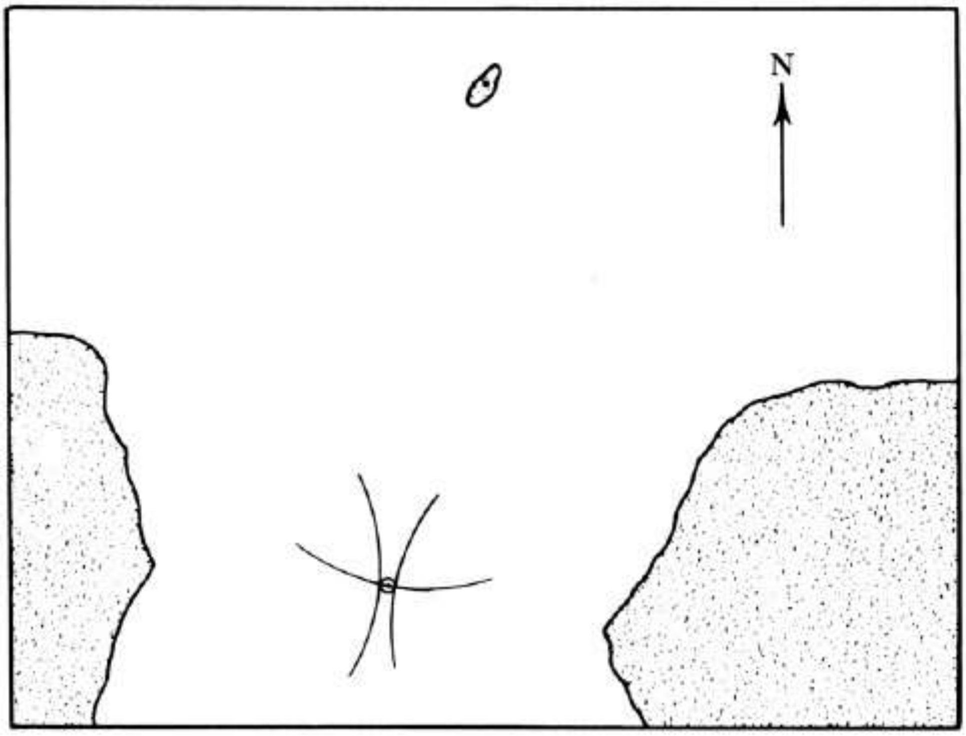
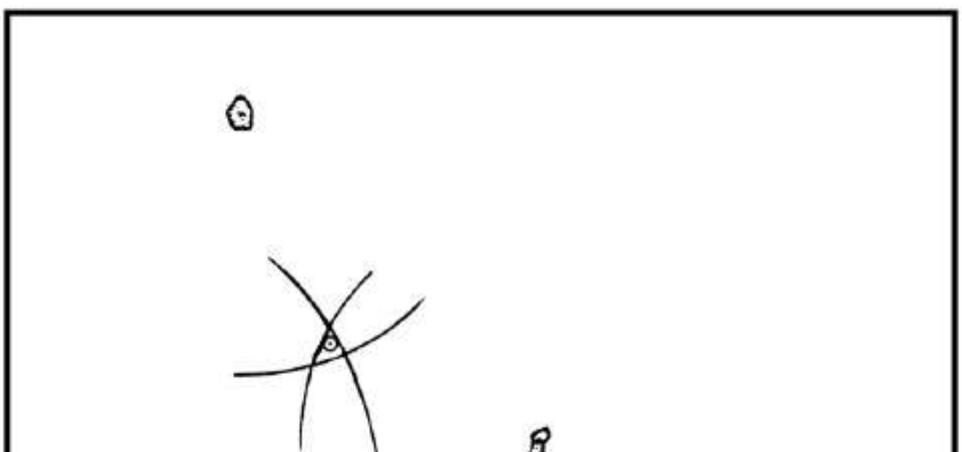


Figure 4.20 - Radar fix.

Small, isolated, radar-conspicuous fixed objects afford the most reliable and accurate means for radar fixing when they are so situated that their associated range arcs intersect at angles approaching 90°.
Figure 4.21 illustrates a fix obtained by measuring the ranges to three well situated radar-conspicuous objects. The fix is based solely upon range measurements in that radar ranges are more accurate than radar bearings even when small objects are observed. Note that in this rather ideal situation, a point fix was not obtained. Because of inherent radar errors, any point fix should be treated as an accident dependent upon plotting errors, the scale of the chart, etc.
While observed radar bearings were not used in establishing the fix as such, the bearings were useful in the identification of the radar-conspicuous objects.



As the ship travels along its track, the three radar-conspicuous objects still afford good fixing capability until such time as the angles of cut of the range arcs have degraded appreciably. At such time, other radar-conspicuous objects should be selected to provide better angles of cut. Preferably, the first new object should be selected and observed before the angles of cut have degraded appreciably. Incorporating the range arc of the new object with range arcs of objects which have provided reliable fixes affords more positive identification of the new object.

.4- Explain possible errors and how to minimize them

The difficulties which may be encountered in radarscope interpretation during a transit may be so great that accurate fixing by means of range arcs is not obtainable. In such circumstances, range arcs having some degree of accuracy can be used to aid in the identification of objects used with the range and bearing method.

With correct identification of the object observed, the accuracy of the fix obtained by the range and bearing to a single object method usually can be improved through the use of a visual gyro bearing instead of the radar bearing. Particularly during periods of low visibility, the navigator should be alert for visual bearings of opportunity.

While the best method or combination of methods for a particular situation must be left to the good judgment of the experienced navigator, factors affecting method selection include:

(1) The general need for redundancy—but not to such extent that too much is attempted with too little aid or means in too little time.
(2) The characteristics of the radar set.
(3) Individual skills.
(4) The navigational situation, including the shipping situation.
(5) The difficulties associated with radarscope interpretation.
(6) Angles of cut of the position lines.

.5- Cross check the accuracy of radar against other navigational aids

Navigation by Pilotage

• In this method, the navigator fixes his position on a map by observing known visible landmarks
• For e.g., in air navigation when the ground is visible the navigator can see the principal features on the ground such as rivers, coastlines, hills etc. and thereby fix his position
• Even at night, light beacons, cities and towns provide information about position of the craft
• Pilotage navigation requires good visibility
• With aid of air-borne radar it is called as Electronic-Pilotage
• The radar used for this purpose is microwave search radar provided with PPI display on which the terrain is mapped
• The PPI picture has poor resolution compared to human eye because the angular resolution is typically 3°
• Electronic-Pilotage has the range of 50 to 100kms that is advantageous in poor visibility.
• Can not applicable over sea.

• Both methods of Pilotage depend upon the availability of accurate maps of the terrain.

.6- Compares Features displayed by radar with character features.

Radar Beacons and Transponders

Ramark

The Ramark is a continuously transmitting beacon, sometimes compared with a lighthouse, and referred to as a "radar lighthouse". Its action is *independent* of own ship's radar. Its signal is detected by ship's radars, causing a bright radial line or a narrow sector of dots and (or) dashes to appear on the PPI showing the true or relative direction of the beacon. Its use is only for direction-finding.

The beacon either uses a *variable* frequency which sweeps through the marine frequency band thus making the signal available to all ships' radars working in that band, or it operates on a *fixed* frequency *outside* the marine radar frequency band. In the latter case the radar set has either to be re-tuned to receive the signal, or a separate receiver is incorporated in the radar set.

Experiments with Ramark transmitters have been carried out in Britain in the past and these have shown that they have a number of operational disadvantages (masking of the picture by many false-indirect and side-echoes). Development in this country was therefore not continued, though beacons of this type are established in Japan, mainly for the use of fishermen.

Racon (Radar Beacon)

This beacon, in the maritime radio-navigation service, is defined as a

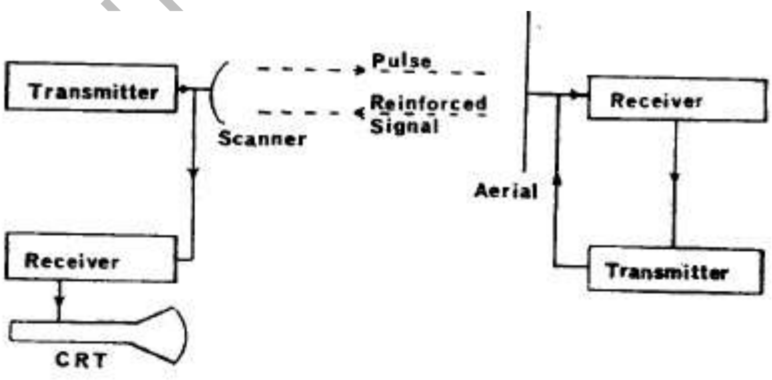


FIG. 11.2 SHIP'S RADAR AND RACON BEACON

automatically returns a distinctive signal which can appear on the display of the triggering radar, and thereby provides range and bearing information .. It is often called "Secondary Radar". See Fig. 11.2.

The Racon consists of a receiver, signal processor and a transmitter, and should be capable of operating in conjunction with any radar equipment working in the marine radar frequency band. The 3 cm. band in which Racons mostly operate, covers the frequency range 9320-9500 MHz, a bandwidth of 180 MHz.

The beacon responds to the pulse transmitted by a ship's radar and it is this pulse which triggers it off. The Racon then transmits a strong signal back which appears on the PPI as a bright radial flash, a series of dots or dashes, or a single morse letter (to provide identity-coding), starting from the Racon echo and making outwards towards the edge of the display.

Hence a Racon echo provides range as well as bearing of the Racon installation from the ship.

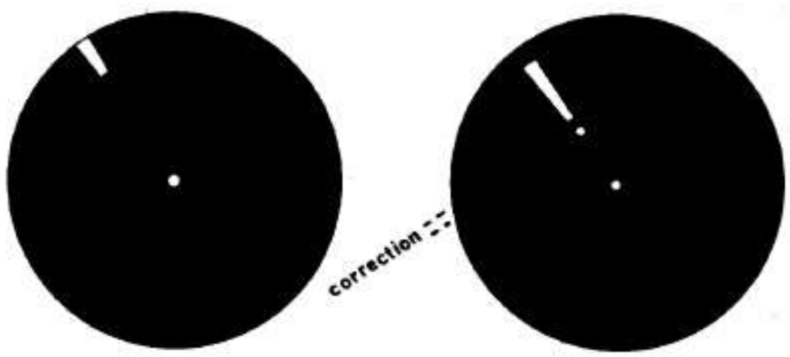


Fig. 11.3 Racon Signal at Long and Short Range

The flash or dots do not start exactly at the range of the echo of the Racon station itself because there is a slight delay in the processor unit of the Racon installation. At short ranges this does not matter because the range can be measured to the Racon station itself, while at long ranges where the Racon station itself is generally not recorded, the range can be measured from the electronic centre to the inner edge of the flash and the small error caused by the slight delay, can be ignored. (Fig. 11.3).

3.2-Radar Navigation Aids

.1- Passive aids(corner reflector) (Recognition and use)

Corner Reflector

A metal device designed for reflecting strong echoes of impinging radar signals towards their source. The *corner reflector* consists of three mutually perpendicular metal plates. Corner reflectors are sometimes assembled in clusters to insure good echo returns from all directions.

RADAR REFLECTORS

Buoys and small boats, particularly those boats constructed of wood, are poor radar targets. Weak fluctuating echoes received from these targets are easily lost in the sea clutter on the radarscope. To aid in the detection of these targets, radar reflectors, of the corner reflector type, may be used. The corner reflectors may be mounted on the tops of buoys or the body of the buoy may be shaped as a corner reflector, as illustrated in figure 4.13.

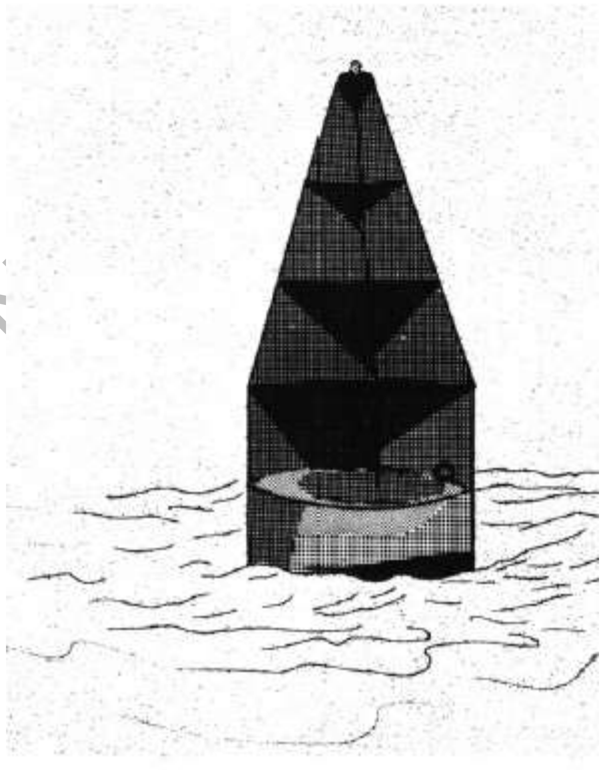


Figure 4.13 - Radar reflector buoy.

Each corner reflector illustrated in figure 4.14 consists of three mutually perpendicular flat metal surfaces.

A radar wave on striking any of the metal surfaces or plates will be reflected back in the direction of its source, i.e., the radar antenna. Maximum energy will be reflected back to the antenna if the axis of the radar beam makes equal angles with all the metal surfaces. Frequently corner reflectors are assembled in clusters to insure receiving strong echoes at the antenna.

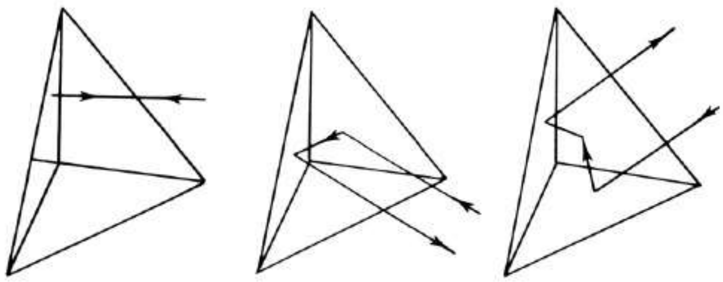


Figure 4.14 - Corner reflectors.

.2- Active Aids (Ramarks, Racon, Echo enhancers, Transponders) Recognition and use

RADAR BEACONS

While radar reflectors are used to obtain stronger echoes from radar targets, other means are required for more positive identification of radar targets. Radar beacons are transmitters operating in the marine radar frequency band which produce distinctive indications on the radarscopes of ships within range of these beacons. There are two general classes of these beacons: *racon* which provides both bearing and range information to the target and *ramark* which provides bearing information only. However, if the ramark installation is detected as an echo on the radarscope, the range will be available also.

From The Use of Radar at Sea, 4th Ed. Copyright 1968, The Institute of Navigation, London. Used by permission.

Figure 4.15 - Racon signal.

Racon is
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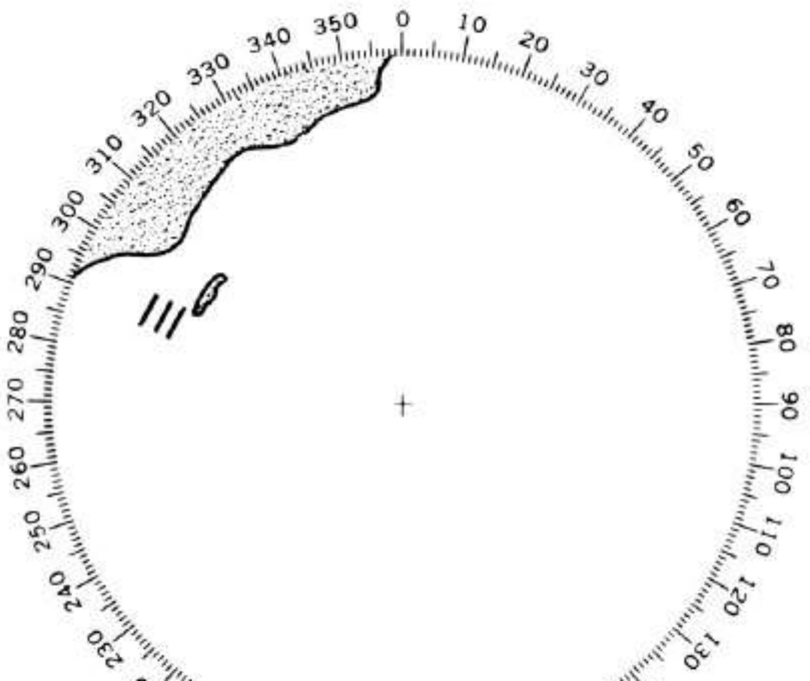
receiver



"Frequency agile" racons are now in widespread use. They respond to both 3 and 10 centimeter radars.

The racon signal appears on the PPI as a radial line originating at a point just beyond the position of the radar beacon or as a Morse code signal displayed radially from just beyond the beacon (see figures 4.15 and 4.16).

Racons are being used as ranges or leading lines. The range is formed by two racons set up behind each other with a separation in the order of 2 to 4 nautical miles. On the PPI scope the "paint" received from the front and rear racons form the range.

Some bridges are now equipped with racons which are suspended under the bridge to provide guidance for safe passage.

The maximum range for racon reception is limited by line of sight.

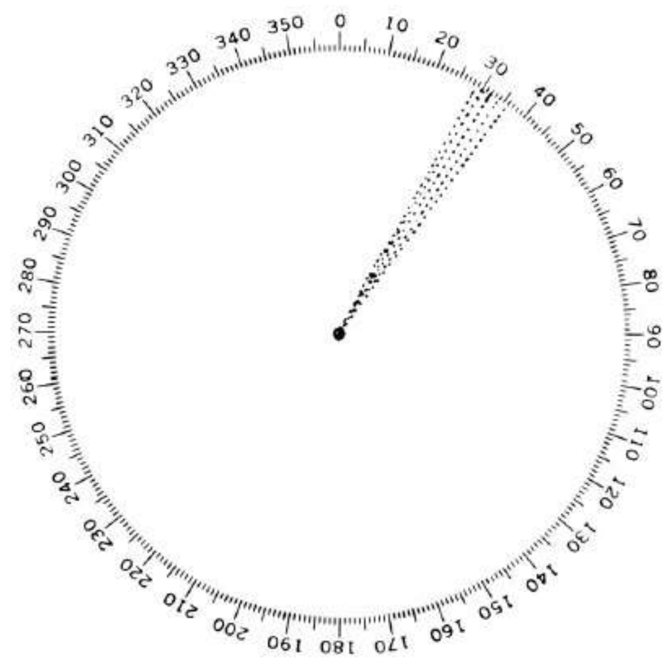
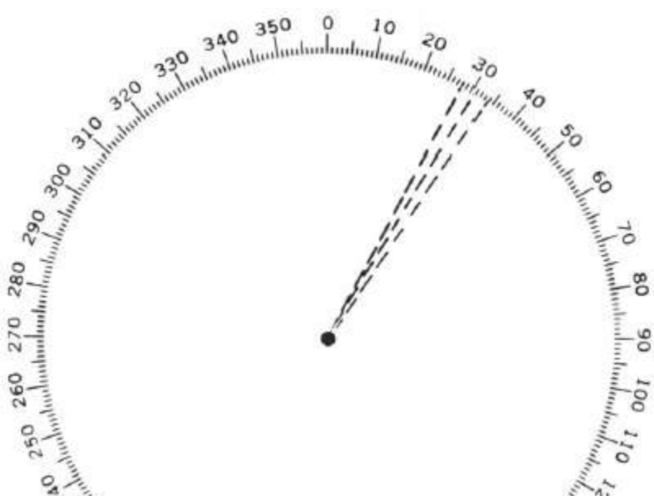


Figure 4.17 - Ramark signal appearing as a dotted line.

Ramark is a radar beacon which transmits either continuously or at intervals. The latter method of transmission is used so that the PPI can be inspected



without any clutter introduced by the ramark signal on the scope. The ramark signal as it appears on the PPI is a radial line from the center. The radial line may be a continuous narrow line, a series of dashes, a series of dots, or a series of dots and dashes (see figures 4.17 and 4.18).

Echo enhancer

Rec. ITU-R M.1176 1 RECOMMENDATION ITU-R M.1176*
TECHNICAL PARAMETERS OF RADAR TARGET ENHANCERS (Question ITU-R 28/8) (1995) Rec. ITU-R M.1176

Summary

Trials of radar target enhancers have indicated that the radar returns from navigation buoys and small craft can be significantly improved by the use of such devices.

This Recommendation provides the technical parameters for radar target enhancers operating in the frequency bands 2 900-3 100 MHz and/or 9 320 (9 300 from 1 January, 2001)-9 500 MHz.

The ITU Radiocommunication Assembly, considering

a) that shipborne radars in the maritime radionavigation service operate in the bands 2 900-3 100 MHz and 9 320 (9 300 from 1 January, 2001)-9 500 MHz;

b) that a transponder is a device that can provide for echo enhancement with the provision that such enhancement should not significantly exceed that which could be achieved by passive means (IMO Resolution A.615(15));

c) that the radar returns from targets such as navigation buoys and small craft can be significantly improved by the use of an active target enhancer consisting of a broadband radio-frequency amplifier, receive and transmit antennas,

.3- SART recognition and use

SEARCH AND RESCUE TRANSPONDER (SART)

A Search and Rescue Transponder (SART) may be triggered by any XBand (3 cm) radar within a range of approximately 8 nautical miles. Each radar pulse received causes it to transmit a response which is swept repetitively across the complete radar frequency band. When interrogated, it first sweeps rapidly (0.4 microseconds) through the band before beginning a relatively slow sweep (7.5 microseconds) through the back band to the starting frequency. This process is repeated for a total of twelve complete cycles. At some point in each sweep, the SART frequency will match that of the interrogating radar and be within the pass band of the radar receiver. If the STRT is within range, the frequency match during each of the 12 slow Rapid radar plotting has been useful for the ocean mariner, but has always been viewed as a burden by the coastal or inland mariner. Some common complaints are listed below:

• I don’t have a reflection plotter!
• I don’t stay on course long enough to plot a target!
• I don’t have time to plot - I’m the only one in the wheelhouse and I have to steer!

Many of these statements are valid, but if one does not use radar plotting or some other form of systematic observation, as required by the Rules of the
Road, that person is missing out on vital information and they are putting themselves and their vessel in an unfavorable position. When the U.S. Coast
Guard N-VIC on radar training for tugboat captains, mates and pilots was issued, it was felt that some sort of useful, practical training should be added to the plotting requirements that have always been part of radar courses.

Because most of the individuals affected by the N-VIC were on tugs or towboats, that practical method of plotting or observation had been geared to the equipment found on board those vessels.

Radar on tugs have small screens and are usually a raster scan head up unstabilized type display. there is no reflection plotter. Because of limited space and time constraints, transfer plotting is not practical. Experience shows that without use, plotting skills deteriorate. To keep these skills sharp, post-it notes and the use of echo trails or the plot feature on certain radar units can be used to substitute for plotting with pencils and rulers. Other variations have been utilized in the past such as tongue depressor or a plastic overlay but the post-it note method seems to be quicker and easier to use. It also deals with the four complaints stated above.

“*I don’t have a reflection plotter.*” In exchange for a reflection plotter, the plot feature on certain small screen radars allows the operator to view the relative track of the target at selected intervals of 15, 30 or 60 seconds or more A continuous track of the target with a timer that counts up in seconds can also be selected. In figure 5.23, a continuous echo trail has been selected and allowed to run for 3 minutes. This is the equivalent of a three minute

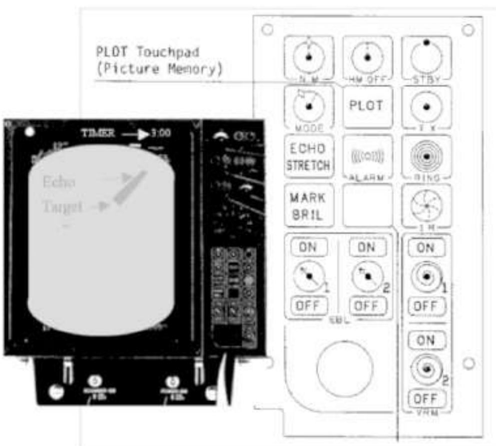


Figure 5.23

"*I don't stay on course long enough to plot a targets* this statement the question is asked, "Do you stay on course for 3 minutes?" The answer is usually "Yes." The plot feature allows the operator to note the time the target began tracking and choose a time interval that is appropriate for the vessel, the range scale used on the radar and the speed of the vessel.

In figure 5.24, our vessel is moving at a speed of 8 knots. A time interval of 3 minutes is selected. Using the 6 minute rule, a vessel moving 8 miles in 60 minutes will move 0.8 miles in 6 minutes (1/10 the time and 1/10 the distance). In order to find the distance traveled in 3 minutes, the distance for 6 minutes is cut in half and a vessel moving 0.8 miles in 6 minutes will move 0.4 miles in 3 minutes (1/2 the time and 1/2 the distance).

The radar range scale in use is 3 miles. A distance of 0.4 miles is measured on the radar using the Variable Range Marker (VRM). Place the ost-it note parallel to the heading flasher and the upper left or right corner touching the 0.4nm VRM. Mark the post-it note at the corner and at the start point of the heading flasher. This measured distance on the pot-it note is the equivalent of a 3-minute segment of our vessel's movement. It is the equivalent of the "er" vector in rapid radar plotting.

Figure 5.24

Repeat the process for the other corner/side of the post-it note. Once made, the post-it note will work for that range scale and speed, and can be stuck to the side of the radar ready for use at any time. Other scales can be mode for different speeds or ranges as needed. This process only takes a few seconds and can be done "on the spot."

"*I don't have time to plot - I'm the only one in the wheelhouse and I have to steer*!" The echo trail allows the single officer in the wheelhouse to "systematically observe" the movement of vessels. The echo trails alone, however will not give the officer much more information than which targets are collision threats. The post-it note will allow the officer to obtain more information. This includes the aspect of the target as well as the ability to obtain the approximate course and speed of the target.
Assume in this example (figure 5.25) that our course is 270 degrees at a speed of 8 knots. To obtain the course and speed of the target place the corner with the first mark on the post-it note at the beginning of the target trail or plot echo parallel to the heading flasher. Observe the direction of a line that would connect the second mark on the post-it note with the target.
This line indicates the course of the target (indicated by a red line). The speed of the target over the 3-minute time period can be compared with the distance we would travel over 3 minutes as indicated by the two marks on the post-it note.

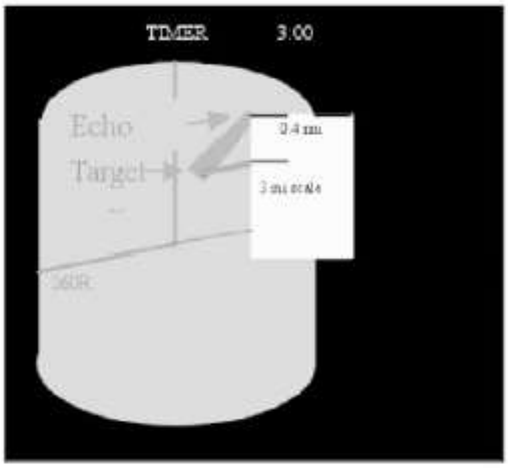


Figure 5.25

If you drew a line drawn from the second mark to the target at the end of a 3 minute interval you can determine the targets course relative to our heading of 270 degrees. The dashed EBL line shown above is parallel to the line drawn from the post-it note to the target position at minute 3.00. It has to be read in the direction from the post-it note to the target (hence the solid line in the direction of 260). With our heading of 270 degrees the relative bearing will read 260 degrees. If you add 260 and 270 (530) and then subtract 360 the target's true course is found to be 170 degrees.
This is shown on the compass rose in figure 5.26.

The length of the line is a little shorter than the distance between marks on the post-it note. This length could be measured at about 0.35nm in three

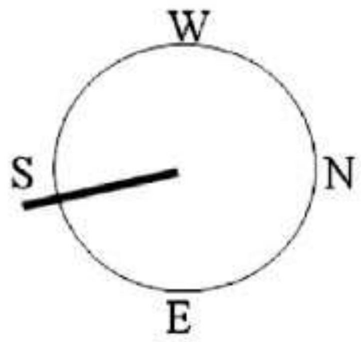


Figure 5.26

minutes which translates to about 7 knots. This line is the equivalent of the target course and speed vector "em" in rapid radar plotting.
A second example is shown in figure 5.27 for a target on a reciprocal course at a speed approximately equal to our own.
Because of the valid statements listed above about the ability to reflection plot, and rules of the road requirement to plot, a practical method of plotting needs to be used. It is hoped the pot-it method will assist the mariner in his efforts to "systematically observe" all targets.

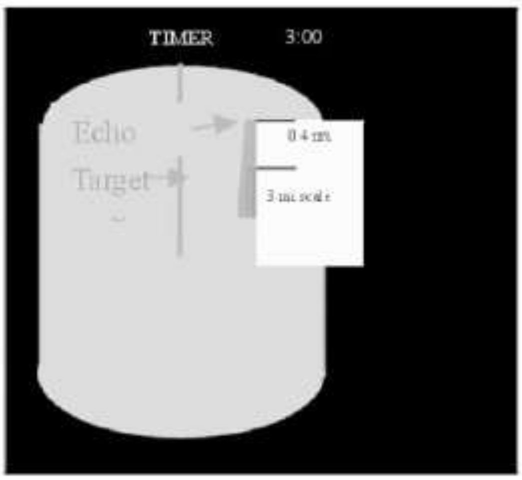


Figure 5.27

.4- Data source information on active and passive aids
Sleeping target

A target symbol indicating the presence and orientation of a vessel equipped with AIS in a certain location. No additional information is presented until activated thus avoiding information overload.
Activated target
A symbol representing the automatic or manual activation of a sleeping target for the display of additional graphically presented information including: – a vector (speed and course over ground); – the heading; and – ROT or direction of turn indication (if available) to display actually initiated course changes.

3.4 Parallel index line Techniques

.1- Set up and uses a PI line by electronic means

Introduction

While navigating from one port to another, it is inevitable that for part of the time the ship will be in confined waters, be it the approaches to the port and berth, or in a busy waterway such as the Dover Strait or Malacca Strait. Leaving aside for the moment any consideration of avoiding collision with other vessels, restrictions on the available sea room require the navigator to monitor the vessel's position, not just with an increased accuracy commensurate with the reduced safety margins and clearing distances imposed upon him, but also with an increased frequency to ensure that environmental and other forces that take the vessel off her desired track are recognized in sufficient time for corrective action to be taken and the vessel to be maintained on a safe track.
Traditionally the navigator would identify the vessel's proximity to the track or danger by putting a fix on the chart, the data for this fix having been obtained from one of a variety of navigation instruments.
Depending upon which navigation system is being used, the time needed to establish the fix will probably be, at best, about two minutes. However, a single fix does not reveal the whole story, merely the ship's position some two minutes ago. Before the navigator can take corrective action, it is necessary to know the trend of the movement, i.e. a series of fixes is required – probably three or more, bearing in mind the inherent imprecision of most fixing systems.
Consequently, there may be a time delay of the order of six to ten minutes between the vessel beginning to deviate from its desired track to the time when proper considered action is taken to return the vessel to safety.
If the reason for the deviation is a five knot crosscurrent and the shoal water is only a few cables away, a reaction time in excess of six minutes is too great.
One might expect that, under conditions such as these, where the shoal water is so close, there ought to be sufficient visual navigation marks nearby to enable the person conning the vessel, be it the master, pilot or officer of the watch, to react almost instantly to any deviation from the planned track. This will probably be the situation in a port approach with moderate to good visibility. In poor visibility, however, when all the visual marks disappear, conning becomes extremely difficult even with the radar giving the relative positions of some of these marks. Consider also the very large vessel fully laden. Its deep draft means that it may be 'confined' to waters well away from port approaches in an area where the navigation marks necessary for the visual conning are sparse.

The usefulness of parallel indexing in the above circumstances is indisputable. There have been numerous incidents of grounding which have resulted from the navigator using a position-monitoring method that had too long a reaction time for the conditions in which the vessel was operating (for instance, the *Metaxa*, and also the *Sundancer* casualties) or where the navigator failed to recognize that the data he was appraising was insufficient on which to base remedial action.

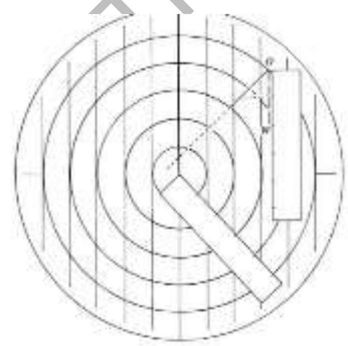
It is in situations like these that parallel indexing shows its true worth by enabling the navigator to monitor the vessel's progress moment by moment and by providing enough data to allow corrective manoeuvres to be made in a time scale which is very similar to that of visual conning, i.e. about two to three minutes.

.2- Construct and uses a PI line on a reflection plotter, where fitted

The practical use of reflection plotters, including the use of the Perspex cursor and parallel index Plotting should be carried out on the plotting surface as if working on a plotting sheet but it is the 'reflections' which must be continually observed. Two techniques are peculiar to reflection plotting:

(a) It will be necessary to make a 'scale' rule for measuring distance on the plotting surface. This is done by brightening the range rings, placing a mark on each ring and then, using stiff card, marking the position of each ring on the card. Sub-divisions may be put in by eye or more precisely, using the variable range marker. See Figure 7.24.

(b) It will be necessary to draw parallel lines on the plotter surface, e.g. *OW* parallel to the heading marker. This is done by lining up the Perspex cursor with the heading marker. The parallel index lines on the cursor will now be parallel with the heading marker. Align the edge of the scale rule with the nearest parallel index line below it – this may meanthat one has to move the position of one's head slightly, or slide the card a short distance.



facilities

Figure 7.24 Constructing and using a scale rule

The facilities for parallel indexing have evolved from the reflection plotter to electronic lines or maps drawn by the user.

Effectively parallel indexing has further evolved into the integration of ARPA or ATA with ECDIS and GNSS where all fixed radar features can be compared with the chart for accuracy, simultaneously checking the GNSS system against the radar.

The simplest parallel index facilities possible are an azimuth-stabilized radar with a reflection plotter.

With this simple system it is usual to use a relative parallel index plot on a relative-motion display. The ability for the user to draw electronic lines on the display has replaced the Perspex reflection plotter.

In fact the lines provided can be relative lines (which remain relative to ownship) or true lines (which are fixed to wherever the system sensors tell the radar the ground remains). The use of electronic lines also means that it is now more straightforward for an azimuth-stabilized radar to use a true parallel index plot, where the user moves the map manually over the radar plot keeping the radar marks in line with marks on the electronic.
The advantage of the true parallel index technique is that the index lines have the same orientation as the chart and take less skill to interpret.
However, this technique becomes far more powerful when the display is additionally automatically ground stabilized.
The automatic ground-stabilization can be provided by:
1 Reference to a known fixed radar target or targets plotted by an ATA or ARPA.
2 Theoretically a ground track dual-axis doppler log, although this would be unusual.
3 Input from a position fixing system such as a GNSS.
The relative motion parallel index plot still has a useful future using electronic lines particularly for use on simple low cost radar displays without speed input but also on more complicated systems for simple parallel index plotting including the 'unplanned' techniques

.3- Takes correct actions when an echo departs from the PI line.

When the ship deviates from its charted track for any reason (collision avoidance, leeway, set), the echo will leave the indexing line and an alteration of course will be required to counteract this, thus bringing the vessel back onto its track.
When indexing without the aid of visual navigation,the question arises 'Which way do I alter? This question resolves itself more readily on some headings than others.
Let s look at the four Cardinalpoint headings:
Course- North

Course — North

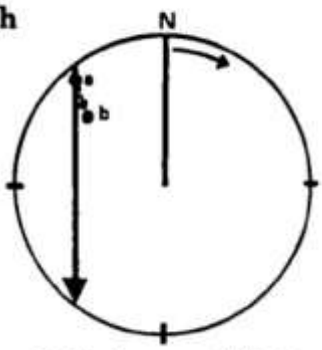
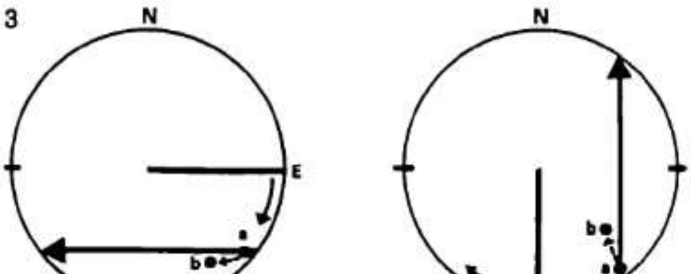


Fig. 2

PPI North up gyro stabilized

figure 2 with the ship steering north, the point of interest should track down the index line in the direction of the arrow. It can be seen that at position a it is doing so but at position 'b' the echo has left the track and is now closer to the ship, so in order to make the line and the echo coincide, the ship must alter course to starboard, the amount of the alteration depending upon the prevailing situation - the larger the alteration the more quickly the line and the echo will come together.

Fig. 3



Course — East In figure 3, on an 090° course, the echo has come off the line at position 'b', i.e. vessel has gone further away from point of interest, so an alteration of course to starboard is required to bring vessel back on course.

Course — South In figure 4, on a 180° course, the echo left the line at 'b' so vessel is too close to point of interest

Course — West In figure 5, on a 270° course, the echo at 'b' indicates the vessel is now too far from the point of interest so an alteration of course to port is required.

It can be seen from the 4 examples on the previous page that the alteration of course by the ship is in such a direction as to always bring the indexing line to the echo. If this principle is remembered, the alteration of course, especially when on a southerly course should raise no doubts in the user s mind.

.4- Uses more than one PI line

IDENTIFYING A RADAR-INCONSPICUOUS OBJECT

Situation:

There is doubt that a pip on the PPI represents the echo from a buoy, a radar-inconspicuous object. On the chart there is a radar-conspicuous object, a rock, in the vicinity of the buoy. The pip of the rock is identified readily on the PPI.

Required:

Identify the pip which is in doubt.

Solution:

(1) Measure the bearing and distance of the buoy from the rock on the chart.

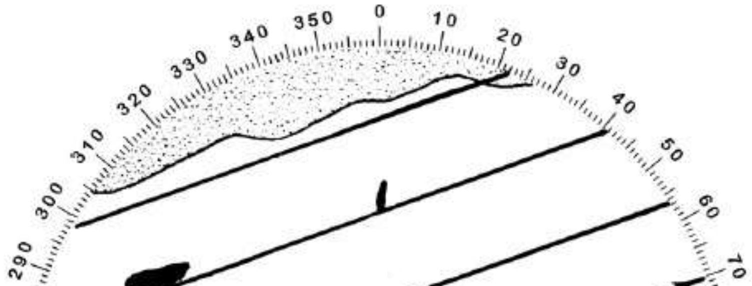
(2) Determine the length of this distance on the PPI according to the range scale setting.

(3) Rotate the parallel-line cursor to the bearing of the buoy from the rock (see figure 4.23).

(4) With rubber-tipped dividers set to the appropriate PPI length, set one point over the pip of the rock; using the parallel lines of the cursor as a guide, set the second point in the direction of the bearing of the buoy from the rock.

(5) With the dividers so set, the second point lies over the unidentified pip. Subject to the accuracy limitations of the measurements and normal prudence, the pip may be evaluated as the echo received from the buoy.

NOTE: During low visibility a radar-conspicuous object can be used similarly to determine whether another ship is fouling an anchorage berth.



FINDING COURSE AND SPEED MADE GOOD BY PARALLEL-LINE CURSOR

Situation:

A ship steaming in fog detects a prominent rock by radar. Because of the unknown effects of current and other factors, the navigator is uncertain of the course and speed being made good.

Required:

To determine the course and speed being made good.

Solution:

(1) Make a timed plot of the rock on the reflection plotter.

(2) Align the parallel-line cursor with the plot to determine the course being made good, which is in a direction opposite to the relative movement (see figure 4.24).

(3) Measure the distance between the first and last plots and using the time interval, determine the speed of relative movement. Since the rock is stationary, the relative speed is equal to that of the ship.

NOTE: This basic technique is useful for determining whether the ship is being set off the intended track in pilot waters. Observing a radar conspicuous object and using the parallel-line cursor, a line is drawn through the radar-conspicuous object in a direction opposite to own ship's course.

By observing the successive positions of the radar-conspicuous object relative to this line, the navigator can determine whether the ship is being set to the left or right of the intended track.

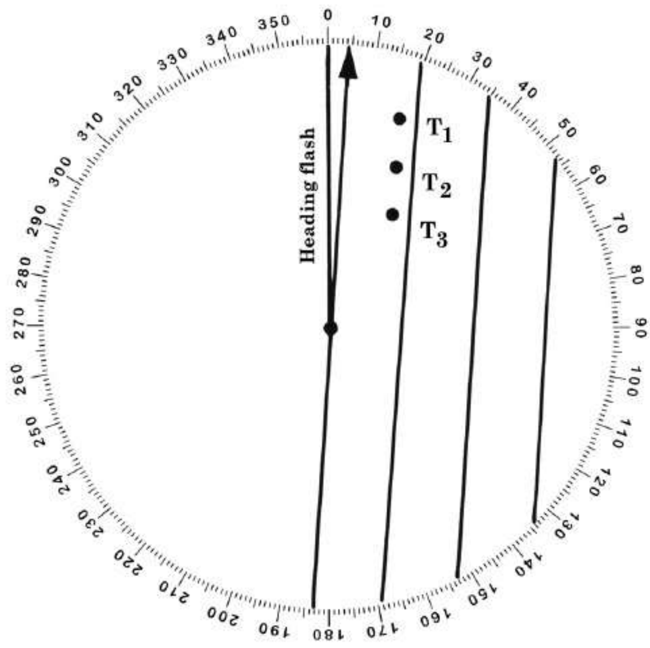


Figure 4.24 - Use of parallel-line cursor to find course and speed made good.

.5- Construct and uses lines for two ranges scales (construction and uses)

Construct of parallel indexing lines using ranging

Up to now we have constructed the parallel indexing lines by transferring the bearing and range of a radar conspicuous object from the charted position of course alterations to the reflection plotter surface.

Many parallel indexing experts prefer another method which uses beam passing distances off a radar conspicuous object. When trans- ferring these ranges to the reflection plotter, only the VRM is required.

Example (see figure 18) A — D represents the safe courses required to be made good. The beacon is radar conspicuous. Before the ship arrives at position A the

Method

1. On the chart lay off, through the radar conspicuous object to be used, lines parallel to the courses to obtain the beam passing distances.
i.e. First course 071° (True) A — B; line A¹ — B¹; beam distance 3.9 miles. Second course 015° (True) B — C; line

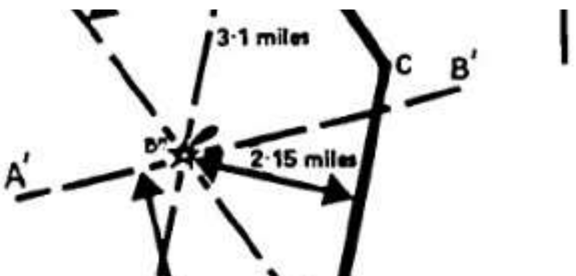


Fig. 18

B¹ — C¹; beam distance 2.15 miles. Third course 323° (True) C — D; line C¹ — D¹; beam distance 2.55 miles.

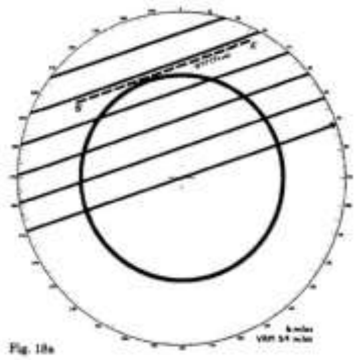


Fig. 18a

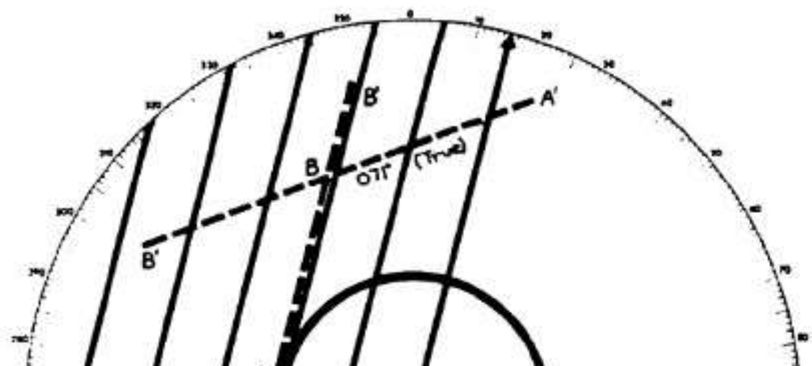
2. On the chart find the ranges of the radar conspicuous object from the starting point A and finishing point D i.e. A distance off — 4.4 miles. D distance off — 3.1 miles. We are now ready to transfer the information obtained on to the reflection plotter.

3. Refer to fig. 18a.

i) Set VRM on range 3.9 miles, beam distance of beacon when on first course 071° (True).

ii) Align mechanical bearing cursor on 071° (True), parallel indexing lines on cursor will now be parallel to 071° (True).

iii) Using Chinagraph pencil and ruler draw in indexing line A¹ — B¹ parallel to 071° line target to the VRM set at 3.9 miles on reflection plotter.



4. Refer to fig. 18b.

i) Set VRM on range 2.15 miles, beam distance of beacon when on second course 015° (True).

ii) Align mechanical bearing cursor on 015° (True); parallel indexing lines on cursor will now be parallel to 015° (True).

iii) Draw in indexing line B¹ — C¹ parallel to 015° tangent to the VRM set at 2.15 miles on the reflection plotter.

iv) Where B¹ — C¹ cuts A¹ — B¹ gives position B, the alteration of course from 071° (True) to 015° (True).

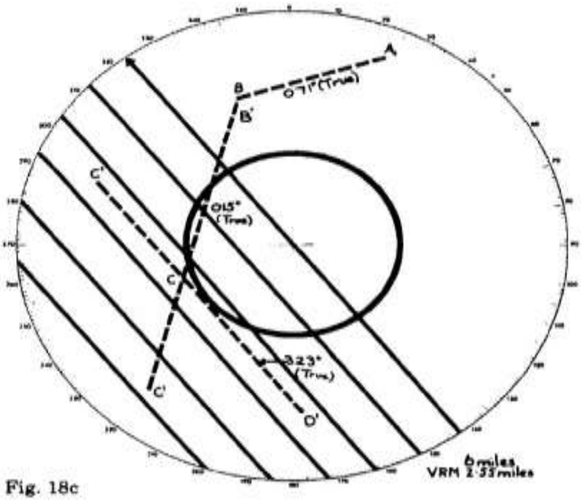


Fig. 18c

5. Refer to fig. 18c.

i) Set VRM on range 2.55 miles, beam distance of beacon when on third course 323° (True).

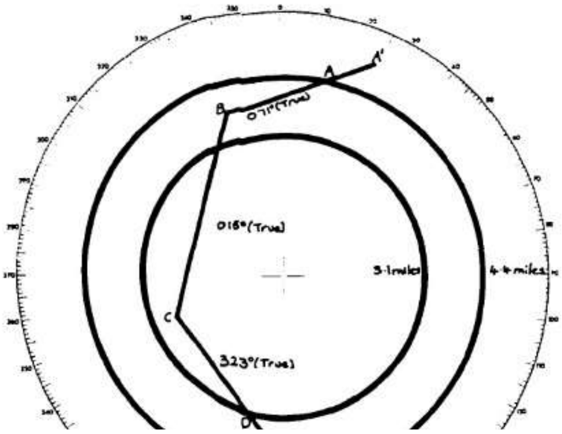
ii) Align mechanical bearing cursor on 323° (True), parallel indexing lines on cursor will now be parallel to 323° (True).

iii) Draw in indexing line C¹ — D¹ parallel to 323° tangent to the VRM set at 2.55 miles on reflection plotter.

iv) Where C¹ — D¹ cuts B¹ — C¹gives position C, the alteration of course from 015° (True) to 323° (True).

6. Refer to fig. 18d.

Finally, the starting point A and the finishing point D can be marked on the reflection plotter.



i) Set the VRM to 4.4 miles, the distance from the radar conspicuous object when at charted position A. Where this range cuts the A¹ — B index (071° (True) course) will give starting point A.

ii) Set the VRM to 3.1 miles, the distance from the radar conspicuous object when at charted position D. Where this range cuts the C — D¹ index (323° (True) course) will give finishing point D.

iii) Erase lines A¹ — A and D¹ — D to complete the indexing.

With practice this method of constructing parallel indexing lines will be more accurate and will take less time if the previous method using bearing and ranges is used.

.6- States the importance of wheel over

When transiting a very confined channel and/or conning a large vessel, it is advisable to plan the wheel over positions using a knowledge of the ship's turning characteristics including any interaction effects. Use of this data should make it possible to keep on the track line required. This information will appear on the chart as a point on the course line spaced a calculated distance prior to the alter-course position. This distance can be used on the display to indicate the point on the index line where the ship should begin to turn. see Figures 8.11(a) and (b).

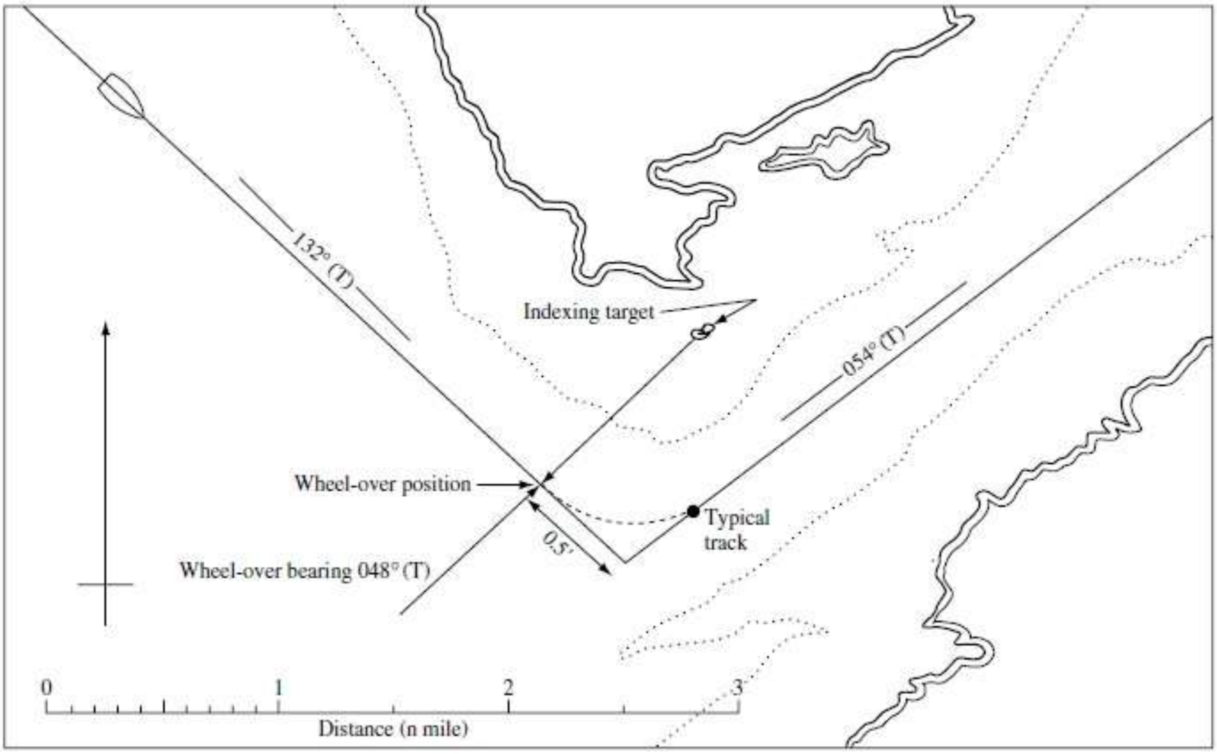


Figure 8.11 Incorporating the wheel-over position
(a) A navigation plan with alter-course and wheel-over positions

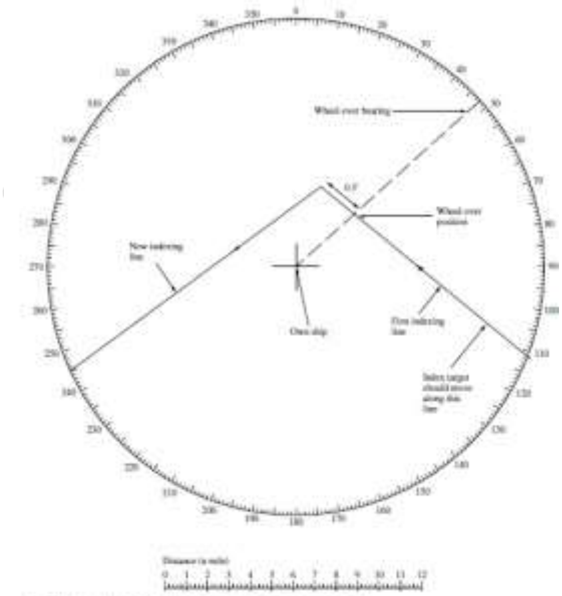


Figure 8.11(b) A parallel indexing plan with the wheel-over position marked

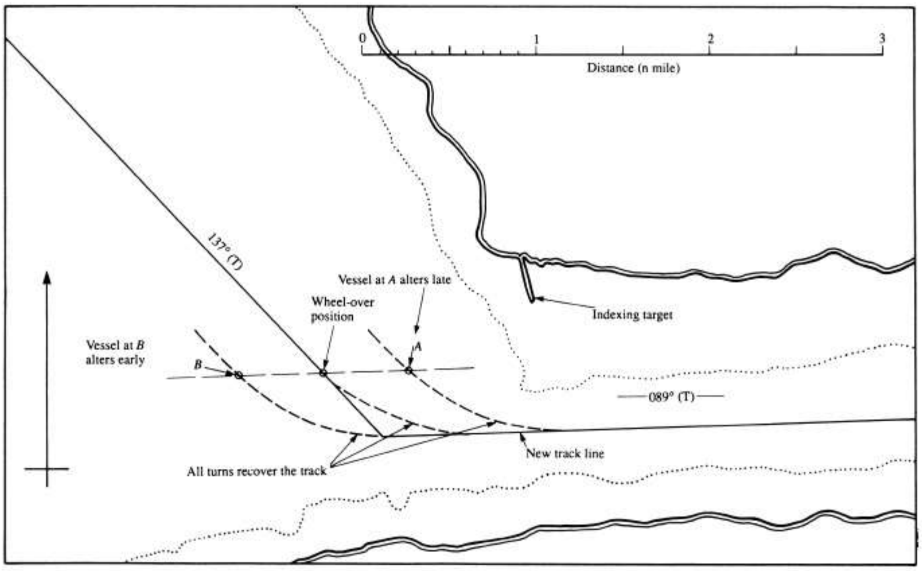
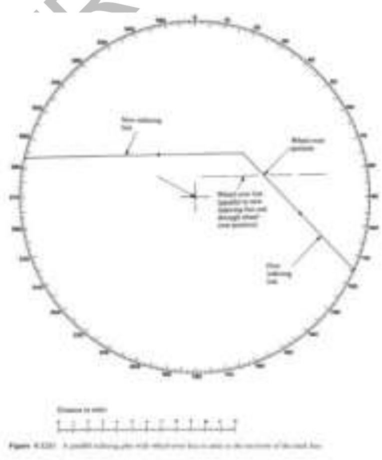


Figure 8.12 Recovering the track
(a) A navigation plan to recover the track line using the wheel-over line

To identify the position at which to begin the alteration of course, a construction line is drawn through the wheel-over position and parallel to the new course line. On the parallel index plot (see Figure 8.12(b)), when the indexing target reaches the construction line through the wheel-over position, the turn begins

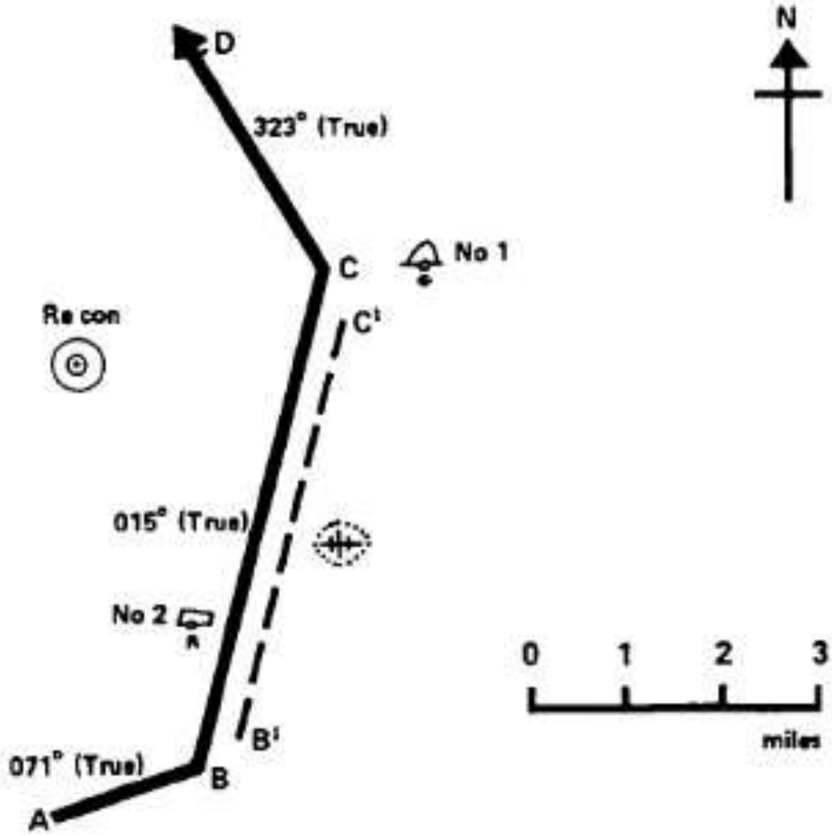


.8- States the importance of safety margins

On the chart shown it would be dangerous to allow the vessel to set too far to the right on the 015 0 (True) course towards the dangerous wreck.

Therefore the $B^1 - C^1$ on the chart might be considered the limit set for any deviation to the right.
This line could be transferred to the reflection plotter thus indicating to the observer just how far the vessel could be allowed to set to the right.

Fig. 6



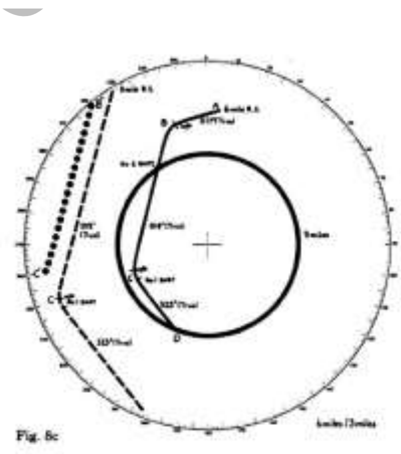
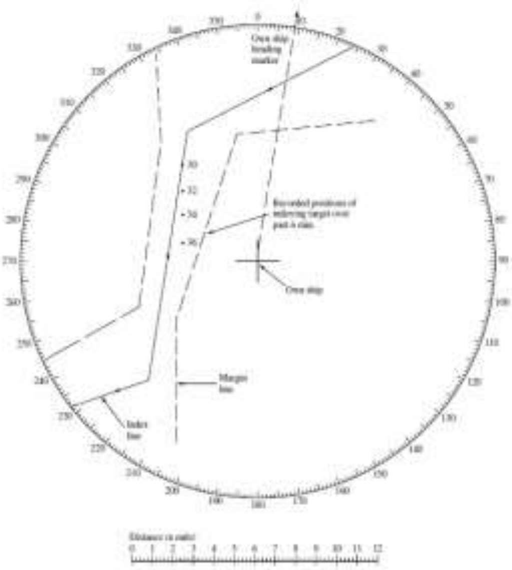


Fig. 8c
Indicating Margins of Safety (refer to figure 6)

.10- Interprets r ... acked echo
toring

The intention wh ... dexing is to keep the indexing target on the relative indexing line that has been drawn for it, or at least within the margin lines

that may apply. To do this the navigator must continuously monitor the movement of the indexing target and take particular note of
(a) the actual position of the indexing target relative to the index line and safety margin lines and
(b) the present trend of movement relative to the desired direction of movement.
Simple observation of the echo and its afterglow can provide this information but on the traditional reflection plotter it was possible to plot the indexing target with grease pencil to make the data more obvious. The actual position of the indexing target relative to the margin lines confirms that the vessel is in safe water and how much sea room is presently available. The trend of movement as provided by the plotting confirms whether or not the vessel is at that time making good the required track. The navigator can now decide, on the basis of these two pieces of information, whether corrective action is needed, either to regain the planned course line or to make good the required track direction.
For example, in Figure 8.13, monitoring the indexing target as the vessel transits the narrow channel shows that over the past few minutes the indexing



target has left the indexing line and is approaching the margin line. This indicates that the ship is being set to the west and that the required corrective action is to turn to starboard by a few degrees so that the indexing target moves back onto the index line, or at least does not move any farther away from it.
Notice that no reference is made to the ship's head in this process because what in fact is relevant here is the course which is being made good rather than the direction in which the ship is pointing. The difference between the two can be large in a tideway when the ship's speed is low. When visibility is restricted, these differences can be very disorientating. It is not being suggested here that the ship's head should be totally

disregarded; obviously there should be some logical relationship between the two directions provided by a knowledge of the tidal set and rate.
As the indexing target moves along the indexing line there is no need to keep the earlier information and plots behind it and these may be progressively cleared from the plotter.
While the vessel is being navigated using parallel indexing it is very important to fix the ship's position on the chart by normal methods at frequent intervals as confirmation that the ship *is* in fact in safe water and *is* in fact moving in agreement with the parallel indexing information.

.11- Take appropriate action to counteract for current

- **on a straight course**

"the manoeuvrability of the vessel with special reference to stopping distance and turning ability in the prevailing conditions";
The manoeuvrability depends on the stern power of the vessel, the number and type of screws, the provision of a bow-thruster, the size of the ship and her loaded condition while the prevailing conditions are mainly governed by the wind and wave directions, wind force and wave height, and current and tidal conditions.

- **When vessel is maneouvring**

Rule 8 (COLREG) is headed "Action to avoid Collision".
Paragraph *(a)* states that, if the circumstances of the case admit, any action shall "be positive, made in ample time and with due regard to the observance of good seamanship".
The word "positive" in this connection means "effective" and bears no relationship to the conventional adaptations "positive and negative actions", mentioned in certain papers about collision-avoidance (more about these later).

.12- Demonstrate use of a line of turn
The Franklin Continuous Radar Plot technique provides means for continuous correlation of a small fixed, radar-conspicuous object with own ship's position and movement relative to a planned track. The technique, as developed by Master Chief Quartermaster Byron E. Franklin, U.S. Navy, while serving aboard USS INTREPID (CVS-11), is a refinement of the parallel-cursor (parallel-index) techniques used as a means for keeping own ship on a planned track or for avoiding navigational hazards.
Ranges and bearings of the conspicuous object from various points, including turning points, on the planned track are transferred from the chart to the reflection plotter mounted on a stabilized relative motion indicator. On plotting the ranges and bearings and connecting them with line segments, the navigator has a visual display of the position of the conspicuous object relative to the path it should follow on the PPI (see figure 4.26).
If the pip of the conspicuous object is painted successively on the constructed path (planned relative movement line or series of such lines), the navigator knows that, within the limits of accuracy of the plot and the radar display, his ship is on the planned track. With the plot labeled with respect to time, he knows whether he is ahead or behind his planned schedule. If the pips are painted to the left or right of the RML, action required

to return to the planned track is readily apparent. However, either of the following rules of thumb may be used:

(1) Using the DRM as the reference direction for any offsets of the pips, the ship is to the left of the planned track if the pips are painted to the left of the planned RML; the ship is to the right of the planned track if the pips are painted to the right of the planned RML.

(2) While facing in the direction of travel of the conspicuous object on the PPI, the ship is to the left or right of the planned track if the pips are painted left or right of the planned RML, respectively.

Through taking such corrective action as is necessary to keep the conspicuous object pip on the RML in accordance with the planned time schedule, continuous radar fixing is, in effect, accomplished. This fixing has the limitation of being based upon the range and bearing method, more subject to identification mistakes than the method using three or more intersecting range arcs.

Except for the limitations of being restricted with respect to the range scale setting and some PPI clutter produced by the construction of the planned RML, the technique does not interfere with the use of the PPI for fixing by other means. Preferably, the technique should be used in conjunction with either visual fixing or fixing by means of three or more intersecting range arcs. Fixing by either means should establish whether the radar-conspicuous object has been identified correctly. With verification that the radar-conspicuous object has been identified correctly, requirements for frequent visual fixes or fixes by range measurements are less critical.

Because of the normal time lag in the latest radar fix plotted on the chart, inspection of the position of the pip of the radar-conspicuous object relative to the planned RML should provide a more timely indication as to whether the ship is to the left or right of the planned track or whether the ship has turned too early or too late according to plan.

Once the radar-conspicuous object has been identified correctly, the planned RML enables rapid re-identification in those situations where the radarscope cannot be observed continuously. Also, this identification of the conspicuous object with respect to its movement along the planned RML provides means for more certain identification of other radar targets.

While the planned RML can be constructed through use of the bearing cursor and the variable range marker (range strobe), the use of plastic templates provides greater flexibility in the use of the technique, particularly when there are requirements for use of more than one range scale setting or a need for shifting to a different radar-conspicuous object during a passage through restricted waters. With a planned RML for a specific radar conspicuous object cut in a plastic template for a specific range scale setting available, the planned RML can be traced rapidly on the PPI. With availability of other templates prepared for different range scale settings or different objects and associated range scale settings, the planned RML as needed can be traced rapidly on the PPI. Other templates can be prepared for alternative planned tracks.

If the range scale setting is continuously adjustable or “rubberized it may be possible to construct the template by tracing the planned track on a chart having a scale which can be duplicated on the PPI. Because the planned RML is opposite to the planned track, the track cut in the template must be rotated 180° prior to tracing the planned RML on the PPI.

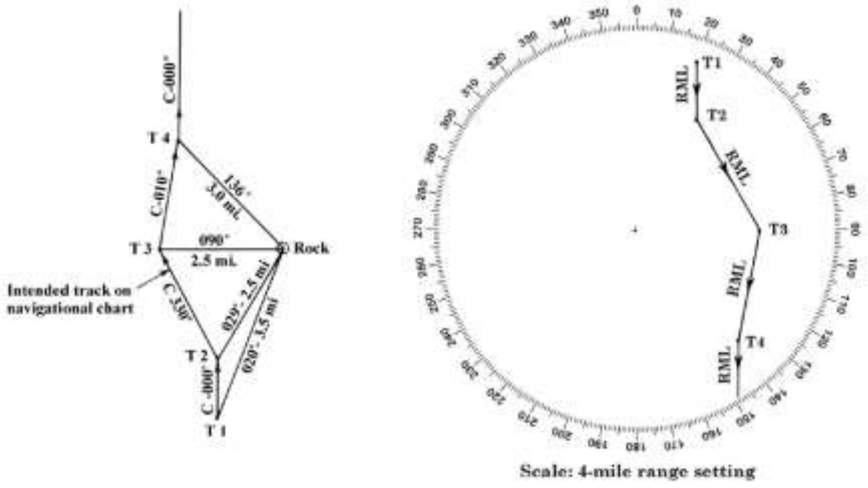


Figure 4.26 - The Franklin continuous radar plot technique.

.13- Construct and use of PI for radial turns

The construction of the plot

(a) The original OAW triangle should have been drawn.

(b) With compasses at W and radius WO, draw an arc.

(c) Draw from W a line at an angle to port or starboard of WO, equal to the proposed alteration of course.

(d) Label as O1 the point at which this line cuts the arc.

(e) Join O1 to A – this now represents the new apparent motion in direction and rate.

(f) Draw in the ship's *new heading line* and expunge the old heading line.

(g) Until the manoeuvre takes place, the target will continue to move down the original apparent motion line. Predict the position of the target at the time at which it is proposed to alter own ship's course and label it O2.

(h) Draw O2A2 parallel with and equal to O1A and produce if necessary to find the new CPA.

Note (a) The prediction is based on the assumption that the target will maintain its course and speed. If the target also manoeuvres then the target will not follow the predicted apparent motion in both direction and rate and a new plot will have to be started.
(b) It is assumed that the alteration of course is instantaneous. For a more practical prediction: (c) When maneuvering at sea, to obtain a more realistic indication of the new CPA, one could predict the effect of the maneuver and check that it is acceptable. If so, bring the ship round to the new course and, when steadied on the new course, plot the position of the target and transfer the new apparent motion, O2A2, through this position.

4. Manual Radar PLOTTING

4.1 Relative motion triangle.

.1- Explain a relative motion triangle, various vectors and angles

PLOTTING

Plotting has two purposes:

(a) It can show us whether danger of collision exists, how close we will pass off the target (nearest approach or distance of the closest point of approach from own ship) and how much time there is left before this will take place.

(b) The approximate determination of the course and the speed of the other vessel from previous observations, so that sensible avoiding action can be taken when needed.

The second purpose is connected with one of the limitations of cm. radar which does not show up the aspect or leading edge of an isolated small (in relation to the horizontal beam-width) target except at very close range.

Plotting does not reveal to us the shape of a target and hence not the present heading. It will inform us, however, about the motion of the target during the plotting interval.

Reporting and Recognition of Collision Hazards

To provide the Master with information about collision hazards, about the possibility of planning avoiding action and about the taking of avoiding action, a good method to be adopted by the radar observer is to report according to a standard pattern. Such a report would consist of two main parts.

1. (a) Last bearing, drawing forward or aft (passing ahead or astern respectively);
   (b) Last range, decreasing or increasing;
   (c) Nearest approach (distance of closest point of approach from own ship) as forecast (CPA);
   (d) Time interval to the nearest approach (closest point of approach) from the last observation (TCP A).

2. (a) True course or relative course or aspect of target;
   (b) Speed of target.

First consider part 1. Whenever an echo is observed on the screen, the Master, especially during reduced visibility, is naturally anxious to know whether there is an appreciable change in the bearing and if the range is increasing or decreasing. H little change in the bearing is observed, and the range is decreasing, at once the question arises how far off will the target pass if both ships maintain their course and speed and how much time is there left before this will occur. Even if there is an appreciable change in the bearing, the Master is likely to want to learn whether the target is passing ahead or astern.
If it is apparent that avoiding action has to be taken, then part 2 must be completed. In that case the Master must know the approximate motion and speed of the target. This is the same as in the visual case where one can only plan avoiding action properly if the other ship's course and speed can be estimated. Alterations of course without establishing the target's direction and speed are irresponsible actions.

The aspect is defined as the relative bearing of own vessel taken from the target. A starboard or port bearing is indicated as Green or Red respectively. For example an aspect of Red 900 means that the target's port side is observed to be beam-on to own ship; a target head-on has zero aspect, stem-on 1800 aspect.

Strictly speaking, as we have seen, the aspect cannot be deduced from a plot, but we will assume that the most probable aspect can be deducedfrom the motion of the target during the plotting interval.

As seen from Fig. 13.1 the direction of movement of the target can be expressed in terms of either her aspect, or relative course or true course and it is entirely up to the Master which he prefers. Often a glance at the plot will suffice.

Aspect appeals to a lot of sailors because it is so closely related to the visual conception when they sight a ship. They automatically estimate the angle between her bearing and her course. It also gives us insight as to whether the target may see us on her starboard or port side or whether own ship is in the overtaking position. Such considerations may help us to form an idea about the possible reactions of the target and they are of special importance when sailing through fogbanks and the Steering and Sailing Rules 11 to 18 must be applied when the fog lifts suddenly.

The report has be be enlarged if avoiding action is going to be taken. Here we must assume initially that the other ship maintains her course and speed. We cannot predict her actions with certainty.

After the alteration of course or reduction in speed, the observer must watch the plot closely and re-estimate the nearest approach and the time when this will take place. If the nearest approach remains dangerous, then the best practice is generally to either reduce speed substantially or to stop own ship or to alter course to put the target right astern. The other ship in such a case, probably, has taken avoiding action at about the same time which has cancelled own ship's action.

If, however, the avoiding action is successful and the nearest estimated approach is safe, then the radar observer can continue his report by informing the Master when the original course or speed can be resumed with safety ..

Two remarks must be made about the nearest approach:

(a) In clear weather, when at close quarters, one can almost immediately see what the other ship is doing and one can act accordingly, if danger of collision is involved. Radar, on the other hand, is not suited for close quarter situations in this connection. Because cm. radar does not possess enough discrimination, it is very slow and sometimes unable to tell us what the other vessel is doing. The target, if she has radar on board, is placed in the same predicament and there is insufficient appreciation on the

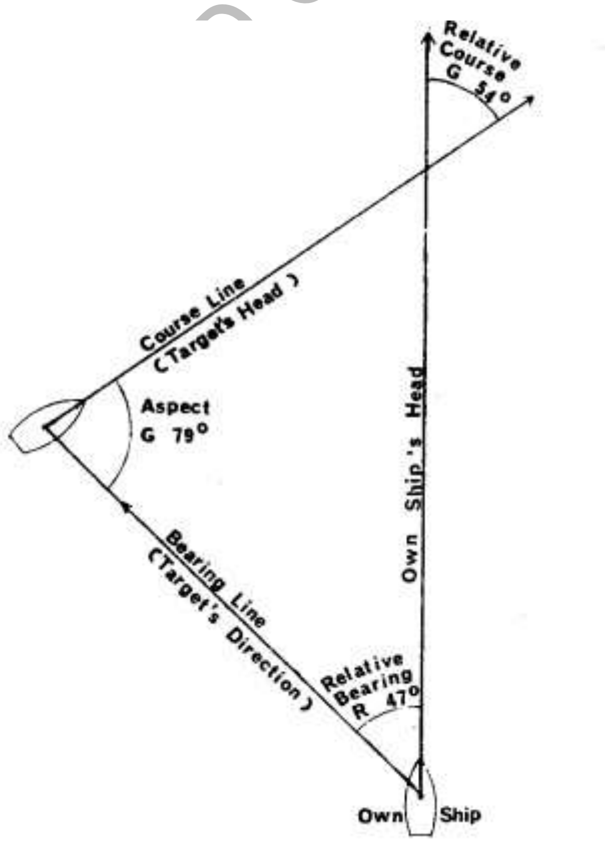


FIG: B.I TARGET'S DIRECTION, TARGET'S HEAD AND ASPECT

part of each vessel of th … cannot use her radar, then, in … on and movements. Hence in … both vessels are using their r

(b) There are many factors which easily cause errors in plotting (Chapter 14) and the nearest approach as obtained from the plot may differ considerably from the actual value.

Therefore taking these two considerations into account, the new nearest approach selected should not be too small. Give the target a wide berth. The situation is not the same as when in clear weather.

It is good practice generally, in the open sea, for the Master to base his plan for taking avoiding action on a bold alteration of course and/ or speed initially so that the other ship, if she is using radar, will be able to detect own ship's action as quickly as possible. Mter taking avoiding action careful plotting should be continued to see if the other vessel is keeping her course and speed. H she does, then a prediction should be made from the plot when it will be safe for own vessel to resume her original course and/ or speed. The following three factors should then be taken into consideration:

(i) The closest distance which one considers it safe to pass the other vessel under the existing circumstances (three miles is generally accepted as a safe minimum distance for average types of merchant ships in the open sea).

(ii) The time factor. In case the other vessel is using radar she should be allowed to have sufficient time to detect own ship's alteration in course and/ or speed (a minimum of about twelve minutes is generally considered necessary).

(iii) If own ship took action by altering course to bring the echo across froin the starboard to the port side or vice versa, then, when the original course is resumed, care should be taken to avoid, if at all possible, bringing the echo back to the opposite side again (if this was done a misunderstanding of the situation might arise if both vessels suddenly came into sight of one another).

The report can be computed either by plotting on a sheet of paper or directly on a screen covering the PPI, or by mechanical or electronic plotting devices. There are two main types of plots:

(a) Relative Motion Plot.

(b) True Motion Plot.

.2- Construct a relative motion triangle on a plotting chart

Relative Motion Plot

The motion of the echo is plotted relative to own ship, which is considered as a fixed reference point. In other words, the motion is plotted as it appears on a Relative Motion Radar Display. The centre-point of the plot represents the electronic centre of the radar screen, i.e. own ship. The heading marker, representing the fore and aft-line of own vessel, is drawn on the plot and indicates the direction of own course.

All the plots shown in the following diagrams, are referred to as Compass Datum Relative Plots. This means that the compass bearing scale is fixed. When course is altered, the heading marker swings round in the same way as it does on a stabilized display, and the movement of the echo is not broken up as it would be on a Head-up Relative Motion Display. The relative bearing scale is not used, though one can, if one wishes, lay-off relative bearings from the heading marker wherever this is positioned.

In nearly all the diagrams it is assumed that North is "up". One may, of course, if this is preferred, always start off with the heading marker upwards, provided one turns the heading marker to the new direction when course is altered. By turning the plot bodily around one could then bring the new heading marker to the upward position again.

After putting in the heading marker, the different bearings (relative to the heading marker or true) and ranges are plotted from the centre-point travelled by own ship in 12 minutes, i.e. a distance of 12/60 X own speed. However, at the end of the plotting interval, the echo is not at W, but at A (00 12 hrs.). This can only mean that WA must represent the true motion of the target during these 12 minutes. Measure WA, multiply by 60/12 and the speed of the target is obtained (in practice, one compares the length of WA to the length of WO and estimates the speed relative to own ship's speed). Measure angle 0WA and the relative course of the target is known. The aspect can also be read off. In the diagram, the aspect is roughly Red 70°.

Items 2 (a) and 2 (b) of the report are now established. If the WO component is plotted during the time interval, then nearest approach, course and speed of the target are obtained simultaneously.

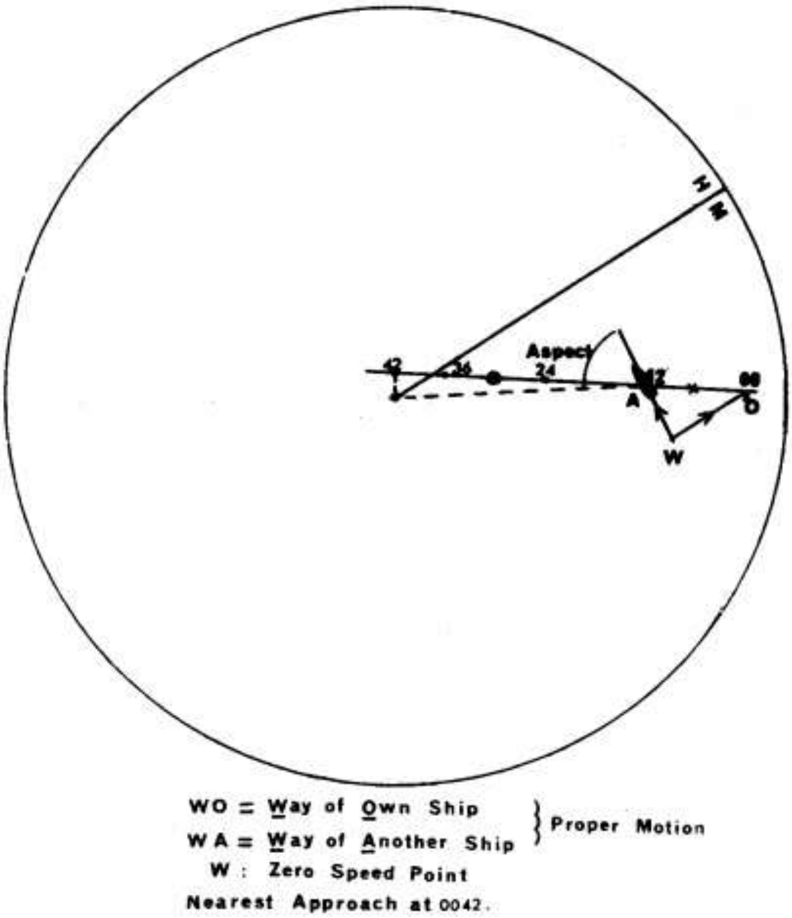
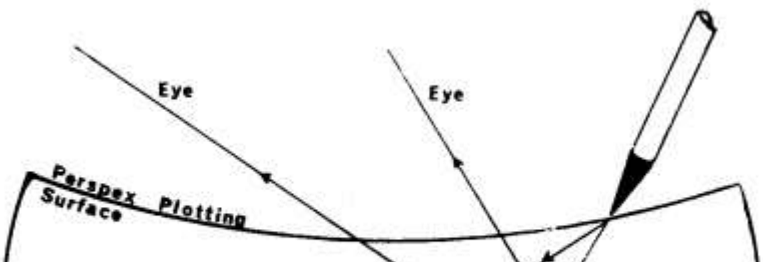


FIG. 13.3 DETERMINATION OF COURSE AND SPEED OF TARGET

An advantage of p ... icer to acquire a better ... ting the true meaning o ... can be useful on those ... are many echoes, it he ...

.3- Constı ... ıere available

The plot is carriec ... ting screen and the PF ... the avoidance of paral ... ıdar echo, then the ima ... ·om whatever direction ... ting light is switched off, the marks disappear and the screen can be observed normally. Different colour wax pencils can be employed to trace the echoes of different ships



On a Relative Motion· Stabilized Display the usual Relative Motion Plot is produced; on a True Motion or Track Indicator Display a True Motion Plot is constructed. Although the scale of the plot is small the result it yields are often more ~urate than those obtained from a larger scale transferred plot. The reason for this is that blunders can be more easily made when observing bearings and ranges of several targets at once and in laying them off on the plotting sheet, whereas with a reflection plotter the positions of the echoes are not so likely to be marked incorrectly on the screen.

To draw lines on the reflection plotter small plastic rulers are provided. The edge of such rulers can be marked with the chinagraph pencil, showing distances appropriate to the scale in use. The distance scale in the vicinity of the plot should be used - to avoid errors due to non-linearity of the time-base. Note that care should be taken when using an Unstabilized Display. In this case, for the sake of accuracy, it is essential to make sure that the ship is right on course at the moment the position of the echoes are being marked on the reflection plotter. When the vessel is yawing, it is recommended to ask someone to sing out when the ship is on course.

Plotting Board and Track Plotter

The Plotting Board, made by radar manufacturers, consists of a flat sheet of glass which can be marked with wax pencils. Concealed edge illumination with controllable brilliance allows plotting to be carried out in darkness. A time/speed distance table, illuminated in the same way, is incorporated in the plotting surface. Bearing and distance can be quickly laid-off by means of a Track Plotter. This Track Plotter consists of a bearing and range scale, suspended by means of a parallel linkage system thus providing translational but no rotational movements.

The whole assembly is mounted on a in. baseboard for securing to an existing table, or it can be supplied in a console with provision for a built-in illuminated clock, timer, log repeater and distance counter.

The Plotting Board and Track Plotter are extremely suitable for carrying out a True Motion Plot. Near land, for this purpose, a navigational chart can be inserted under the plotting surface.

4.2- Course , speed and aspect of a target ship

.1- Determine course, speed and aspect of other ships from a relative presentation (stabilized and unstabilized)

Since the radar is carried along by the vessel as it proceeds, the direct measurements obtainable are always *relative to the observing vessel.* Thus, in order to determine the true courses and speeds of other vessels, it is necessary to resolve this observed relative or apparent motion into its components by using a knowledge of own ship's true course and speed. The means by which this may be achieved ranges from pencil-on-paper plotting sheets via reflection plotters and true-motion displays to computer based collision avoidance systems. Irrespective of the mechanism used, if a complete appreciation of the dynamic situation in the vicinity of own ship is to be obtained, the relative motion of targets must be systematically recorded and the true motion derived by means of a plot. The techniques employed to extract the relevant data and the use to which it is put will

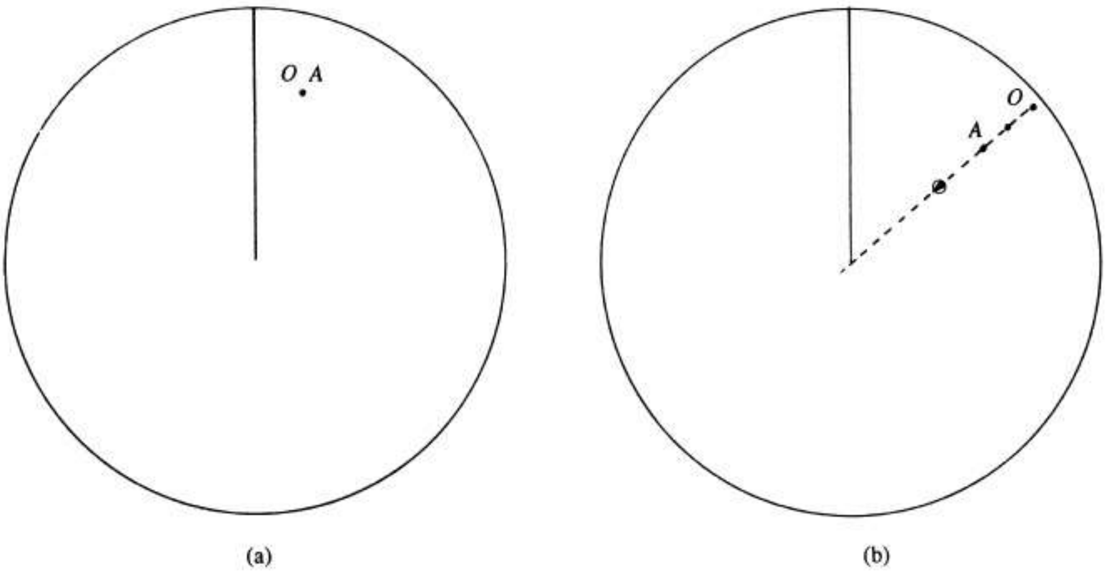
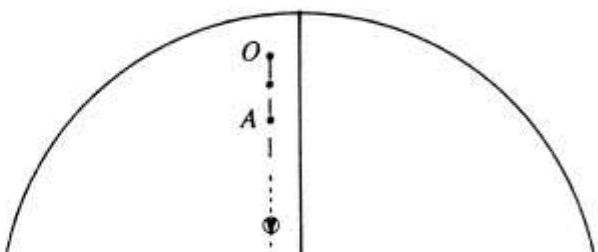
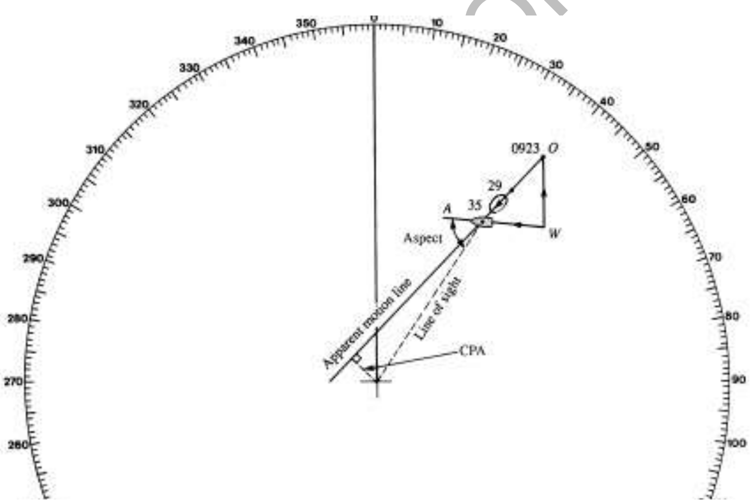


Figure 7.1 Common misinterpretations of relative-motion displays
(a) The target, believed to be stopped, is in fact on the same course and at the same speed as own ship
(b) A vessel which might be expected, if observed visually at night, to be showing both sidelights, i.e. to be head-on and to present no threat, is in fact crossing broad starboard-to-port and on a collision course

vessels maintain their present courses and speeds. If this condition is not met, the apparent motion will not be uniform, i.e. the echo will not move across the screen in a constant direction at a constant rate.

It is important to realize that the measurements obtained thus far are only subject to those errors inherent in the radar system itself, the azimuth stabilization and in the observations. They are therefore uncontaminated by errors (or blunders) to which other inputs – notably own ship's speed – might be subjected. For this reason, relative





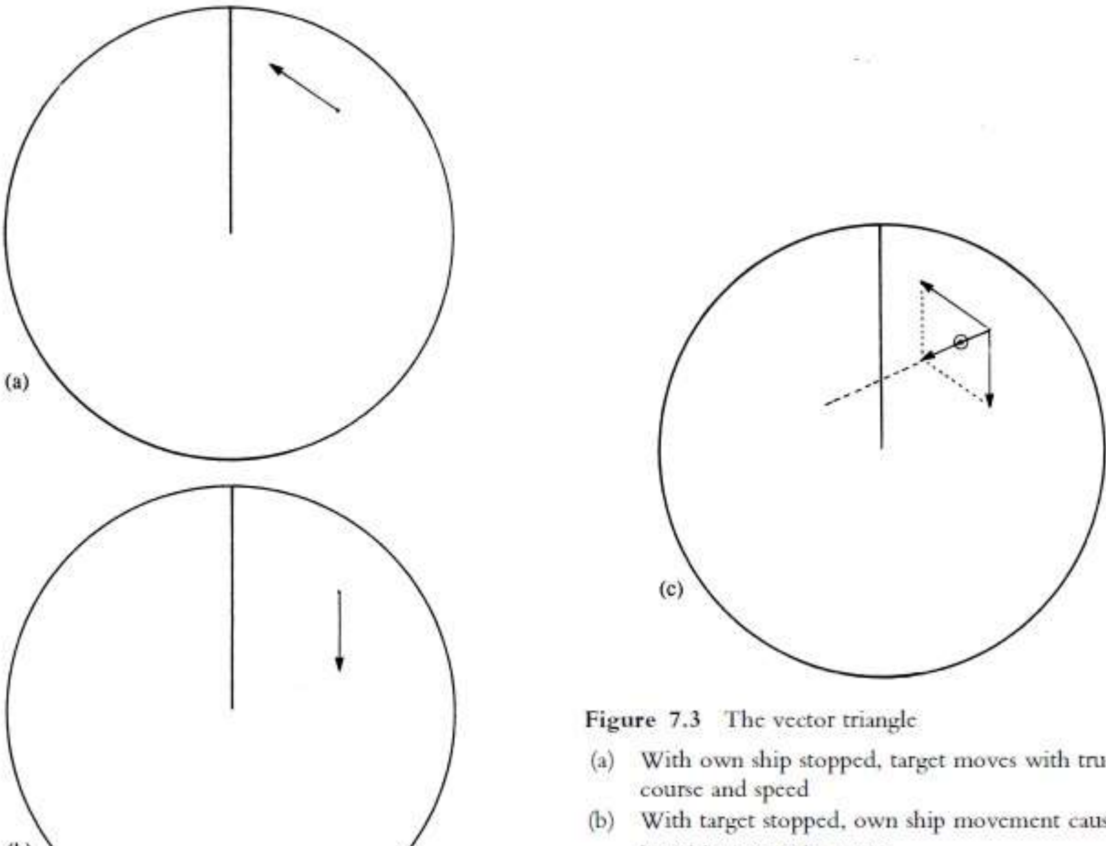


Figure 7.3 The vector triangle

(a) With own ship stopped, target moves with true course and speed

(b) With target stopped, own ship movement causes the

Example 7.1 While steering 090_(T) at 12 knots, the echo of a vessel is observed as follows:

0923 echo bearing 127_(T) at 9.5 n mile
0929 echo bearing 126_(T) at 8.0 n mile
0935 echo bearing 124_(T) at 6.5 n mile

At 0935, determine the target's true course and speed; CPA and TCPA; and aspect.

The data relating to the target in Figure 7.4 as extracted from the plot at 0935 is as follows:
Course: 008_(T) CPA: 1.0 n mile Aspect: Red 65_ Speed: 11 kn TCPA: in 26 min

The construction of the plot

(a) Draw in own ship's heading line on the plotting sheet.
(b) Plot the first position of the target. Label it O. Insert the time.

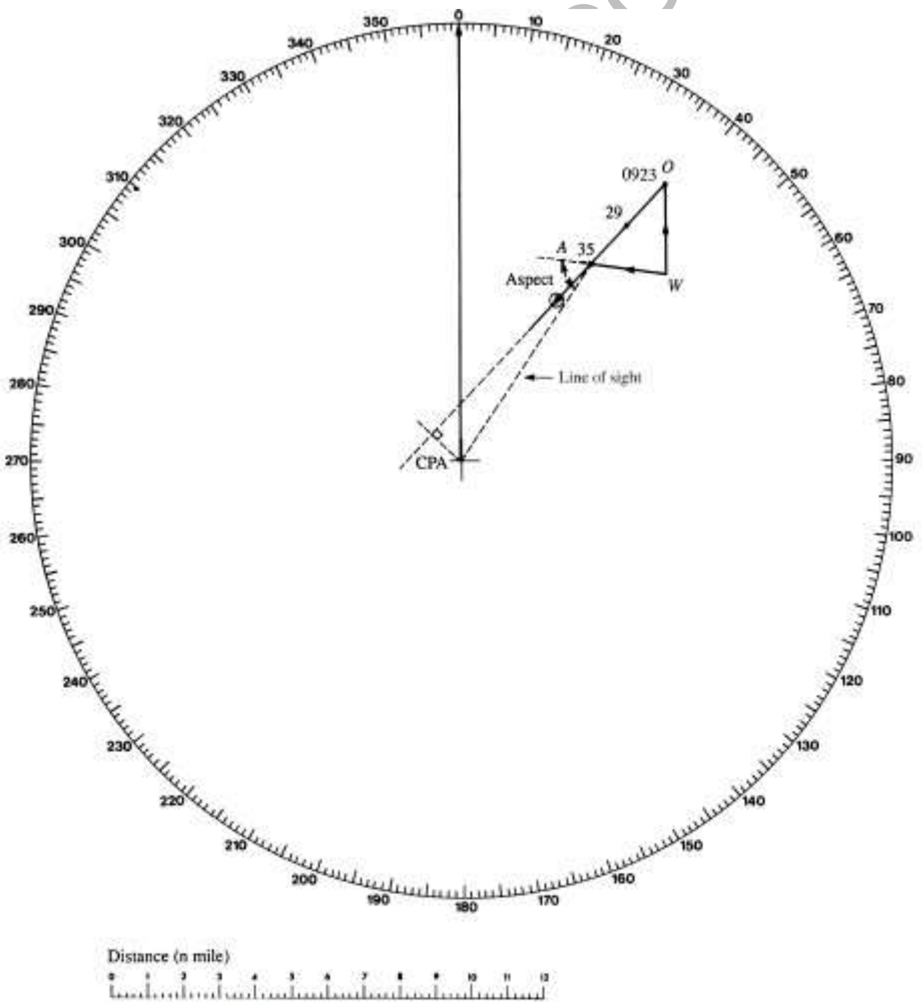


Figure 7.4 (a) The relative plot for Example 7.1 Ship's head up

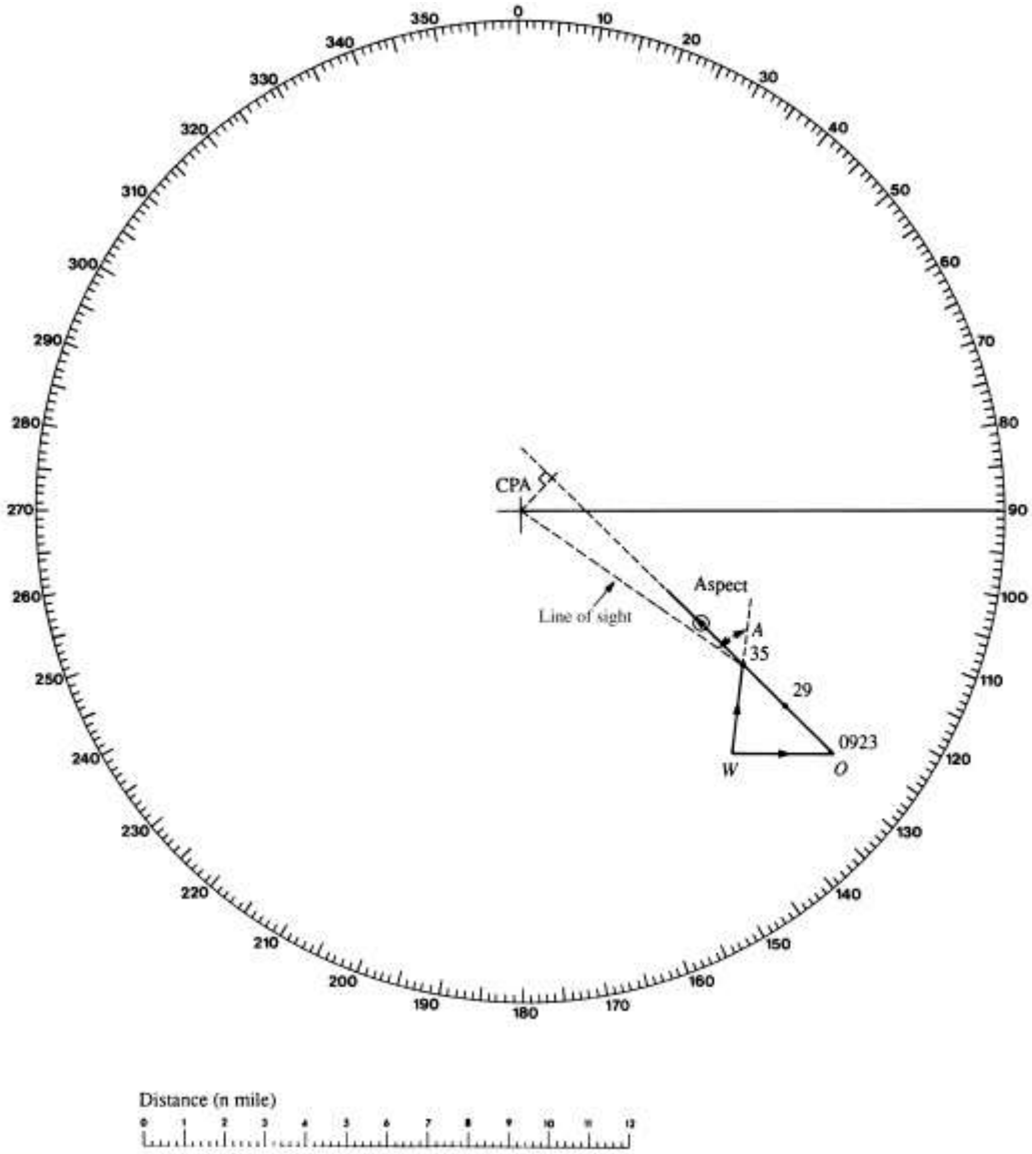


Figure 7.4(b) True north up

(c) Lay off a line to represent the apparent motion of a stationary target, from O, opposite to the direction of the heading line.
(d) Plot at least one intermediate position of the target to ascertain that its apparent motion is not changing. Insert the time.
(e) Plot the final position, with the time, and label it A. Ensure that the apparent motion is consistent in direction and rate. Join OA and label it thus: _←
(f) Produce the apparent motion line OA to find the closest point of approach (CPA) and the time to closest point of approach (TCPA).
(g) The 'plotting interval' is the time between the readings of range and bearing for O and A. Calculate the distance that own ship has steamed in this time and plot the position in

which you would expect to find the stationary target W at the end of the plotting interval. (OW is derived from own ship's speed and course reversed.)
(h) If A and W coincide, the target is stationary. If they do not, the line W to A represents the proper motion of the target in the plotting interval.
(i) 'Aspect' is measured between the 'line of sight' and the WA direction as in Figure 7.4.
It can be seen that, whichever orientation is used for the plot, the answers obtained will be the same, but some consideration must be given to the actual practicalities of plotting and the way in which the results are to be used. Where it is not possible to compass-stabilize the radar display, the ship's-head-up display will be the obvious choice.
Where the radar display is capable of being compass stabilized, it makes good sense to orientate the plot in the same way as the radar display, i.e. true-north-up when the radar display is true-north-up etc., especially when the vessel is on a southerly heading. There can be considerable confusion and even potential danger in trying to relate a ship's-head-up plot to a displayed radar picture which is 'upside down' e.g. when heading south. On the other hand, when conning the vessel and therefore relating the plot to the visual scene ahead of the vessel, it is sensible to orientate the display and to plot ship's-head-up or course-up accordingly.

The practicalities of plotting

The way in which the plot is constructed in practice is very different from the way in which one theoretically tackles a plot. In the first place, ranges and bearings are obtained only at intervals of some 3 to 6 minutes (not all at the same time), and it is unlikely that the plotter will be able to enjoy the luxury of radar plotting as a dedicated task, having rather to dovetail this activity into the many other bridge duties.
If plotting is not to become all-consuming or if it results in peaks and troughs of activity, some wrinkles will have to be adopted to assist in spreading the load:

(a) Always draw in the heading line before starting to plot.
(b) When a target is first plotted, draw in OW and graduate it in 3-minute steps up to about 12 minutes. This is not to suggest that one should plot slavishly at 3-minute intervals but, rather, that one should plot when the opportunity arises and interpolate visually between the 3-minute graduations on the OW line.

The frequency with which the target should be plotted is dependent on a number of factors, namely, the range, the approach rate and the CPA. A target which is closing fast will require more frequent plots than, say, one which the observing vessel is slowly overhauling.

(c) Make a quick, early plot after, say, 3 minutes. Although the triangle will be small and not particularly accurate, it will give early warning of the potential of the encounter which is arising and allow time for some pre-planning. *Do not wait 12 minutes* before drawing the first triangle.
(d) Obtain at least three consistently spaced positions in a reasonably straight line before being prepared to make a decision based on the plot.
(e) Plotted positions should be in a reasonably straight line and spaced at distance intervals which are related to the time intervals between the plots. Where a plotted position appears significantly different from what is anticipated, it should be investigated immediately for an error either in reading the range and bearing from

the radar or in plotting the position. Where a change in apparent motion is found to have occurred, a new triangle should be started.

(f) Only essential lines should be put on the plot and then kept to a minimum in length. Extending WA beyond A should be avoided as it can be dangerously misleading and mistaken for an indication of CPA. On the other hand, OA should *not* be stopped short but extended at least beyond CPA.

(g) It can be extremely helpful, especially when other officers are likely to observe the plot, to adopt some standard form of labelling (the labelling used in all figures in this text conforms with the United Kingdom Department of Transport's recommendations).

(h) Times should be placed alongside each plotted position. This is essential when the plotting interval varies as it can justify the unequal spacing of the positions. 'Minutes' are quite sufficient, with the occasional indication of the hour.

(i) TCPA should be given as the 'time to elapse', i.e. 'CPA in 16 minutes' rather than 'CPA at 1743' which is far less meaningful to someone who has then to check the time and subtract mentally. Also, time to elapse will in itself convey the degree of urgency in the situation.

(j) After some 12 minutes there should be no real need to continue plotting bigger and bigger triangles, but it is essential to continue to plot positions and ensure that the target's apparent motion is being maintained. As soon as the apparent motion is observed to change, a new plot should be commenced

(k) Neatness is essential at all times. An untidy plot – lines everywhere, no labels, with times not related closely to plots, crossings out etc. – is likely to be more of a hindrance than a help. There is no merit in a plot which even the plotter has difficulty in understanding.

(l) The range scale on which to plot requires some consideration. As a general rule, plots should be initiated on the 12 n mile range scale, but two differing requirements can arise. Where targets are likely to be closing fast, the earlier the plot is commenced the better, in which case the 12 n mile range scale should be adequate; when targets are close, a shorter (3 or 6 n mile) scale should be in use, possibly off-centred. The advantages of the shorter range scale are that there is better intrinsic accuracy and that changes in the target's movement are quickly and easily identifiable. As a target closes, a shorter range scale should be selected, but the plotter should, at intervals, temporarily return to the longer range scale(s) to search for newly arrived targets which could be a potential threat.

.2- Determine course, speed and aspect of other ships from a true presentation

The need to extract numerical data

Plotting theory provides for the extraction of data in numerical form but this takes time and is needed only rarely. Also, the precision with which it is displayed often belies its accuracy and therefore the reliance which can be placed upon it.

Of the information normally available on a clearly constructed plot, CPA and the target's aspect/course should be directly observable with sufficient accuracy and without precise measurement. The target's speed should be mentally assessable by visual comparison with own ship's speed vector, i.e. by comparing WA with WO, which is known. By this means, the target's aspect/course, speed and CPA should be obtainable with sufficient accuracy for the practical assessment of the situation and only TCPA will require some form of measurement.

The true plot

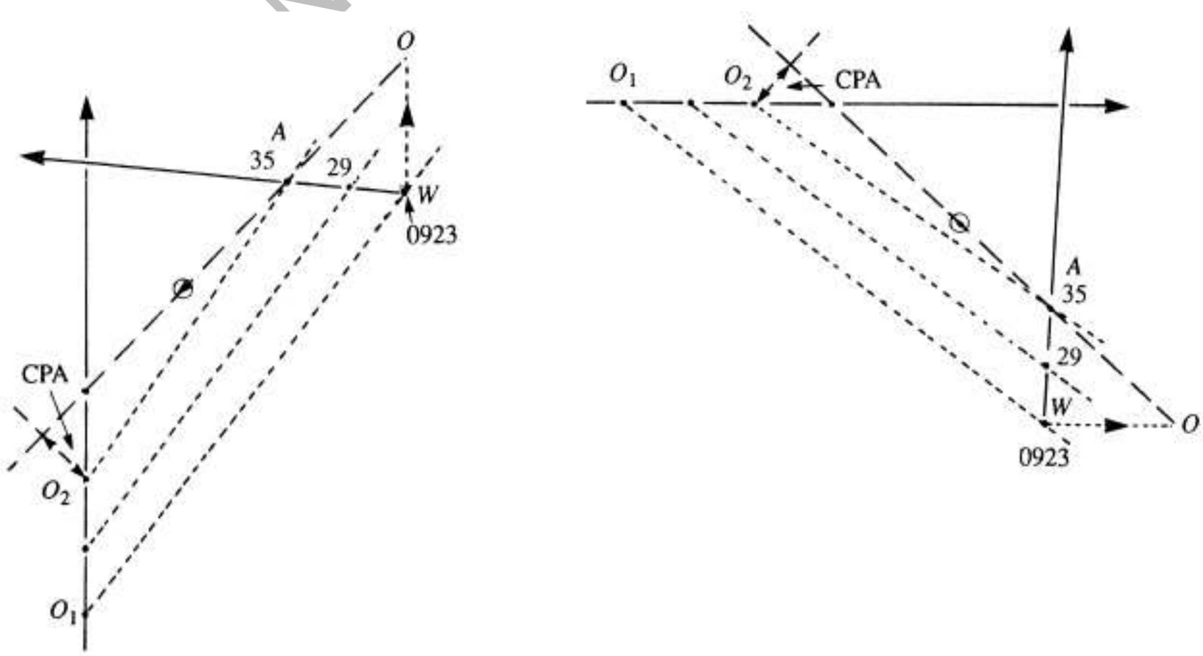
The data given in Example 7.1 can be plotted on graph paper or on the chart as a 'true plot' (Figure 7.6).

In this case, own ship's course line is laid off on the plotting sheet and own position marked. From this position the bearing and range of the target are laid off. Own ship's position at, say, 3 minute intervals is then marked off along the course line. What will be obtained directly is the target's course and the distance travelled in the plotting interval but, as already stated, perhaps the most important single piece of information available from a plot is the target's CPA, which is not immediately available and must be determined by the following geometrical construction:

(a) Lay off a line WO, parallel with the course line and of a length equal to the distance that own ship has travelled in the plotting interval.

(b) Join O to the current position of the target A and extend OA to pass O2 i.e. own ship's current position, thus giving CPA. The static situation is identical with that depicted in Figure 7.4 and the required information is extracted in the same way. To this extent, relative and true plots are equally valid, but some practical points are worth noting:

(i) The convenience of a bearing scale and range circles on a relative plotting sheet are not



(a) Ships head up

(b) True north up

Figure 7.6 The true plot for Example 7.1

(iii) Any error in plotting own ship's position (i.e. an error in the course and/or speed input) will result in an error in the directly obtained answer, i.e. the course and speed of the target.

Note. If this error is repeated when laying off WO the CPA of the target will in fact be correct.

(iv) Perhaps the most disconcerting product of this plotting technique is the temporary nature of the apparent-motion line. (Figure 7.7). It is essential to appreciate that the 'displayed' CPA relates to *only one* own ship position, after which the apparent motion line can be at worst misleading. Where a number of targets are being plotted on the same sheet, apparent-motion lines can relate to *different* own ship positions.

In general, where manual plotting has to be carried out, time is of the essence and in this respect the relative plot is better. For this reason the subsequent treatment will assume the use of the relative plot except in the case of reflection plotting on a true motion display. In the latter case, a true plot can be easily and quickly produced.

.3- Takes ranges ad bearings at frequent, regular intervals

Errors in Plotting Errors in plotting can be due to:

(i) Errors in bearings;

(ii) Errors in ranges;

(iii) Wrong estimation of the course and distance followed by own ship during the plotting interval, Le. an error in own ship's velocity;

(iv) Errors in the time of the plotting interval.

Errors in bearings taken on the Relative Motion Non-Stabilized Display can be out ± 2° The chance in errors in bearings taken on a Stabilized Display is less and the greatest bearing accuracy is obtained on a Stabilized Display with an electronic curzor, although errors in the time interval of the plot may occur with some electronic curzors which are difficult to align quickly.

Errors in ranges can attain a maximum value of I ~% of the maximum range of the range scale in use. In diagrams 14.1, 14.2 and 14.3 two observations are plotted. It is logical that errors due to wrong bearings and ranges can occur in each observation but the discussion will be easier to understand if we assume that there is no error in the first observation while the total errors of both is concentrated round the second observation. Such assumption does not affect the final conclusion. In some of the diagrams "A" is depicted as a circle. This means that on account of bearings and range errors - which to certain limits are unknown - "A" can be anywhere within the circle. Let us now have a closer look at the diagrams. Figure 14.1 shows the effect on the plotting triangle owing to errors in bearings and ranges. All the three ships, P, Q and R are on near-collision courses. Ship P's speed is slow compared with own ship's speed but the speeds of ship's Q and R are nearly the same as the speed of own ship. Large percentage errors may be made in the estimated course and/ or speed of the very slow ship P and much smaller errors may occur in the estimated speed (ignoring the course error) of the other vessel coming from a direction fine on the bow (Q) or in the estimated course (ignoring speed error) of the other vessel, coming from a direction broad on the bow (R). Figure 14.2 shows the effect on the plotting triangle owing to errors in the estimated speed of the observer's ship. All the three ships, X, Yand Z are on near-collision courses. Large errors may occur in the estimated course of the other ship if her speed is slow compared with own ship's speed (X). Much smaller errors may be made in the estimation of course and speed where the speed of the other vessel is nearly the same as the speed of own ship (Y and Z).

The conclusion can be summed up as follows: (a) Errors in ranges and bearings and errors in own estimated speed:
may give rise to large estimated course and speed errors of another vessel on a near-collision course if her speed is slow compared with that of own ship's speed. These errors become smaller for ships on near-collision courses which have speeds similar to that of the speed of own ship. They may be confined mainly to errors in estimated speed or estimated course, depending on the relative direction of approach of the other vessel.

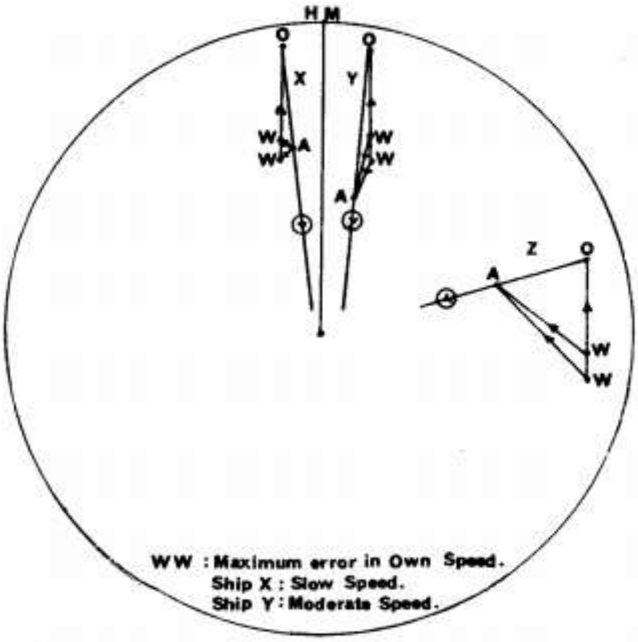


FIG. 14.2 EFFECT ON PLOTTING TRIANGLE OWING TO ERRORS IN ESTIMATED SPEED OF THE OBSERVER'S SHIP

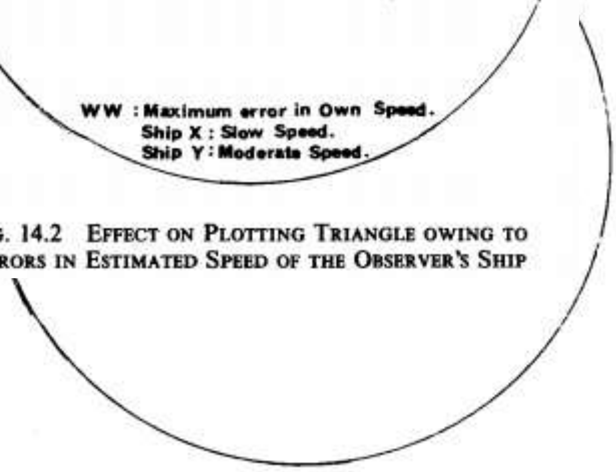


FIG. 14.1 EFFECT ON PLOTTING TRIANGLE OWING TO ERRORS IN BEARINGS AND RANGES

(b) Slow speed of a target vessel makes the plot very unreliable. It is generally impossible to find out from a plot whether another vessel is steaming slowly, or is stopped. When a target vessel is stopped, it is, of course, impossible to deduce aspect or heading. The unfortunate consequence must be faced that during fog when most ships slow down, the plots tend to become less accurate.

(c) Doubling the plotting interval will halve the chance of errors in nearest approach. Results obtained from plotting are often not very accurate. However, the navigator can take comfort from the fact that when the results are inaccurate the situation is generally not very dangerous and conversely, when the situation is potentially dangerous the plot is generally sufficiently accurate to help him in planning satisfactory action. For example, when

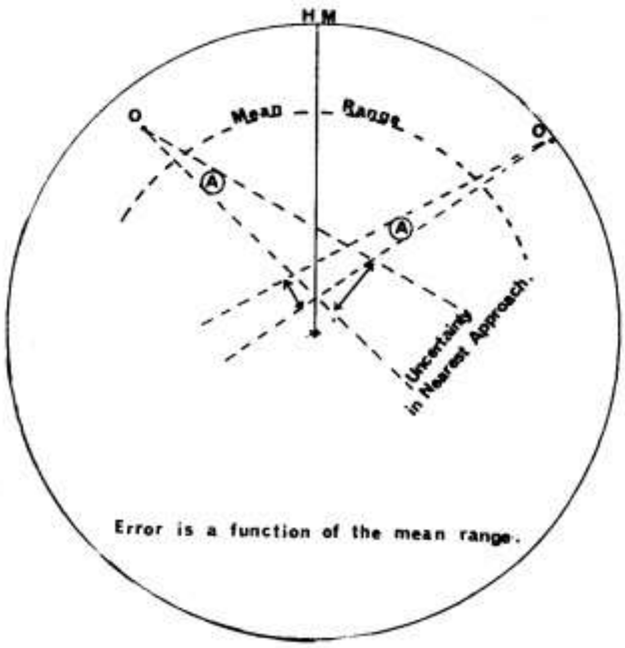


FIG. 14.3 A GREATER PLOTTING INTERVAL DECREASES THE UNCERTAINTY IN THE PREDICTED NEAREST APPROACH

the OA line is short, the accuracy of the predicted nearest approach is poor but as the relative motion is small, there is usually plenty of time for more observations of the echo to be plotted so that a more accurate estimate of the time and distance of the predicted nearest approach can be found.

Again, when the target is moving slowly, the course of the target cannot be accurately obtained - but, obviously when a target is moving slowly it is not likely to present much of a hazard and a knowledge of its precise course is not so essential.

.4- State the factors affecting the accuracy of derived course, speed and aspect.

Manual plotting – accuracy and errors

The error in the result from any computation depends upon the accuracy of the data used. The intrinsic sources of error in the radar system relate to the measurement of ranges and bearings. Other data needed to complete the radar plot and subject to error are own ship's course and speed, and the plotting interval. Also, there are of course personal errors and blunders. While a *constant* (or systematic) error in input will result in a constant error in the answer obtained, it is the errors which are of a random nature which govern the size of the 'circle of uncertainty' around the plotted position which, if not actually drawn, should be borne in mind when plotting a position.

Note Precision of measurement and accuracy of measurement should not be confused. For example, it is no good being able to measure bearings to 0_1_ if the 'free play' in the mechanical gearing is +/- 2°

Accuracy of bearings as plotted.

Errors in bearings may arise from any of the following causes:

1 The existence of inherent errors which fall within the limits allowed by the IMO Performance Standard. The individual error sources are discussed in detail in

It is also indicated that some components of the total error can be expected to remain constant over a series of bearings and these will have the effect of slewing all plotted positions by a fixed amount. There will, of course, be a random component which is most likely to arise from an instantaneous misalignment of the antenna and trace and should not exceed +/-1°. This error will have the effect of scattering the observed positions about the correct apparent motion.

2 Parallax when bearings are taken with a Perspex cursor.

3 Failure to centre the origin correctly when use is to be made of a Perspex cursor.

4 Errors of alignment of the electronic bearing line.

5 Failure to check the heading at the time a bearing is taken when a ship's-head-up unstabilized orientation is selected. This error is likely to be random.

6 Personal errors and blunders.

Accuracy of own ship's speed

In general, the means of obtaining the ship's speed can be flawed in the extreme and is the quantity most susceptible to error. Speed (or rather, distance travelled in the plotting interval) can be derived from a variety of sources, for example:

1 *Distance (towed) log*. In this case, it is not possible to know one's speed quickly, particularly when altering speed (e.g. in poor visibility). Also, it is common practice to hand the log when the engines are put on stand-by, so as to avoid fouling the propeller when the engines are put astern (some towed logs do have an additional unit which provide a read-out of speed.

2 *Speed (pitot, impeller, electromagnetic) log*. Although the speed may be read at any instant, the sensor is frequently withdrawn when the vessel is in shallow water, e.g. in port approaches.

3 *Engine revolutions*. This is only accurate in so far as 'slip' is accurately known and this is rarely the case when changing speed such as when Manoeuvring in fog.

4 *Doppler log*. It should be borne in mind that if ground locked, this indicates speed over the ground which in tide can lead to misinterpretation of the aspects of

other ships. Also, there is some uncertainty as to just what 'speed' is being measured if using a single-axis sensor which is 'ground locked'.

5 *Speed derived from positions plotted on the chart or GNSS*. There is a common misconception that this is the ship's 'correct' speed and on this basis it is used for plotting and as the manual input to the true-motion unit and ARPA

It must be remembered that the speed derived is measured over the ground, whereas it is the speed through the water which is required for plotting. Thus, if there is any tide involved, its effect *must* be allowed for in order to deduce the water speed.

Note The slower own ship's speed, the greater will be the proportionate effects of errors in the knowledge of own ship's speed. Unfortunately, the plot can be at its most inaccurate when both vessels are moving slowly as they might be when proceeding in fog.

Accuracy of own ship's course

Compass error should be small and relatively constant so, although it will produce errors in target course and speed, they too should be small and constant. Where the ship is off course for minutes at a time and this

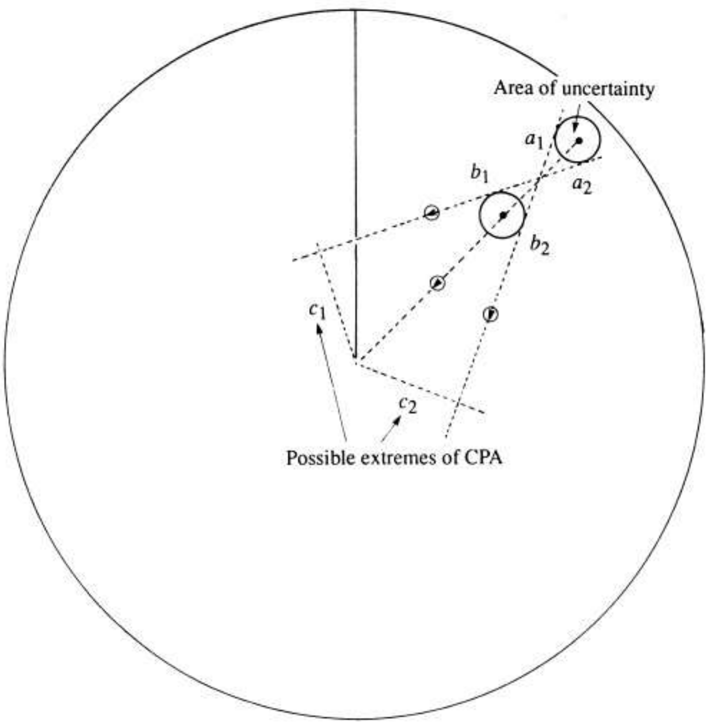
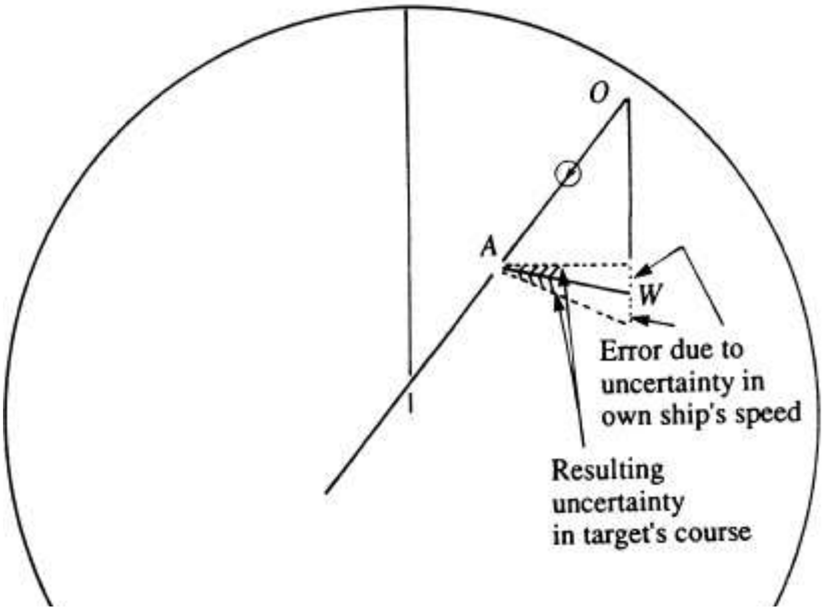


Figure 7.28 The accuracy with which CPA can be determined

is not taken into account in the plot, errors in the target's course and speed will result (see Figure 7.29).



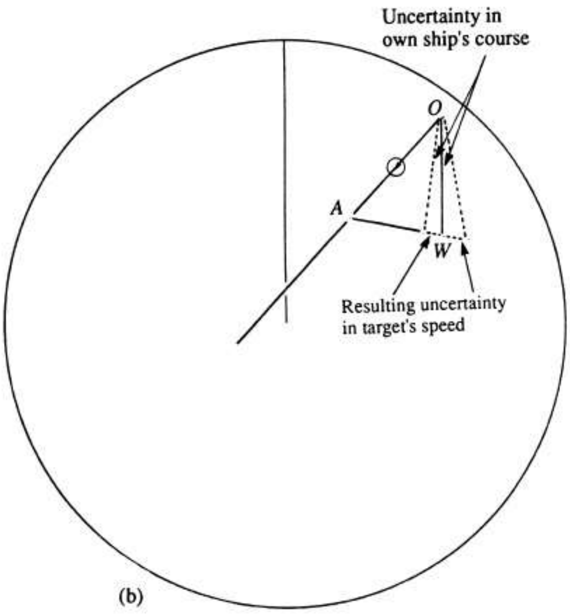


Figure 7.29 Errors resulting from inaccuracy
(a) in own ship's speed
(b) in own ship's course
Note Assume no error in *O* or *A*

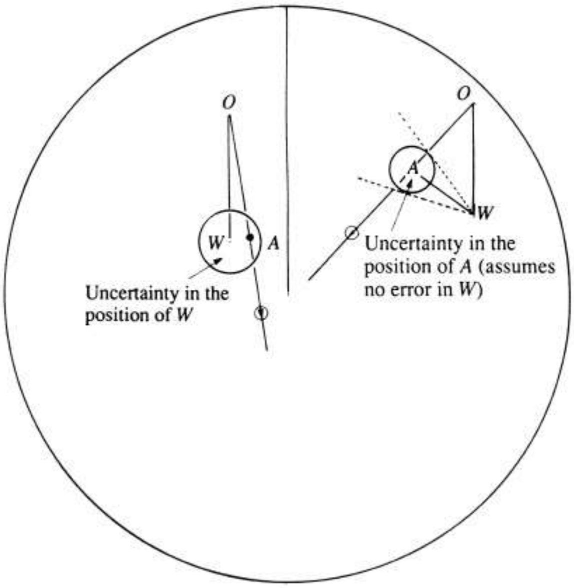


Figure 7.30 Slow-moving targets

1. The speed log is not operating properly. or not connected to the radar.
2. The vessel has no device which can measure ship's leeward movement (doppler sonar, speed log, etc.) though leeward movement cannot be disregarded.

If you select target based speed, the Auto Plotter calculates own ship's speed relative to a fixed reference target.

Note: When the target based speed is adopted, automatically or manually entered ship's speed is disregarded.

To establish target based speed:
1. Select a small fixed island or any radar prominent point located at 0.2 to 24 nm from own ship.
2. Place the cursor (+) on the target by operating the trackball.
3. Press the TARGET BASED SPEED key. the reference target mark appears at the cursor position and the own ship data label changes from
"LOG", "NAV" or "MENU" to "REF". Note that it takes one minute before a new speed is displayed.
Notes:
1. When the reference target is lost or goes out of the acquisition range, the reference target mark blinks and the speed reads "xx.x."
2. When all targets are deleted, the reference target mark is also deleted and the target based speed becomes invalid. the speed is indicated in KTBT where BT means Bottom Track (speed over ground).
3. The vector of the reference target can be displayed by menu operation (Auto Plot 1 menu)

.6- explain the track made over the ground by own ship.

Given good information regarding the vessel's movement over the ground, it still remains for the radar equipment to track accurately in response to this information. On some older radar sets, this cannot be taken for granted.
In the *ground-stabilized* display own ship moves on the display in accordance with its course and speed over the ground. Thus, the movements of target echoes on the display indicate the true courses and speeds of the targets over the ground. Ground-stabilization is effected as follows:

(1) The speed control is adjusted to eliminate any movements of the echoes from stationary targets dead ahead or dead astern. If the echoes from stationary targets dead ahead are moving towards own ship, the speed setting is increased; otherwise the speed setting is decreased.

(2) The course-made-good control is adjusted to eliminate any remaining movement at right angles to own ship's heading. The course-made-good control should be adjusted in a direction counter to the echo movement.

4.3- Determine the closest point of approach (CPA and time to closest approach (TCPA)

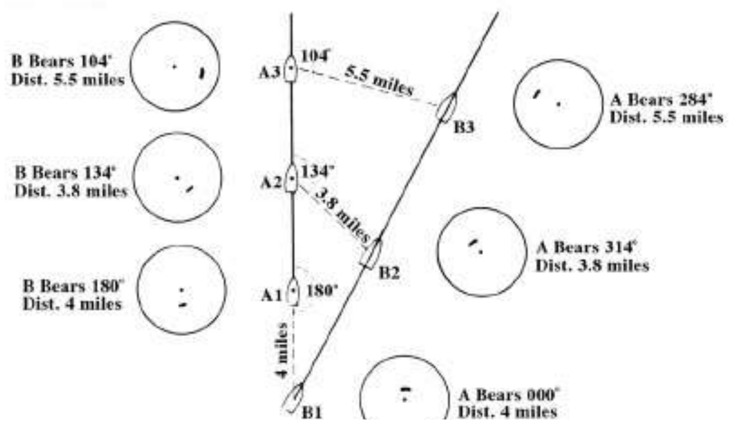
.1- Determines CPA and TCPA with relative presentation (stabilized and unstabilized)

RELATIVE MOTION

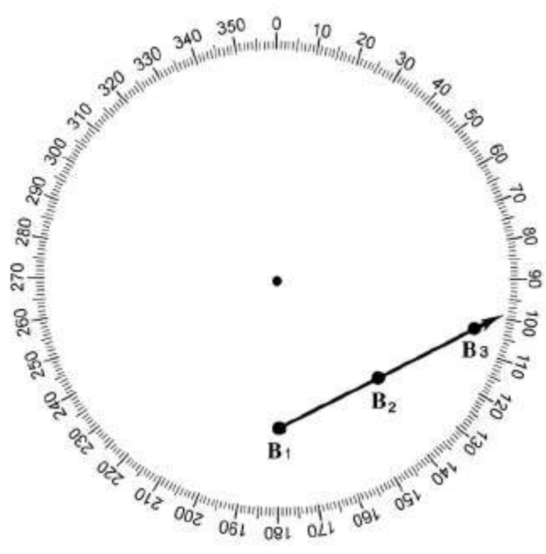
In the Universe there is no such condition as absolute rest or absolute motion. An object is only at rest or in motion relative to some reference. A mountain on the earth may be at rest relative to the earth, but it is in motion relative to the sun. Although all motion is relative, as used here *actual* or *true motion* is movement with respect to the earth; *relative* *motion* is motion with respect to an arbitrarily selected object, which may or may not have actual or true motion.

The actual or true motion of an object usually is defined in terms of its direction and rate of movement relative to the earth. If the object is a ship, this motion is defined in terms of the true course and speed. The motion of an object also may be defined in terms of its direction and rate of movement relative to another object also in motion. The relative motion of a ship, or the motion of one ship relative to the motion of another ship, is defined in terms of the *Direction of Relative Movement (DRM)* and the *Speed of Relative Movement (SRM)*. Each form of motion may be depicted by a velocity vector, a line segment representing direction and rate of movement. Before further discussion of *velocity vectors* and their application, a situation involving relative motion between two ships will be examined.

In figure 3.1, ship A, at geographic position A1, on true course 000° at 15 knots initially observes ship B on the PPI bearing 180° at 4 miles. The bearing and distance to ship B changes as ship A proceeds from geographic position A1 to A3. The changes in the positions of ship B relative to ship A are illustrated in the successive PPI presentations corresponding to the geographic position of ships A and B. Likewise ship B, at geographic position B1, on true course 026° at 22 knots initially observes ship A on the PPI bearing 000° at 4 miles. The bearing and distance to ship A changes as ship B proceeds from geographic position B1 to B3. The changes in the positions of ship A relative to ship B are illustrated in the successive PPI presentations corresponding to the geographic positions of ships A and B.



If the radar observer al ... e to his position fixed at the ce ... E PLOT or RELATIVE MOTI...



If the radar observer aboard ship B plots the successive positions of ship A relative to his position fixed at the center of the PPI, he will obtain a relative plot illustrated in figure 3.3. The radar observer aboard ship A will determine that the Direction of Relative Movement (DRM) of ship B is 064° whereas the radar observer aboard ship B will determine that the DRM of ship A is 244°.

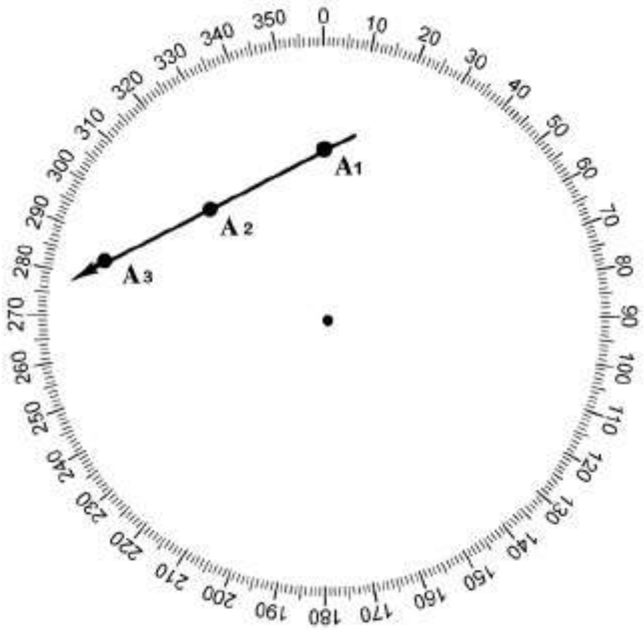


Figure 3.3 - Motion of ship A relative to ship B.

Of primary significance ... the relative plot on each PPI is not r... speed of the other ship. Figure 3.4 i... ed upon the relative plot obtained by ... *e aspects of ship targets*. For either r... of the other ship, additional graphica... are required.

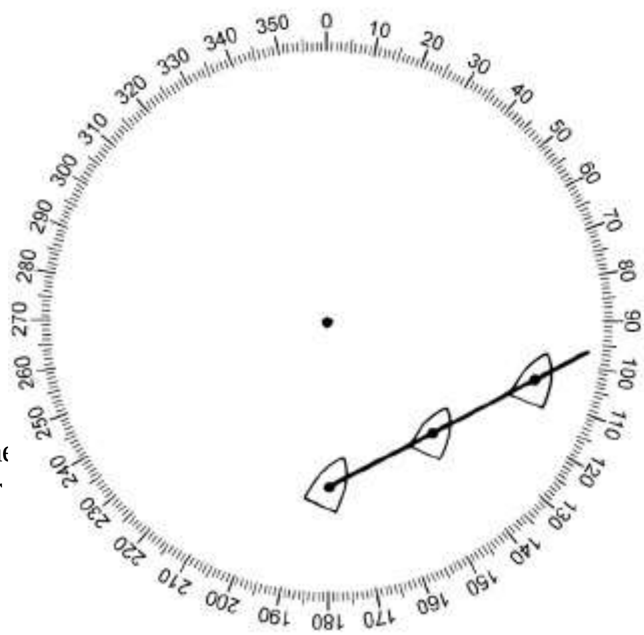


Figure 3.4 - The actual heading of ship B.

Figure 3.5 illustrates the ... respect to the earth. This plot, similar ... rk, is called a geographical (navigational) plot. Ship R proceeding on course 045°, at a constant speed passes through successive positions R1, R2, R3, R4... equally spaced at equal time intervals. Therefore, the line segments connecting successive positions represent direction and rate of movement with respect to the earth. Thus they are true velocity vectors. Likewise, for ship M on course 325° the line segments connecting the equally spaced plots for equal time intervals represent true velocity vectors of ship M. Although the movement of R relative to M or M relative to R may be obtained by additional graphical construction or by visualizing the changes in bearings and distances between plots coordinated in time, the geographical plot does not provide a *direct* presentation of the relative movement.

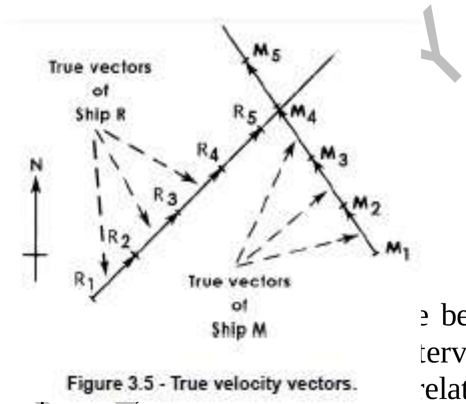


Figure 3.5 - True velocity vectors.

Figure 3.6 illustrates a modifica ... e bearing lines and ranges of other ship M from ow ... tervals. On plotting these ranges and bearings from a ... relative to own ship R is directly illustrated. The lines between the equally spaced plots at equal time intervals provide direction and rate of movement of M relative to R and thus are relative velocity vectors.

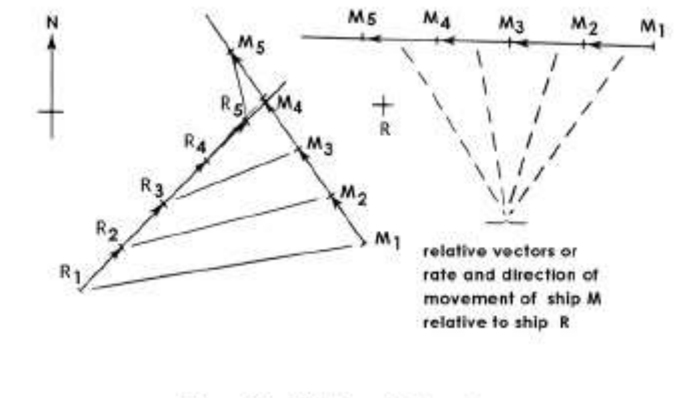
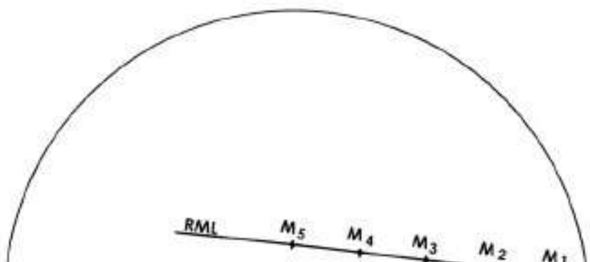


Figure 3.6 - Relative velocity vectors.

The true velocity vect ... *ship's true (course-speed) vector*; ... e motion is called *other ship's true* ... epicting the *relative motion* betwee ... DRM-SRM) *vector*.

In the foregoing discussion and illustration of true and relative velocity vectors, the magnitudes of each vector were determined by the time interval between successive plots. Actually any convenient time interval can be used as long as it is the same for each vector. Thus with plots equally spaced in time, own ship's true (course-speed) vector magnitude may be taken as the line segment between R1 and R3, R1 and R4, R2 and R4, etc., as long as the magnitudes of the other two vectors are determined by the same time intervals.



A plot of the successive positions of other ship M in the same situation on a relative motion display on the PPI of the radar set aboard own ship R would appear as in figure 3.7. With a Relative Movement Line (RML) drawn through the plot, the individual segments of the plot corresponding to relative distances traveled per elapsed time are relative (DRM-SRM) vectors, although the arrowheads are not shown. The plot, called the RELATIVE PLOT or RELATIVE MOTION PLOT, is the plot of the true bearings and distances of ship M from own ship R. If the plots were not timed, vector magnitude would not be indicated. In such cases the relative plot would be related to the (DRM-SRM) vector in direction only. Figure 3.8 illustrates the same situation as figure 3.7 plotted on a Maneuvering Board. The center of the Maneuvering Board corresponds to the center of the PPI. As with the PPI plot, all ranges and true bearings are plotted from a fixed point at the center, point R. Figure 3.8 illustrates that the relative plot provides an almost direct indication of the CLOSEST POINT OF APPROACH (CPA). The CPA is the true bearing and distance of the closest approach of one ship to another.

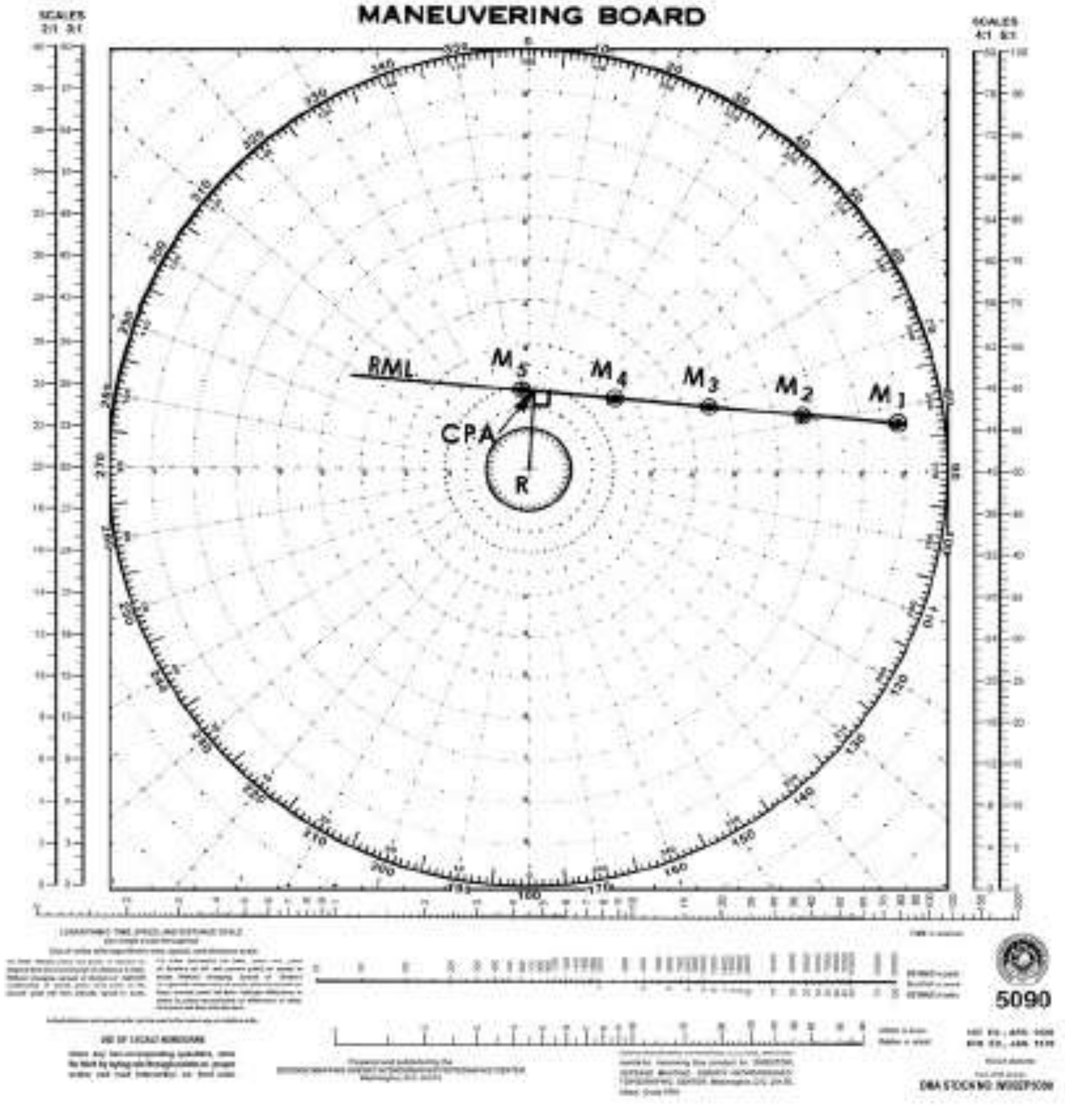


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Figure 3.8 - Relative Plot on the Maneuvering Board.

In the addition of vectors, the vectors are laid end to end, taking care that each vector maintains its *direction* and *magnitude*, the two essential elements of a vector. Just as there is no difference whether 5 is added to 3 or 3 is added to 5, there is no difference in the resultant vector whether the relative (DRMSRM) vector is laid at the end of own ship's true (course-speed) vector or own ship's true (course-speed) vector is laid at the end of the relative (DRMSRM) vector. Because of the notations used in this manual, the relative (DRM-SRM) vector is laid at the end of own ship's true (course-speed) vector, unless otherwise specified.

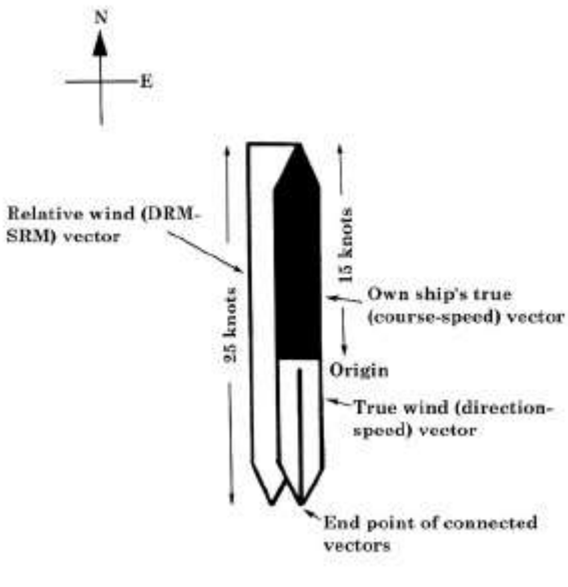


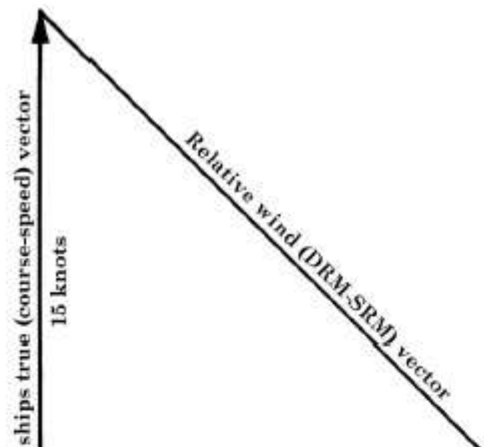
Figure 3.9 - Relative and true wind vectors.

The resultant vector, the tı ... ınd by drawing a vector from the origin o ... Unless the two vectors added have the sar ... ector triangle is formed on drawing the res ... Insight into the validity ... ı the mariner's experience with the effect

If a ship is steaming due north at 15 knots while the true wind is 10 knots *from* due north, the mariner experiences a relative wind of 25 knots *from* due north. Assuming that the mariner does not know the true wind, it may be found by laying own ship's true (course-speed) vector and the relative wind (DRM-SRM) vector end to end as in figure 3.9.

In figure 3.9, own ship's true (course-speed) vector is laid down in a due north direction, using a vector magnitude scaled for 15 knots. At the end of the latter vector, the relative wind (DRM-SRM) vector is laid down in a due south direction, using a vector magnitude scaled for 25 knots. On drawing the resultant vector from the origin of the two connected vectors to their end point, a true wind vector of 10 knots in a due south direction is found.

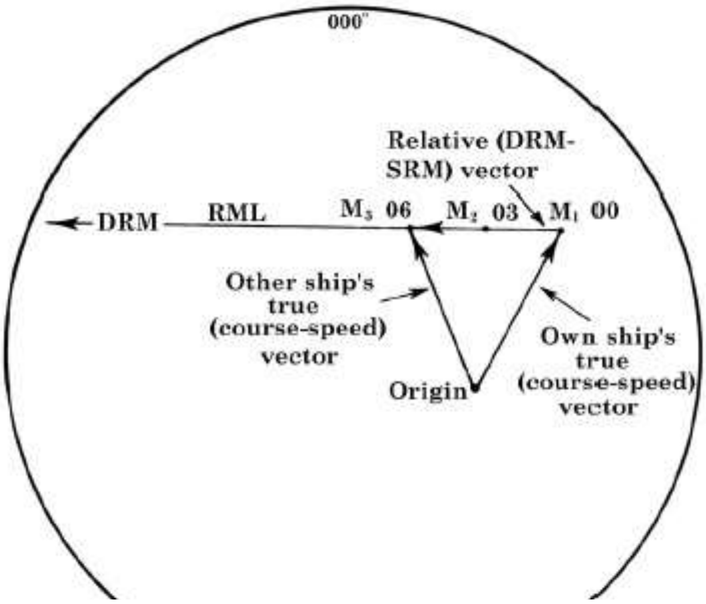
If own ship maintains a due north course at 15 knots as the wind direction shifts, the relative wind (DRM-SRM) vector changes. In this case a vector triangle is formed on adding the relative wind (DRM-SRM) vector to own ship's true (course-speed) vector (see figure 3.10).



Returning now to the problem of relative motion between ships and using the same situation as in figure 3.7, a *timed* plot of the motion of other ship M relative to own ship R is made on the PPI as illustrated in figure 3.11.

Assuming that the true (course-speed) vector of other ship M is unknown, it may be determined by adding the relative (DRM-SRM) vector to own ship's true (course-speed) vector.

The vectors are laid end to end, while maintaining their respective directions and magnitudes. The resultant vector, the true (course-speed) vector of other ship, is found by drawing a vector from the origin of the two connected (added) vectors to their end point.



Where:
em is other ship's true
er is own ship's true (
rm is relative (DRM-S
em = er + rm
er = em - rm
rm = em - er
(See figure 3.12)

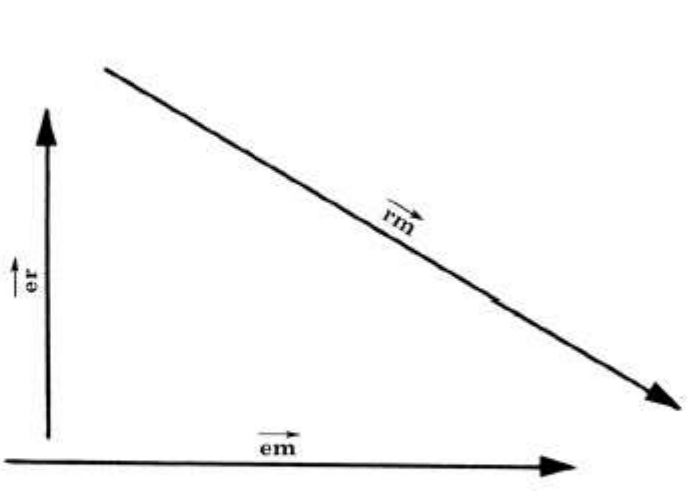


Figure 3.12 - True and relative vectors.

To determine vector *em* fr ... laying them end to end and drawi ... nnected vectors to their end point (
To determine vector *er* fro ... ctor *em* by laying vector rm, with ... wing a resultant vector, *er*, from t ... nt (see figure 3.14).

To determine vector *rm* from vectors *em* and *er*, vector *er* is subtracted from vector *em* by laying vector *er*, with its direction reversed, at the end of vector *em* and drawing a

resultant vector from the origin of the two connected vectors to their end point (see figure 3.15).

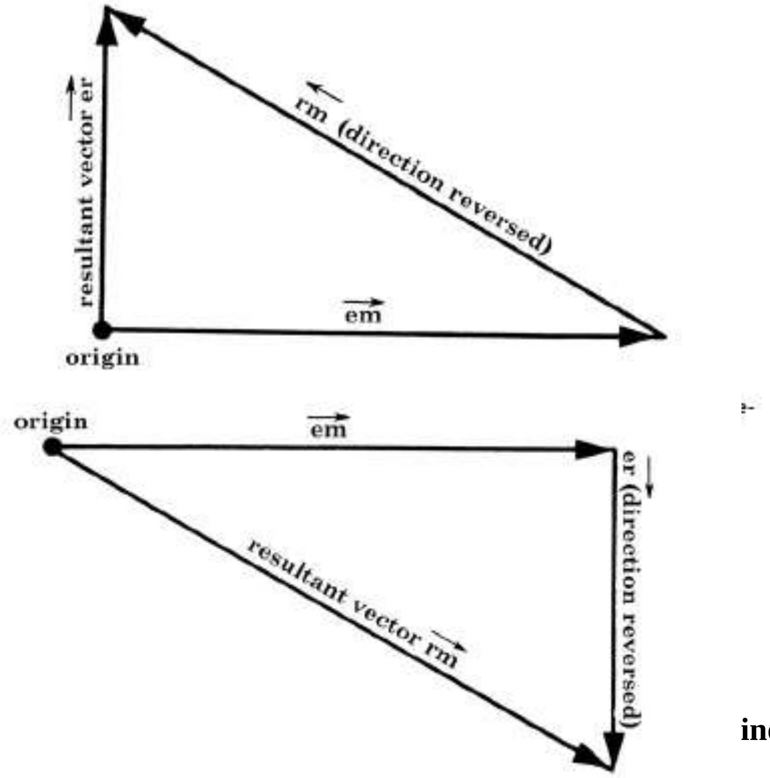


Figure 3.15 - Subtraction of own ship's true (course-speed) vector from other ship's true (course-speed) vector to find the relative (DRM-SRM) vector.

.3- State ... ined by plotting

Factors ...

As already menti... the ship manoeuvrability, area of navigation, and accuracy of the ARPA device. This paper deals with the value of CPA within the unlimited area of navigation, under assumption that only two ships are approaching each other. In such conditions the CPA primarily depends on the ship manoeuvrability and the accuracy of the ARPA device. The ship manoeuvrability is determined by the IMO resolution MSC.137 (76) [10]. The standards require the advance not to exceed 4.5 ship lengths (L) at maximum rudder deflection, while tactical diameter should not be greater than 5 ship lengths. If the sea depth is lower than four times the draught, this diameter becomes even greater, but rarely more than 8 ship lengths. ARPA Performance Standards are defined by the IMO resolution A.823 (19) [11] which requires ARPA to provide accuracies (95% probability values) within 1 minute of tracking for four scenarios that do not exceed the maximum permissible error listed in Table 1.

Table 1 – The maximum permissible error of ARPA within 1 minute of tracking

Scenario	Relative course [°]	Relative speed [kt]	CPA [M]
1	11	2.8	1.6
2	7	0.6	-
3	14	2.2	1.8
4	15	1.5	2.0

4.4- Recognized the effect of course and speed changes (2hrs)

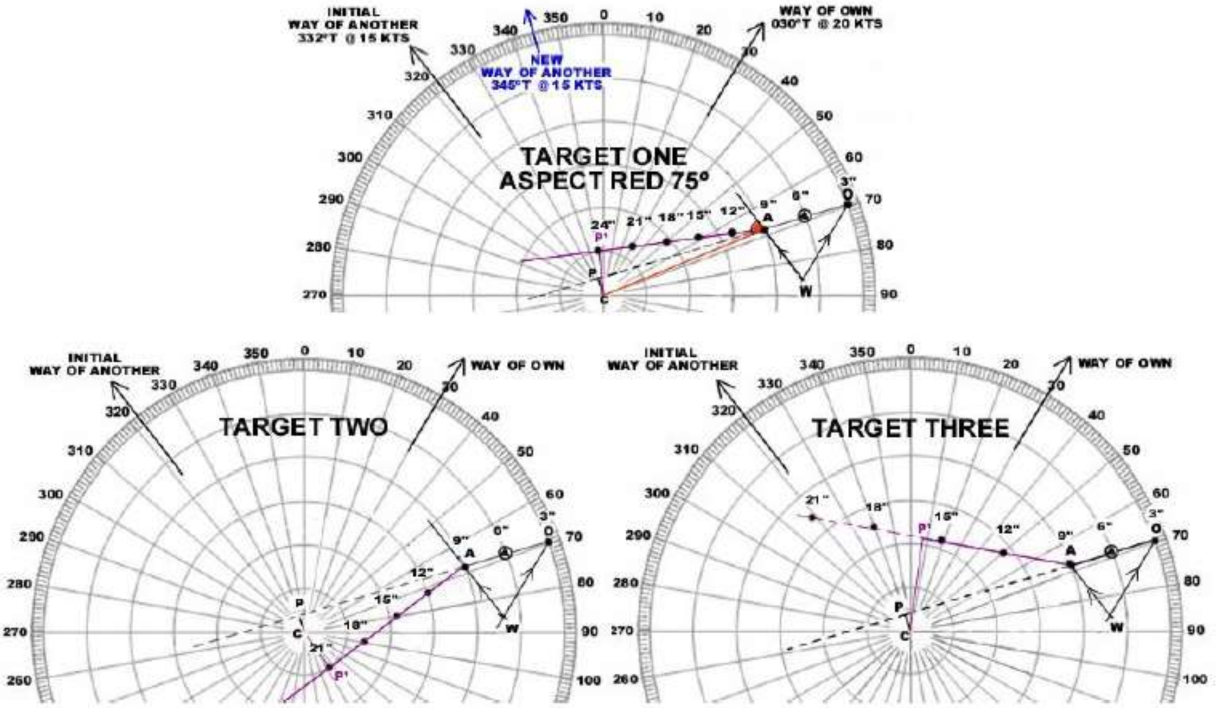
.1- Recognized the effect of changes of course and / or speed by other ships

Another vessel's change in course or speed.

Detecting and interpreting change in target's motion:

Targets detected at close quarters were plotted below to find their initial OAP line, predicted CPA, course/speeds and aspects (all Red 75º). Following best practice, the targets were subsequently monitored and deviations from the predicted OAP lines were detected.

Caution is required to ensure target "wander" is not a changing relative view due to our own vessel's yaw. An additional consideration is that larger craft can take ten minutes or more to settle on a new course and even longer to reach a higher speed. In our decisions the Collision Regulations, *Risk of Collision Rule 7c*, must be considered - *Assumptions shall not be made on the basis of scanty information, especially scanty radar information.* In this case however, at successive 3 minute intervals the targets consistently lined up as new AP^1 lines, coincidentally originating from A as the moment of target behaviour change. The OA line is the resultant of the vectors of course & speed of own vessel (WO) and course & speed of another vessel (WA). As our vessel maintained constant course & speed (no leeway/current were present) this target behaviour must have been due to the other vessel's changes in course, or speed or both.



becoming an overtaking give way vessel. Hence the radio message to ensure we understood its actions. However, while Targets 2 and 3's new CP^1A's are displayed, the course/speed/aspect require re-plotting with new $O^1A^1W^1$ vector triangles as shown below.

Aspects of all other vessels must be monitored and re-assessed in order to visually identify them, allowing that they may not have detected us and their changed behaviour may not be avoidance action but an operational manoeuvre.

.2- Compare between visual and radar observations

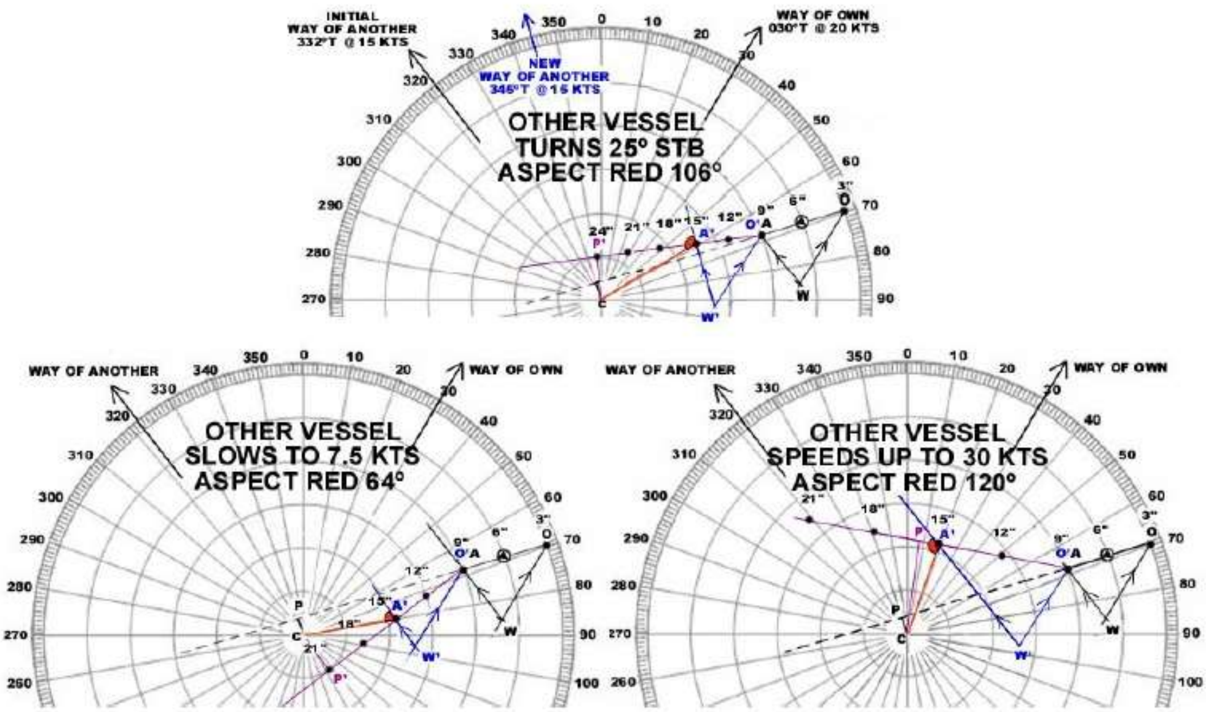
Radar should be used to complement visual observation in clear weather to assist in the assessment of whether risk of collision exists or is likely to develop. It also provides accurate determination of range to enable action taken to avoid collision to be successful bearing in mind the manoeuvring capabilities of own ship.

When there are many echoes on the screen, indirect echoes are likely to escape notice. It is when the screen is reasonably clear that one starts wondering about some echo, which one knows, from experience or visual observations, should not be there.

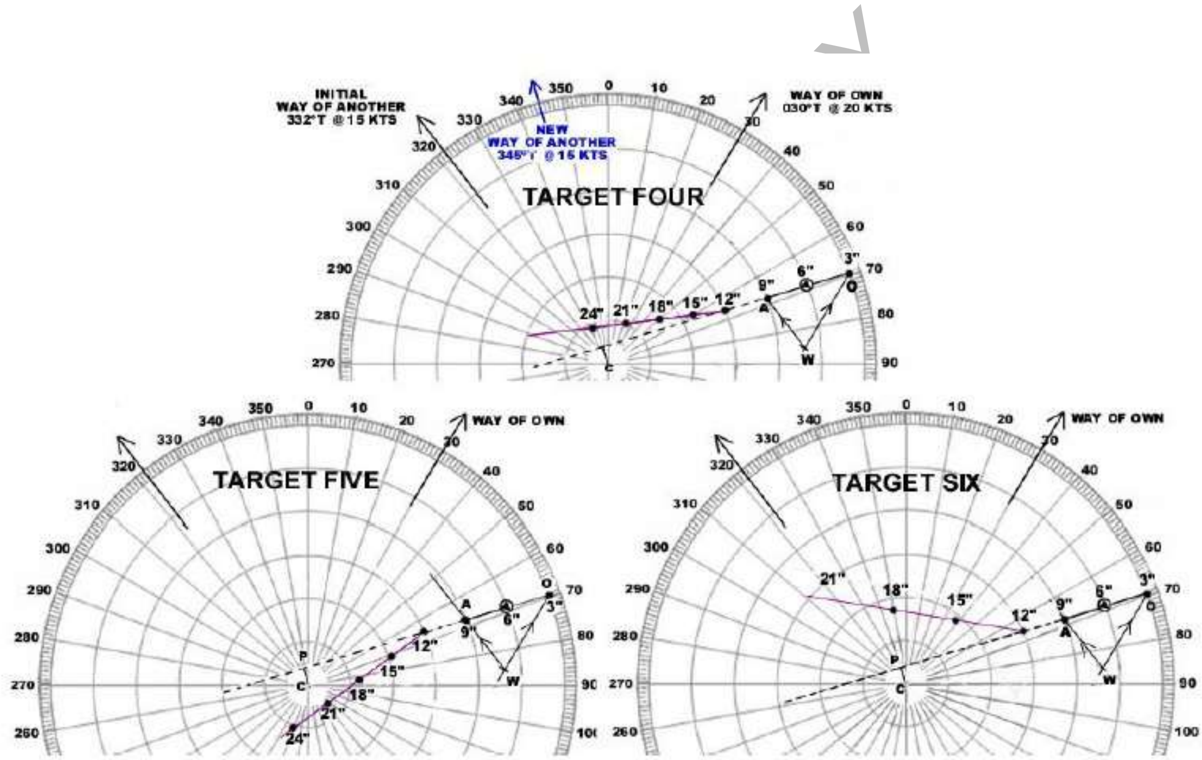
.3- Explain the delay between change in the course or speed and detection of that change.

Changing of course, slowing down or speeding up:

The new $O^1A^1W^1$ plots can be constructed by transferring the 6 minutes (9”- 3”) constant OW vector from the point A when target motion changed, (in the example below called O^1). Position A^1 is at the target detection at the repeat 6 minute interval. The direction and length of W^1A^1 enable the other’s course, speed and aspect to be determined.

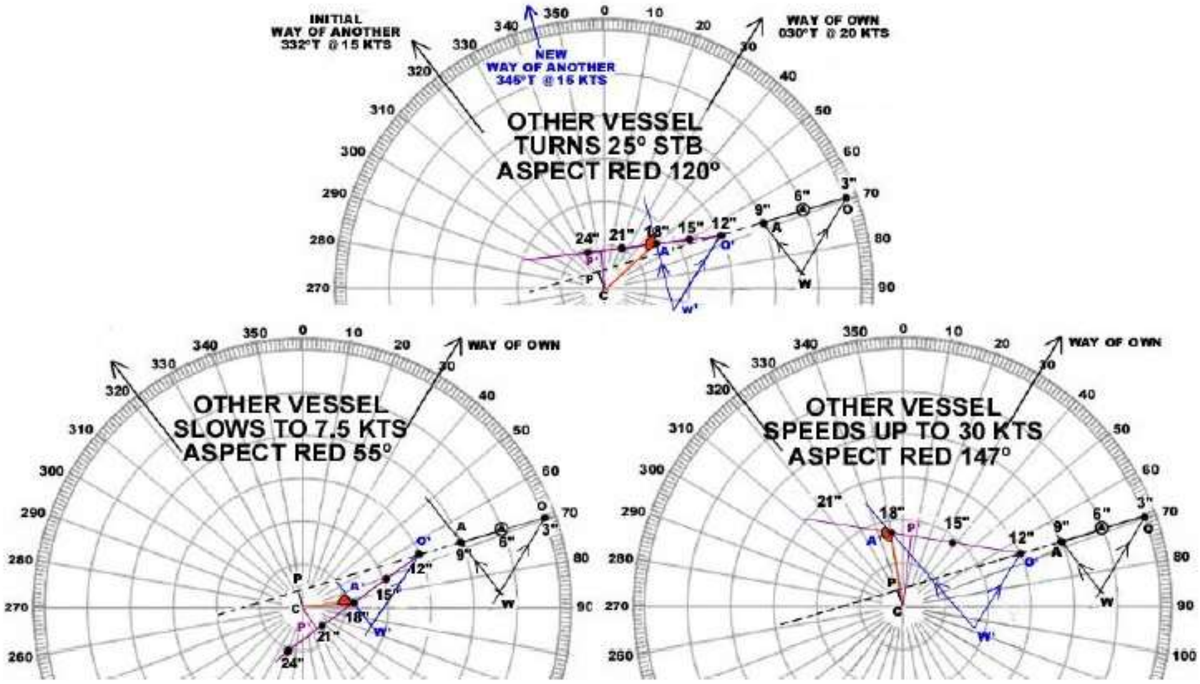


For the purpose of simplifying the explanation of constructing a proving plot, in the previous examples we selected position A as the moment that the behaviour of the targets 1-3 changed. In reality, the more likely scenario is that at some time after position A the change will occur. Below are detections of another set of targets 4-6 that in these examples changed their behaviour after a 3 minute delay from when position A was detected and the initial plot constructed.



Changing of course, slowing down or speeding up after a delay:

As with the previous examples of the $O^1A^1W^1$ plots can be constructed by transferring the initial 6 minutes (9"- 3") and constant OW vector from the point of target motion change, called O^1. But in the case of this 3 minutes delay not at position A, but from the point that the newly lined up target detections cross the initial OA line extension. Position A^1 is found at the target detection point at the repeat 6 minute interval. The direction and length of W^1A^1 enable the other's course, speed and aspect to be determined.



Ground stabilization:-

- In ground stabilization mode true motion display of *Radar* is used & the Course & Speed is fed from *GPS*, hence the fixed objects on the PPI remain stationary.
- The movement of all moving objects is their movement over ground (COG & SOG).
- It is used for collision avoidance with fixed objects.

Sea stabilization:-

- In sea stabilization mode relative motion display of radar is used & the Course is from *Gyro* course and speed is from log speed. Hence the fixed objects on the PPI appear to have a course & speed equal to the reverse course& speed of own vessel.
- The movement of own vessel, fixed object & moving object is their movement through the water.
- This is ideal for collision avoidance action.

.5- Explain the effect of changes in own-ship course or speed on the observed movement of targets (stabilized rel/ true; or unstabilized)

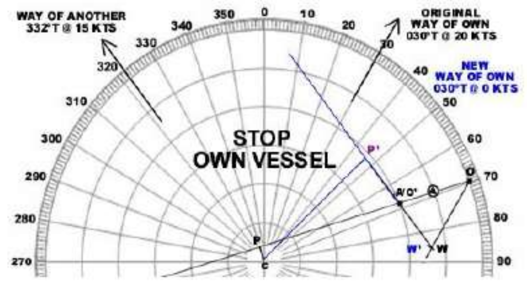
Own vessel's change in speed.

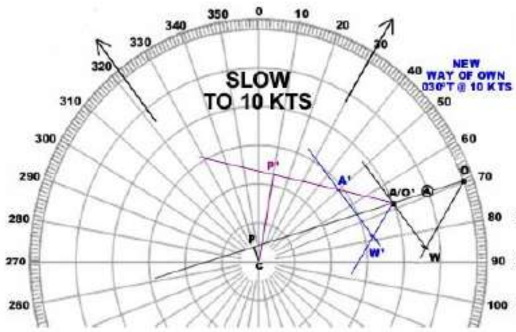
To minimize collision risk by increasing CPA a vessel could stop, slow down or (often less achievable) speed up. In seeking this improved CPA a new vector plot is first drawn. In the examples below we altered speed at A, so this is effectively also a new position O^1.

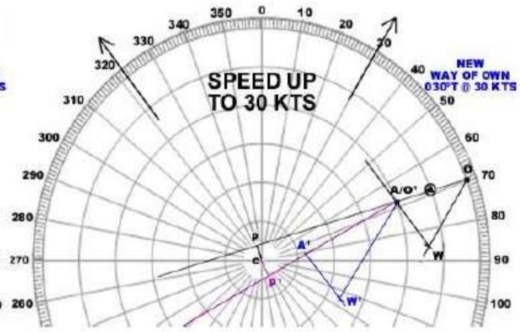
The W^1A (our speed) is the vector that changes while the W^1A^1 vector (another's speed) stays constant.

Stopping, slowing down or speeding up:

Plots for our vessel on initial course 030ºT and speed 20 kts plots with 0.5 mile CPA and the consequence of altering speed are shown below. If our vessel stops WO vector stops increasing while the W^1A vector keeps going to extend past the new CP^1A (3.8 miles). In this case relative motion and true motion are identical as only one changing vector is in play, the other vessel.







In the examples above we changed speed at A, so this is also a new position O^1 for the new vector plot. If our 20 knots vessel slows to10 knots or speeds up 30 knots, the W^1O^1 own speed vector is drawn proportionally shorter or longer but in the same direction of the initial WO vector. After finding W^1 the constant WA length and direction can be repeated as W^1A^1, thus providing the line A/O^1 A^1 and its extension to CP^1A (2.3 miles ahead and 0.5 miles behind).

Plotting own vessel's change in speed.

Plot 1a. Own vessel's slows its speed.

Our vessel while on a course of 030ºT at a speed of 20 kts plots a target ahead with 0.5 miles predicted CPA requiring avoidance speed change.

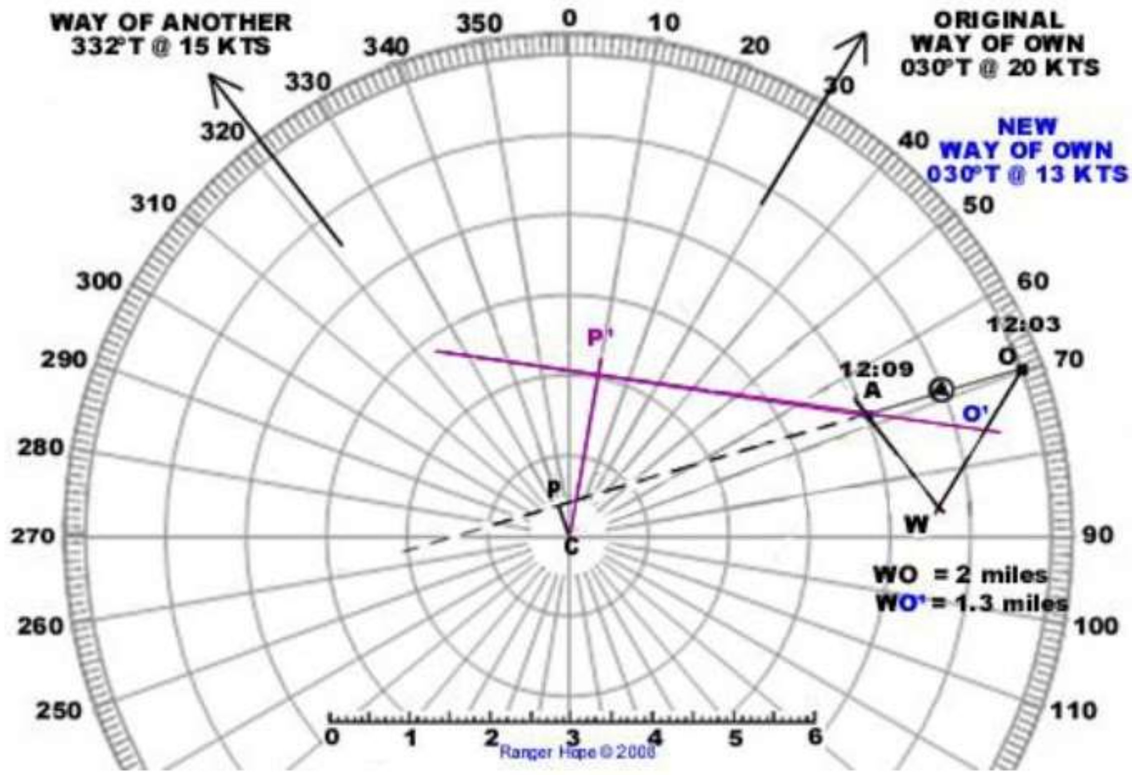
Finding the CP^1A resultant on decreased speed to13 knots:

Calculate the new speed vector of 13 knots x 6" interval (1/10th hour) =1.3 nm. Draw this shorter speed vector line from W to a new position O^1. A new O^1 line extended through and past A will provide the new CP^1A.

Finding speed change required to increase CPA from 0.5 to 2 miles:

Draw a line from P^1 (the chosen 2 miles CP^1A^1) to A (the 2:09 position) and extend it to cross the initial WO line at new position O^1. From this vector WO^1 the required speed can be calculated from the length times the interval period:

Measured 1.3 nm x 10 = 13 kts



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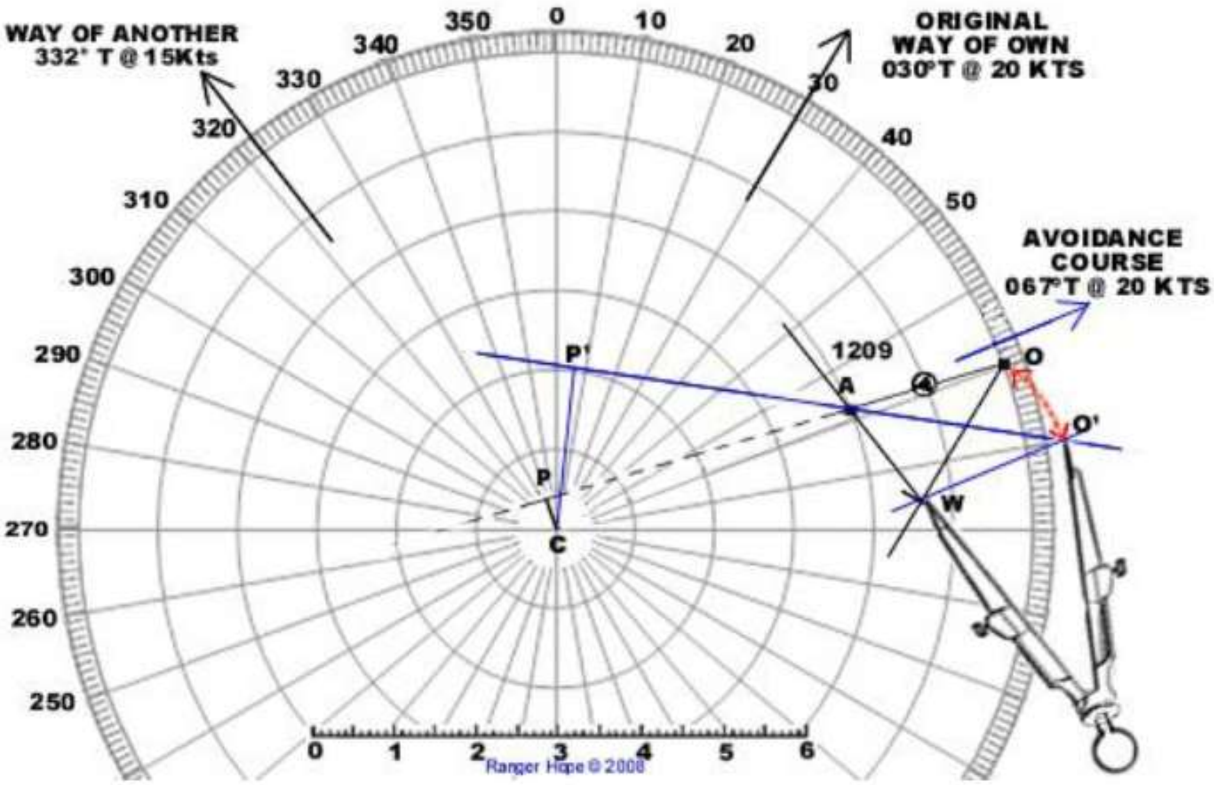
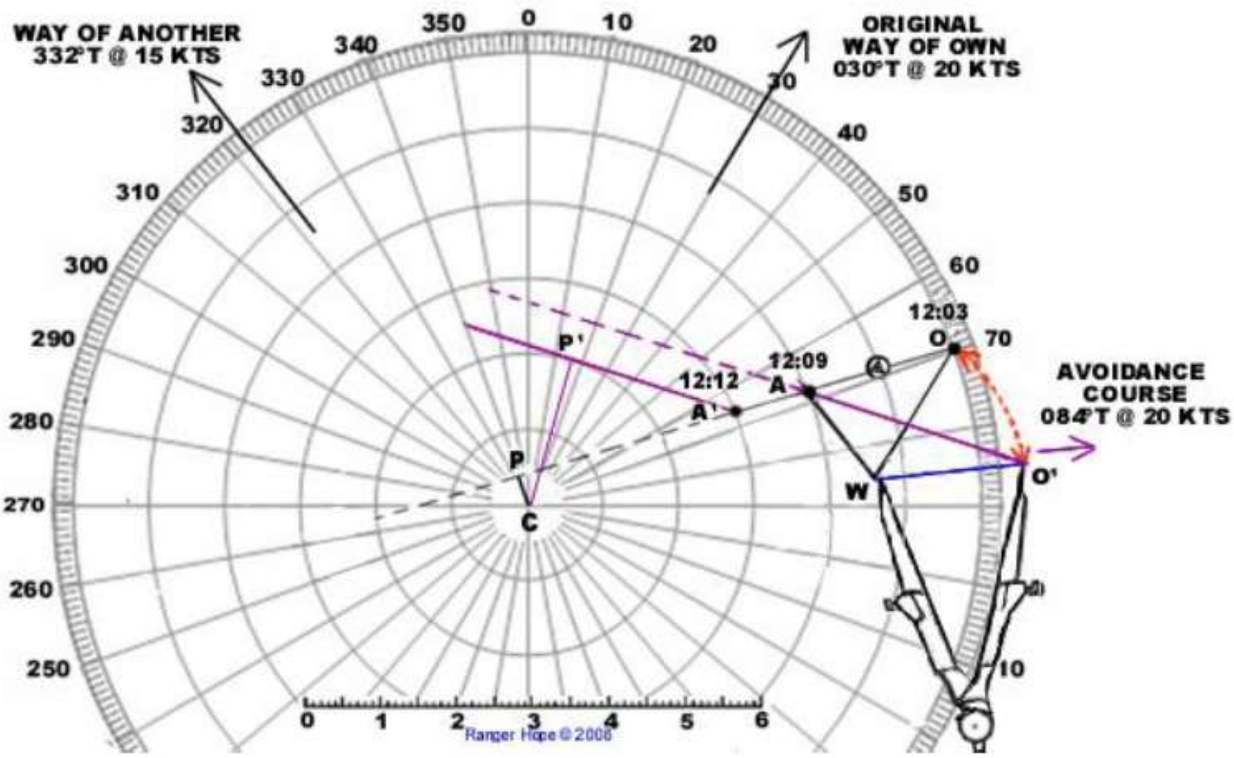
line is crossed. Call this O¹. Draw line WO¹ and transfer it to the outer bearing scale to read off the avoidance course, in this case 067ºT.



Finding the CP^1A^1 with delayed 54º to Stb course change:
Calculate the new avoidance course from the current course plus or minus the turn away from it (in the example, 030ºT + 54º Stb = 084ºT). From initial W to O^1. draw this directional vector the same length as initial WO. From O^1 draw a line
back through A and past the centre. Transfer a line parallel to this to pass through A^1 (the 12:12 position) and past the centre. This gives the new CP^1A^1 of 2 miles.

Finding course required to increase 0.5 miles CPA to 2 miles after delay:
Draw a line from P^1 (the chosen new 2 miles CP^1A^1) to A^1 (the 12:12 position). Draw a line parallel to this and extend through the initial A to well past the initial WO line. With dividers spanning the initial WO line, sweep an arc from W to find new position O^1 where the previously drawn line is crossed. Line WO^1 is the new avoidance course, in this case 084ºT.



Changing course If you do need to take avoiding action to avoid risk of collision, you have a number of tools available. Use them wisely. If you choose only to alter course, it is good practice to engage hand steering, using the lookout as helmsman. Do not take that role yourself; you will be limited in your ability to multi-task by steering and monitoring the compass bearing. You may decide to use the autopilot, but do so with care. It may be tempting to make a series of small alterations on the autopilot to avoid large rudder angles, but that series of small changes will not be readily apparent to the other vessel. An appropriate significant alteration of course in hand steering can be achieved without resort to large rudder angles.

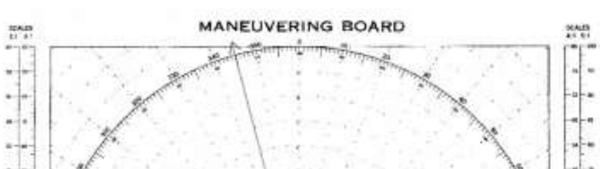
4.5- Report radar plot data

.1- make a report stating the elements: bearing, range, CPA, TCPA, c course aspect, speed.

Radar Plotting procedures. We'll begin with the vector triangle. As is the case with all triangles, this one has three sides.
• Side e→r represents the true course (direction) and speed (length) of our ("er") vessel ("we are e-r.")
• Side e→m represents the true course and speed of the other ("them's") vessel.
• Side r→m represents the relative motion vector, the direction and speed of the other vessel's "apparent" movement.
Letter "e" is anchored in the plot. "m" may and "r" certainly will be relocated, but "e" does not move. Next, terminology:
• CPA: Closest point of approach. If the line of relative motion is extended, the CPA is the shortest distance from that line to the center of the plotting sheet (where our own ship is located). If the CPA is 0, we are on a collision course with the other vessel. • RML: Relative Motion line
• NRML: New Relative Motion line.
• SRM: Speed of relative motion (length of r→m)
• DRM: Direction of relative motion (direction of r→m)
• Mx: The position of the other ship on RML at planned time of evasive action; point of execution. Radar Plotting used to be referred to as Rapid Radar Plotting, with an emphasis on "Rapid." In order to make the procedure quick and mathematically painless, contacts are usually observed at intervals of 6 minutes, 12 minutes or 15 minutes. Calculating speeds and/or distances is extremely easy at these intervals. For example,
• if a vessel is traveling 18.2 knots, that is, 18.2 nautical miles per hour, she will travel 1/10 of that speed (1.82 miles) in 6 minutes (1/10 of an hour).
• if a vessel has traveled 1.2 miles in 6 minutes, her speed is 10 times that, 12 knots. The table below shows the distances traveled in 6-minute and 12-minute intervals at a speed of 15 knots.

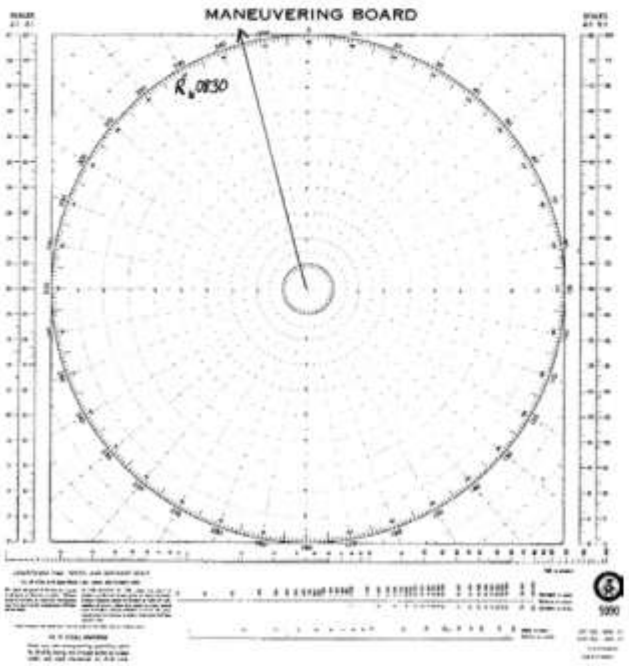
15.0 knots	60 minutes
1.5 miles	6 minutes
3.0 miles	12 minutes

We'll work a standard 6-minute plot, step-by-step. Your ship is on course 345°. Speed is 15.0 knots. You note the following radar contact: At 0830 the contact bears 329° at a range of 9.0 miles. At 0836 the same contact bears 326° at a range of 6.0 miles. • What will be the CPA?
• What is the contact's relative speed?
• What is the contact's true speed?
• When the range to the contact drops to 4.5 miles, you want to change course, contact passing you on your port side, with a new CPA of 2 miles. What is your ship's new course?
Step 1: Notice that the plot is a 6-minute plot. Speeds, distances and time will be based on a factor of 1/10. Using a Maneuvering Board or a Radar Transfer Plotting Sheet, draw

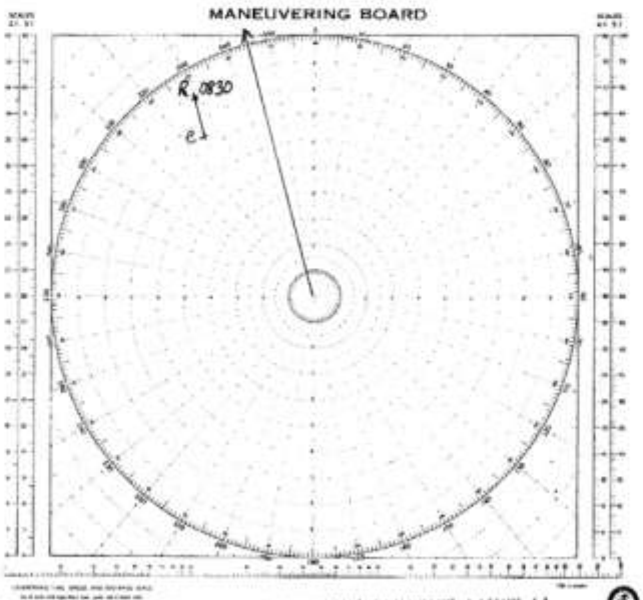


a line from the center (our ship) in the direction the vessel is heading. This represents the heading flasher. In this case, our course is 345°.

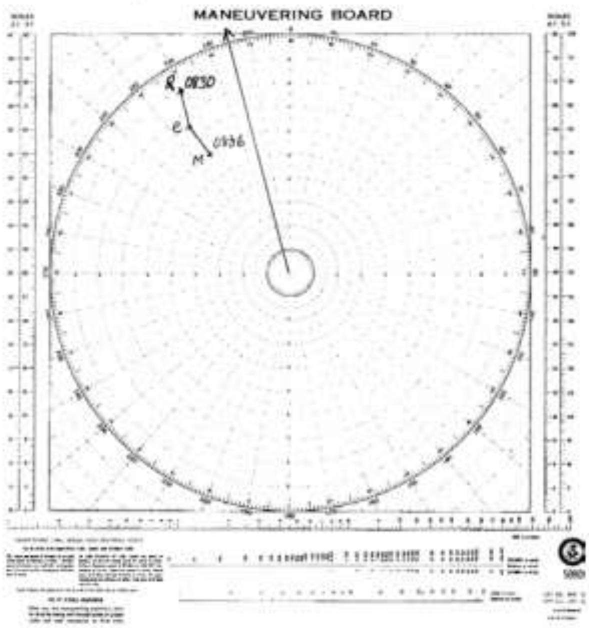
Step 2: Plot the first (0830) contact using the 1:1 scale (the ten concentric circles on a Maneuvering Board each represent 1 mile in length) at a bearing of 329° and range of 9 miles. Label it r.



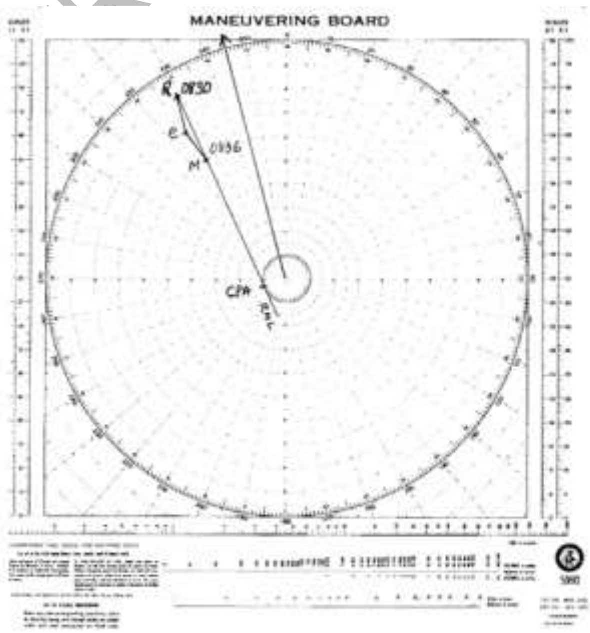
Step 3: Locate e on the plot. Set dividers for the distance our vessel will travel in the interval of the plot -- in this case, 6 minutes at a speed of 15 knots is 1.5 miles. Parallel the course line (345°) over to r and draw it in backwards, away from r. [Remember the course is from e→r.] Label this position e.



Step 4: Locate m, which is bearing 326° at a range of 6.0 miles at 0836. Now it is possible to finish the triangle and solve for the other vessel's course and speed by connecting e → m (approximately 146° at 16.0 knots).

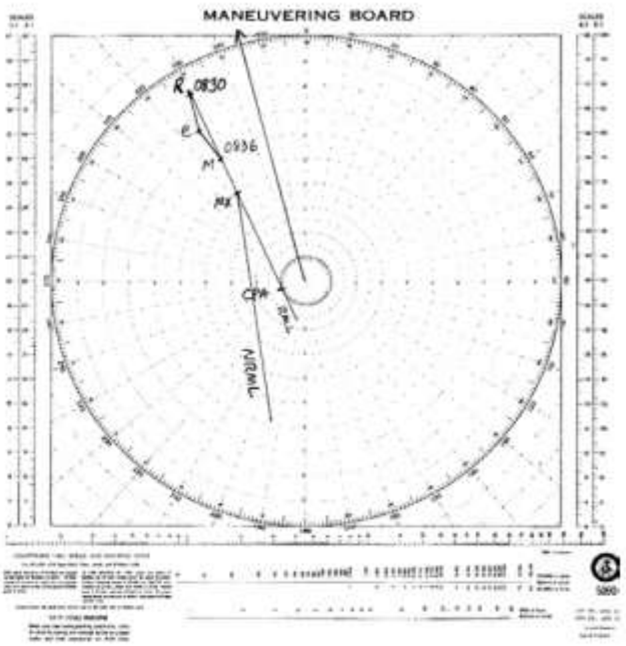


Step 5: Draw a line from r through m and past the center of the maneuvering board. This is the line of relative motion (RML). The distance from the center of the plot (our vessel) to the

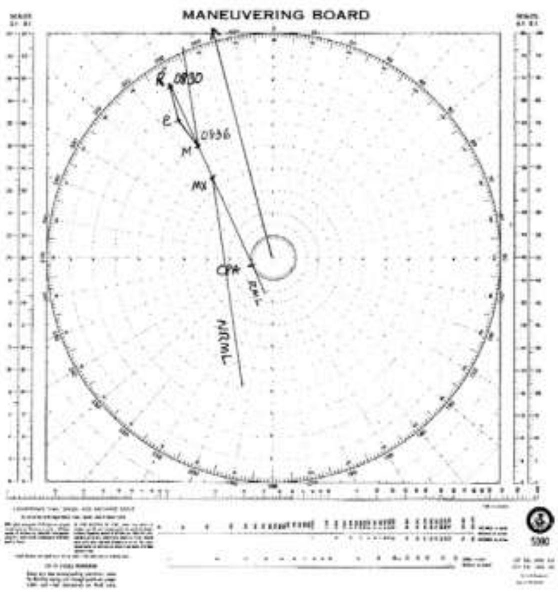


closest point (a perpendicular) on the RML is the CPA (closest point of approach). In this case, the CPA is about one mile. Measure the length of r→m to find the contact's relative speed. Here it is approximately 30 knots.

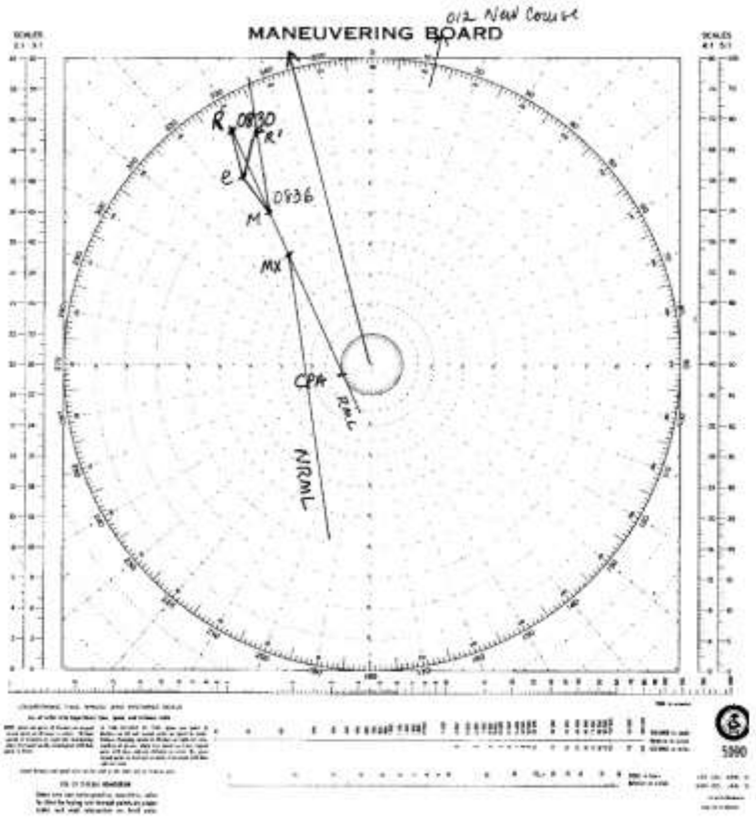
Step 6: According to the problem, when the range to the contact drops to 4.5 miles, we are to change course so that the contact will pass on our port side with a CPA of 2 miles. The next step then is to mark on the RML the point at which the contact reaches a range of 4.5 miles from us at the center. Label this point Mx. From Mx draw a line tangent to (touching) the two-mile circle. When we change course, this will be the NRML (new line of relative motion).



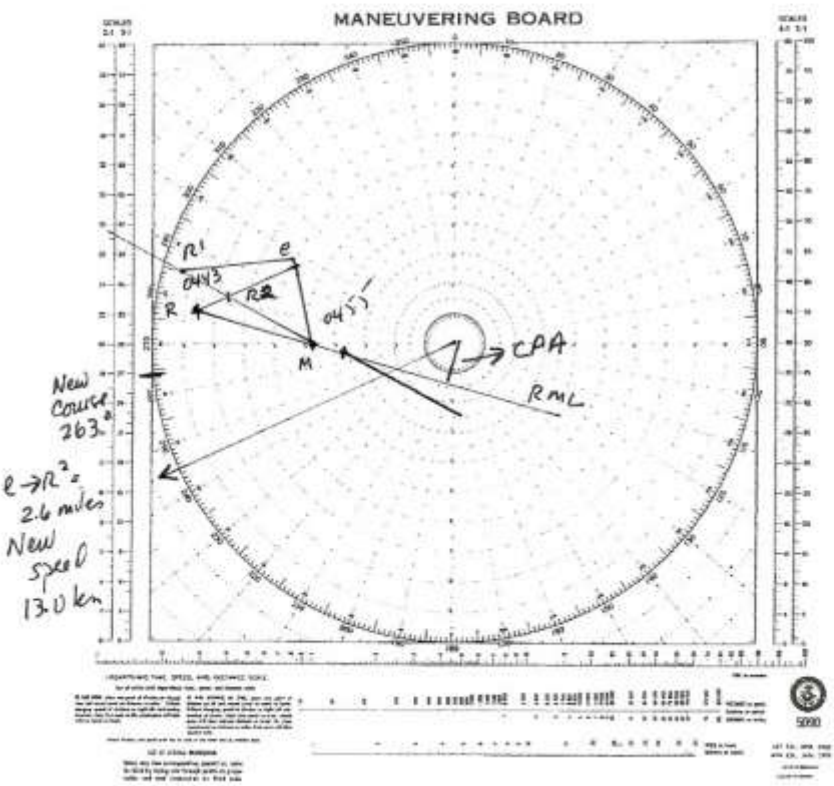
Step 7: Parallel the NRML from Mx to M (not to e, not to r, to M!) Draw the paralleled line away from M.



Step 7: We are going to change our course but maintain our speed. Place one leg of the dividers on e and place the other leg on r. Swing the dividers so that the r leg (remember e never moves), crosses the NRML. Label the point of intersection r 1 . The direction from e→r 1 is our vessel's new course. In this case, that new course is approximately 012°.



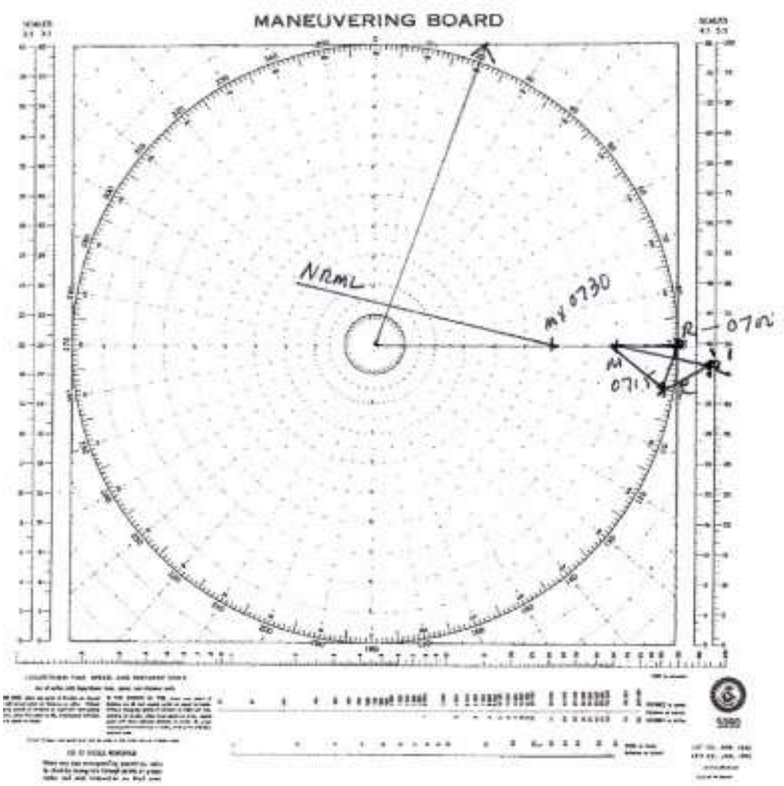
Plots generally allow reasonable tolerances for answers, hence the "approximately" used throughout this explanation.
The finished plot for the following problem is on the next page.
Your ship is on course 245°. Speed is 18.0 knots.
You note the following radar contact: At 0443 the contact bears 277° at a range of 8.5 miles.
At 0455 the same contact bears 270° at a range of 4.7 miles.
• What will be the CPA?
• What is the contact's true course?
• What is the contact's true speed?
• At 0458, you want to change course, contact passing you on your port side, with a new CPA of 2 miles.
• What is your ship's new course?
• You cannot change course, so at 0458 you want to change speed, contact crossing your bow, with a CPA of 2 miles.
• What is your ship's new speed?
This is a 12-minute plot, so speeds are divided or multiplied by 5.



• The original CPA is about 1.3 miles.
• The contact's course is approximately 170°.
• The contact's true speed is approximately 13.5 knots. To find Mx , note that since this is a 12-minute plot and since 0458 is 3 minutes from the 0455 position of M and since 3 minutes is ¼ of 12, eyeball the distance to Mx as about ¼ the length of r→m.
• When the NRML is paralleled back to M and the dividers (with one leg at e) swung to find r 1 , the ship's new course is found to be approximately 263°.
• Since the problem now says that a course change is not possible, the other option is to find r 2 along the original e→r line at the point it intersects the NRML. If the vessel maintains its original course of 245° but reduces her speed from 18.0 to 13.0 knots, the other vessel will cross her bow at a CPA of 2 miles.

For the final example, we'll do a 15-minute plot. As 15 minutes is ¼ hour, we will be dividing or multiplying by 4.
Your ship is on course 020°. Speed is 7.0 knots. You note the following radar contact: At 0700 the contact bears 090° at a range of 10.0 miles. At 0715 the same contact bears 090° at a range of 8.0 miles.
• What will be the CPA?
• What is the contact's true course?
• What is the contact's true speed?
• At 0730, you decide to change course to 060°.
• What will be the new CPA?

• What will be the time of the new CPA?
Here's the plot:



• The CPA is 0 (constant bearing, decreasing range, Rule 7 of the Rules of the Road).
• The contact's true course is approximately 320°.
• The contact's true speed is approximately 8.8 knots.
• Mx is 15 minutes beyond the 0715 M on the RML, which is to say, with one leg of the dividers positioned at R and the pivot leg at M, one swing of that span down the RML.
• The new CPA is approximately 1.5 miles.
• The time of the new CPA is approximately 0759 (almost but not quite two swings the length of the NRML from Mx).

5.4- Imo Performance Standards for automatic Radar plotting Aids (ARPA) or TT and AIS reporting functions

.1- States IMO performance standards for ARPA relating to accuracy

Annex Recommendation on performance standards for automatic radar plotting aids (ARPAs)

PERFORMANCE STANDARDS

1. Detection

   Where a separate facility is provided for detection of targets, other than by the radar observer, it should have a performance not inferior to that which could be obtained by the use of the radar display.

2. Acquisition

   1. Target acquisition may be manual or automatic for relative speeds up to 100 knots. However, there should always be a facility to provide for manual acquisition and cancellation: ARPA with automatic acquisition should have a facility to suppress acquisition in certain areas. On any range scale where acquisition is suppressed over a certain area, the area of acquisition should be defined and indicated on the display.

   2. Automatic or manual acquisition should have a performance not inferior to that which could be obtained by the user of the radar display.

3. Tracking

   1. The ARPA should be able automatically to track, process, simultaneously display and continuously update information on at least 20 targets, whether automatically or manually acquired.

   2. If automatic acquisition is provided, description of the criteria of selection of targets for tracking should be provided to the user. If the ARPA does not track all targets visible on the display, targets which are being tracked should be clearly indicated with the relevant symbol* on the display. The reliability of tracking should not be less than that obtainable using manual recordings of successive target positions obtained from the radar display.
      * Refer to IEC 872M : Marine Automatic Radar Plotting Aids (ARPAs)

   3. The ARPA should continue to track an acquired target which is clearly distinguishable on the display for 5 out of 10 consecutive scans, provided the target is not subject to target swop.

   4. The possibility of tracking errors, including target swop, should be minimized by ARPA design. A qualitative description of the effects of error sources on the automatic tracking and corresponding errors should

be provided to the user, including the effects of low signal-to-noise and low signal-to-clutter ratios caused by sea returns, rain, snow, low clouds and non-synchronous emissions.

5. The ARPA should be able to display on request with relevant symbol* at least four equally time-spaced past positions of any targets being tracked over a period appropriate to the range scale in use. The time-scale of the past position plot should be indicated. The operating manual should contain an explanation of what the past position plots represent. * Refer to IEC 872M : Marine Automatic Radar Plotting Aids (ARPAs)

4. Display

   1. The display may be a separate or integral part of the ship's radar. However, the ARPA display should include all the data required to be provided by a radar display in accordance with the performance standards for navigational radar equipment.
   2. The design should be such that any malfunction of ARPA parts producing data additional to information to be produced by the radar as required by the performance standards for navigational equipment should not affect the integrity of the basic radar presentation.
   3. The ARPA facilities should be available on at least 3, 6 and 12 nautical mile range scales, and there should be a positive indication of the range scale in use.
   4. ARPA facilities may also be provided on other range scales permitted by resolution A.477(XII) and, if provided, should comply with these standards.
   5. The ARPA should be capable of operating with a relative motion display with "north-up" and "course-up" azimuth stabilization. In addition, the ARPA may also provide for a true motion display. If true motion is provided, the operator should be able to select for the display either true or relative motion. There should be a positive indication of the display mode and orientation in use.
   6. The course and speed information generated by the ARPA for acquired targets should be displayed in a vector or graphic form which clearly indicates the target's predicted motion with relevant symbols*. In this regard:
      * Refer to IEC 872M : Marine Automatic Radar Plotting Aids (ARPAs)

      1. an ARPA presenting predicted information in vector form only should have the option of both true and relative vectors. There

should be an indication of the vector mode selected and, if true vector mode is selected, the display should show whether it is sea or ground stabilized;

2. an ARPA which is capable of presenting target course and speed information in graphic form should also, on request, provide the target's true and/or relative vector;
3. vectors displayed should be time-adjustable;
4. a positive indication of the time-scale of the vector in use should be given; and
5. if stationary targets are being used for ground referencing, this fact should be indicated by the relevant symbol*. In this mode, relative vectors including those of the targets used for ground referencing should be displayed when requested.
   * Refer to IEC 872M : Marine Automatic Radar Plotting Aids (ARPAs)

7. The ARPA information should not obscure the visibility of radar targets. The display of ARPA data should be under the control of the radar observer. It should be possible to cancel the display of unwanted ARPA data within 3 s.
8. Means should be provided to adjust independently the brilliance of the ARPA data and radar data, including complete extinction of the ARPA data.
9. The method of presentation should ensure that the ARPA data are clearly visible in general to more than one observer in the conditions of light normally experienced on the bridge of a ship by day and by night. Screening may be provided to shade the display from sunlight but not to the extent that it will impair the observer's ability to maintain a proper look-out. Facilities to adjust the brightness should be provided.
10. Provisions should be made to obtain quickly the range and bearing of any object which appears on the ARPA display.
11. When a target appears on the radar display and, in the case of automatic acquisition, enters within the acquisition area chosen by the observer or, in the case of manual acquisition, has been acquired by the observer, the ARPA should present in a period of not more than 1 min an indication of the target's motion trend, and display within 3 min the target's predicted motion in accordance with 3.4.6, 3.6, 3.8.2 and 3.8.3.

12. After changing range scales on which the ARPA facilities are available or resetting the display, full plotting information should be displayed within a period of time not exceeding one scan.

5. Operational warnings

    1. The ARPA should have the capability to warn the observer with a visual and audible signal of any distinguishable target which closes to a range or transits a zone chosen by the observer. The target causing the warning should be clearly indicated with relevant symbols* on the display. * Refer to IEC 872 : Marine Automatic Radar Plotting Aids (ARPAs)

    2. The ARPA should have the capability to warn the observer with a visual and audible signal of any tracked target which is predicted to close within a minimum range and time chosen by the observer. The target causing the warning should be clearly indicated with relevant symbols* on the display. * Refer to IEC 872 : Marine Automatic Radar Plotting Aids (ARPAs)

    3. The ARPA should clearly indicate if a tracked target is lost, other than out of range, and the target's last tracked position should be clearly indicated on the display.

    4. It should be possible for the observer to activate or de-activate the audible warning signal.

6. Data requirements

    1. The observer should be able to select any tracked target to obtain data. Targets selected should be marked with the relevant symbol* on the radar display. If data is required for more than one target at the same time each symbol should be separately identified, for example with a number adjacent to the symbol*. * Refer to IEC 872 : Marine Automatic Radar Plotting Aids (ARPAs)

    2. The following data for each selected target should be clearly and unambiguously identified and displayed immediately and simultaneously in alpha-numeric form outside the radar area:

        1. present range of the target;
        2. present bearing of the target;
        3. predicted target range at the closest point of approach (CPA);
        4. predicted time to CPA (TCPA);
        5. calculated true course of the target; and
        6. calculated true speed of the target.

3. The display of the data in 3.6.2.5 and 3.6.2.6 should include an identification of whether the data provided is referenced to sea or ground stabilization.

4. When data for several targets is displayed, no fewer than two items listed in 3.6.2 should be displayed simultaneously for each target selected. If the items of data are displayed in pairs for each target, the groupings should be 3.6.2.1 with 3.6.2.2, 3.6.2.3 with 3.6.2.4, and 3.6.2.5 with 3.6.2.6.

7. Trial manoeuvre

    1. The ARPA should be capable of simulating the effect on all tracked targets of an own ship manoeuvre with or without time delay before manoeuvre without interrupting the updating of target tracking and display of actual target alpha-numeric data. The simulation should be indicated with the relevant symbol* on the display.
    * Refer to IEC 872 : Marine Automatic Radar Plotting Aids (ARPAs)

    2. The operating manual should contain an explanation of the principles underlying the trial manoeuvre technique adopted including, if provided, the simulation of own ship's manoeuvring characteristics.

    3. It should be possible to cancel a trial manoeuvre at any time.

8. Accuracy

xxxxxxxxxxxxxxxxxxxxxxxx- lost -xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx

monitor the proper operation of the system. Additionally, test programmes should be available so that the overall performance of ARPA can be assessed periodically against a known solution. When a test programme is being executed, the relevant test symbols* should be displayed.
* Refer to IEC 872 : Marine Automatic Radar Plotting Aids (ARPAs)

11. Sea and ground stabilization

    1. The ARPA should be capable of sea and ground stabilization.

    2. Log and speed indicators providing inputs to ARPA equipment should be capable of providing the ship's speed through the water in the fore and aft direction.

    3. The ground stabilized input may be provided from the log, from an electronic position-fixing system, if the speed measurement accuracy is in accordance with the requirements of resolution A.824(19), or from tracked stationary targets. The type of input and stabilization in use should be displayed.

.2- States the requirements for acquisition and tracking of targets

Acquisition

- Target acquisition may be manual or automatic for relative speeds up to 100 knots. However, there should always be a facility to provide for manual acquisition and cancellation: ARPA with automatic acquisition should have a facility to suppress acquisition in certain areas. On any range scale where acquisition is suppressed over a certain area, the area of acquisition should be defined and indicated on the display.

- Automatic or manual acquisition should have a performance not inferior to that which could be obtained by the user of the radar display.

Tracking

- The ARPA should be able automatically to track, process, simultaneously display and continuously update information on at least 20 targets, whether automatically or manually acquired.

- If automatic acquisition is provided, description of the criteria of selection of targets for tracking should be provided to the user. If the ARPA does not track all targets visible on the display, targets which are being tracked should be clearly indicated with the relevant symbol* on the display. The reliability of tracking should not be less than that obtainable using manual recordings of successive target positions obtained from the radar display.

- The ARPA should continue to track an acquired target which is clearly distinguishable on the display for 5 out of 10 consecutive scans, provided the target is not subject to target swop.

- The possibility of tracking errors, including target swop, should be minimized by ARPA design. A qualitative description of the effects of error sources on the automatic tracking and corresponding errors should be provided to the user, including the effects of low signal-to-noise and low signal-to-clutter ratios caused by sea returns, rain, snow, low clouds and non-synchronous emissions.

- The ARPA should be able to display on request with relevant symbol* at least four equally time-spaced past positions of any targets being tracked over a period appropriate to the range scale in use. The time-scale of the past position plot should be indicated. The operating manual should contain an explanation of what the past position plots represent.

.3- List operation warning required

Operational warnings

- The ARPA should have the capability to warn the observer with a visual and audible signal of any distinguishable target which closes to a range or transits a zone chosen by the observer. The target causing the warning should be clearly indicated with relevant symbols* on the display.

- The ARPA should have the capability to warn the observer with a visual and audible signal of any tracked target which is predicted to close within a minimum range and time chosen by the observer. The target causing the warning should be clearly indicated with relevant symbols* on the display.

- The ARPA should clearly indicate if a tracked target is lost, other than out of range, and the target's last tracked position should be clearly indicated on the display.

- It should be possible for the observer to activate or de-activate the audible warning signal.

.4- States which data which should be available in alphanumeric form

Data requirements

3.6.1 The observer should be able to select any tracked target to obtain data. Targets selected should be marked with the relevant symbol* on the radar display. If data is required for more than one target at the same time each symbol should be separately identified, for example with a number adjacent to the symbol*.

3.6.2 The following data for each selected target should be clearly and unambiguously identified and displayed immediately and simultaneously in alpha-numeric form outside the radar area:

1. present range of the target;
2. present bearing of the target;
3. predicted target range at the closest point of approach (CPA);
4. predicted time to CPA (TCPA);
5. calculated true course of the target; and
6. calculated true speed of the target.

3.6.3 The display of the data in 3.6.2.5 and 3.6.2.6 should include an identification of whether the data provided is referenced to sea or ground stabilization.

3.6.4 When data for several targets is displayed, no fewer than two items listed in 3.6.2 should be displayed simultaneously for each target selected. If the items of data are displayed in pairs for each target, the groupings should be 3.6.2.1 with 3.6.2.2, 3.6.2.3 with 3.6.2.4, and 3.6.2.5 with 3.6.2.6.

.5- Describes the effects of sensor errors of ARPA equipment complying with IMO performance standards

Appendix 3 Sensor errors

The accuracy figures quoted in 3.8 of these standards are based upon the following sensor errors, and are appropriate to equipment complying with the performance standards for shipborne navigational equipment.
Note: σ means "standard deviation".

Radar

Target glint (scintillation) (for 200 m length target)
Along length of target σ = 30 m (normal distribution)
Across beam of target σ = 1 m (normal distribution)

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

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

Beam shape - assumed normal distribution giving bearing error with σ = 0.05°
Pulse sharp - assumed normal distribution giving range error with σ = 20 m

Antenna backlash - assumed rectangular distribution giving bearing error ± 0.05 ° maximum

Quantization
Bearing - rectangular distribution ± 0.1° maximum.
Range - rectangular distribution ± 0.01 nautical miles maximum.
Bearing encoder assumed to be running from a remote synchro giving bearing errors with a normal distribution σ = 0.03°.

.6- States the Performance Standards for Gyro and log inputs

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

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

.7- States the performance standards for range and bearing accuracy and discrimination for radar

Radar Range and Bearing Accuracy

The radar system range and bearing accuracy requirements should be:
Range – within 30m or 1 per cent of the range scale in use, whichever is greater;
Bearing – within 1_.

5.5- Criteria for acquisition of radar targets and activation of AIS targets

.1- States the criteria for target acquisition

Acquisition is the term used to describe the process whereby target tracking is initiated. This may be 'manual', in which case the operator, using the screen marker (see below) indicates to the computer which targets are to be tracked, or may be 'automatic', when the computer is programmed to acquire targets which enter specified boundaries. When a target is 'acquired', the computer starts collecting data relating to that target.

A graphic symbol known as the *screen marker*, controlled by a joystick or tracker ball, is positioned over the target. When the 'acquire' button is pressed, an area centred on the screen marker is defined within the computer memory. This area is termed the 'tracking gate' or 'tracking window'. The gate is made to appear automatically on some ARPA displays; on others, the operator may display it if desired. Within the gate, the computer will expect to find evidence of a target, i.e. a binary 1 in the appropriate memory location

The acquisition specification

Target acquisition may be manual or automatic for relative speeds up to 100 knots. However, there should always be a facility to provide for manual acquisition and cancellation. ARPAs with automatic acquisition should have a facility to suppress acquisition in certain areas. On any range scale where acquisition is suppressed over a certain area, the area of acquisition should be indicated on the display.

Automatic or manual acquisition should have a performance not inferior to that which could be obtained by the user of the radar display.
If automatic acquisition is provided, a description of the criteria of selection of targets for tracking should be provided to the user.
Although it would seem that anything is possible in today's technological climate, some practical problems still exist and fully automatic acquisition systems do not give quite the results which one might have been led to expect. The main problem with automatic acquisition is that the 'sensitivity' of the detection circuitry, if set too high, will acquire thermal noise and clutter, leading to false alarms, while if its sensitivity is reduced, poor-response targets can evade the plotter.
The ATA acquisition is simpler as it only covers manual acquisitions

.2- States the criteria for automatic selection of targets given in the set instruction manual

If automatic acquisition is provided, the criteria for selection of targets should be known to the user - there is either guard ring or guard zone selection, or the observer should be acquainted with the priority programme for selection or "threat profile"; this is especially important when the computer becomes saturated and may "shed" certain targets.
A qualitative description of the effects of error sources on automatic tracking, and corresponding behaviour, should be provided to the user.
This includes the effects of low signal-to-noise and low signal-to-clutter ratios caused by sea returns, rain, snow, low clouds and non-synchronous emissions. It should also include a description of "target swop"; if this takes place, then, if both targets were being tracked, information displayed about the targets will have exchanged and will be wrong for a period, or if only one target was being tracked, its data and tracking would become attached to the other, formerly untracked vessel. This data displayed on the latter vessel will correct itself after a short period but the result could be that the tracking has changed from a dangerous to a less dangerous vessel.
An ARPA should continue to track a target which is clearly distinguishable on the display for 5 out of 10 scans, and targets which are being tracked should be clearly indicated on the display.

.3- List the criteria to be used for manual acquisition of targets

In this case, the operator specifies the target to be acquired and subsequently tracked. To do this, a joystick and screen marker or tracker ball and screen marker are used. The target is entered into (acquired) or removed from (cancelled) the computer memory when the *acquire* or *cancel* button is pressed.
In some ARPAs, tracking can be initiated by touching the position of the target on a special touch sensitive screen.
One way of setting up an ARPA could be as follows:-
I. Select the range scale and adjust brilliance and contrast.
2. Select presentation mode (Relative or True Motion).
3. Select orientation - Head-up, North-up or Course-up.

4. Input speed. This can be done manually, or via the log sensor (sea speed) or via an ARPA facility called Auto-Drift or Echo Ref, whereby the computer keeps the radar picture (true or relative motion) in the ground-stabilized mode. In the latter case, the input is not "speed", but "velocity" and can be represented by a vector, having magnitude *and* direction.
5. Select the acquisition mode - Manual or Automatic. For manual acquisitioning the Joystick and circle-marker is used.
6. Set minimum CPA and TCP A limits.
7. Set Vector Mode - True or Relative Motion.
8. Set 'vector length' - in minutes. 'History track' can also be selected, but it will take some time after acquisition before the track is shown on the display. Note the spacing between successive dots.
9. Watch for alarm signals and compare the graphical presentation shown by acquired targets with the digital read-outs. Again, when switching on, certain conditions may appear automatically (default) such as the vector mode and the vector time.

.4- States the maximum number of targets which may be acquired

The number of targets to be tracked

The ARPA should be able to automatically track, process, simultaneously display and continuously update the information on at least 20 targets, whether manually or automatically acquired.

The ATA Performance Standard is the same except 10 tracking channels are required and not 20. However, from 2008, the minimum requirement is 20 to 40 (see Table 4.3). It has been suggested that even 20 tracking channels might be insufficient in heavy traffic but from practical experience it has been found that ship's officers can quickly identify the targets which need to be tracked and acquire them. (Although at times there will be some 40 plus targets on the screen, not all of them will need to be tracked.) In fact, it has been found that an excess of vectors can produce 'ARPA clutter' and be counter-productive.

Table 4.3 Differences in the performance requirements for various sizes of ship/craft to which SOLAS applies

Size of ship/craft	*<500 grt*	*500 grt to <10 000 grt and HSC <10 000 grt*	*All ships/craft ≥ 10 000 grt*
Minimum operational display area diameter	180 mm	250 mm	320 mm
Minimum display area	195×195 mm	270×270 mm	340×340 mm
Auto acquisition of targets	—	—	Yes
Minimum *acquired* radar target capacity	20	30	40
Minimum *activated* AIS target capacity	20	30	40
Minimum *sleeping* AIS target capacity	100	150	200
Trial manoeuvre	—	—	Yes

of tracking should not be less than that obtainable using manual recordings of successive target positions obtained from the radar display.
In many cases it may be obvious that a target is being tracked by virtue of the fact that its predicted movement will be indicated by a graphic line known as a vector. The line originates on the target and its remote end indicates the predicted position of the target after an elapsed time selected by the observer. However, the need for tracked targets to be clearly indicated on the display is important because in the early stages (up to about one minute) of tracking a fresh target, in most systems the vector is suppressed because the available data is unlikely to be sufficiently accurate or stable. Furthermore, in certain cases, even when the vector is present it may have zero length (e.g. the true vector of a stationary target or the relative vector of a target on the same course and speed as the observing vessel).
Once tracking is initiated, by whatever method, the tracker will continue to follow the target until tracking is cancelled (manually, or automatically because some other criterion has been met, e.g. 'more than 16 miles away and range increasing') or the target is 'lost'. The precise nature of the algorithms used to ensure that the tracking window will faithfully follow the target varies with manufacturer. The fine detail of such methods are beyond the scope of this text but the general principle can be illustrated by the following description of the technique known as *rate aiding*.

Rate aiding
When the target is first acquired, a large gate is necessary since there is uncertainty as to the direction in which the target will move. Figure 4.6 shows how successive positions can be used to improve the forecast of the next position in which the target is expected to appear. The radius of the gate is really a measure of confidence in the tracking and the smaller this value becomes, the more precise the prediction will be. In this way it is possible to establish a feedback loop in the computer which will progressively reduce the size of the tracking gate.
The advantages of a reduced tracking gate are:
(a) A lower likelihood of target swap
(b) An improved ability to track targets through rain and sea clutter.
(c) An ability to continue tracking, even when target response is intermittent.
One problem which can arise with reduced gate size is that if a target manoeuvres and, as a result, is not found by the computer in the predicted position, the computer may continue to track and look in the predicted direction and end up by losing the target altogether. To avoid this possibility, as soon as the target is missed, i.e. not found in the predicted position, the gate size is increased. If the target is till detectable and subsequently found, the tracking will resume and a new track will gradually stabilize.
If, after six fruitless scans, the target is still not found then an alarm is activated and a flashing marker.

.6- Describe appropriate use of suppression of target acquisition over certain areas

A continuous or broken line to define the limits outside of which automatic acquisition is suppressed.

Safe limit vector suppression

This facility, if selected, suppresses the vectors of targets whose predicted motion does not violate the safe limits and is an attempt to reduce ARPA 'clutter'. The computer continues to track the targets whose vectors are suppressed. If any of them should manoeuvre in such a way as to violate the set safe limits, the vector of that target will reappear and the safe limit alarm will be activated. If a decision is taken to use this facility, considerable thought must be given to the implications of the selected values of safe limits. In general, it is advisable to switch the facility off before contemplating a manoeuvre.

.7- States that target first appearing closer that guard ring will not be acquire

Guard rings and area rejection boundaries (ARBs)

With this method of acquisition, the usual provision is for up to two 'rings' (of predetermined depth) plu up to two area rejection boundaries (ARBs). The rings and ARBs may be positioned by the operator (Figure 4.5).

When a target is automatically acquired in a guard zone/guard area, it is usual for an alarm to be activated to attract the operator's attention.

The target activating the alarm will be indicated on the screen by, for example, a flashing symbol.

In general, automatic acquisition has not been as successful as was at first predicted. There is a tendency to acquire sea clutter, rain clutter, noise and interference, while disassociated elements of land echoes will very quickly fill up the available tracking channels. Land echoes can be excluded by careful setting of the zones/areas and ARBs, but spurious targets (e.g. clutter), after having been acquired, are quickly lost and the 'lost target' alarm can sound continually.

While it is argued that automatic aquisition will reduce the operator's workload, in practice there is a tendency for it to acquire spurious targets, also to 'over-acquire' and so clutter the screen with unnecessary and unwanted vectors. This has led to auto-acquisition falling out of favour. Enquiries have indicated that it is rarely used in areas of high-density traffic, but can be useful on long ocean passages where

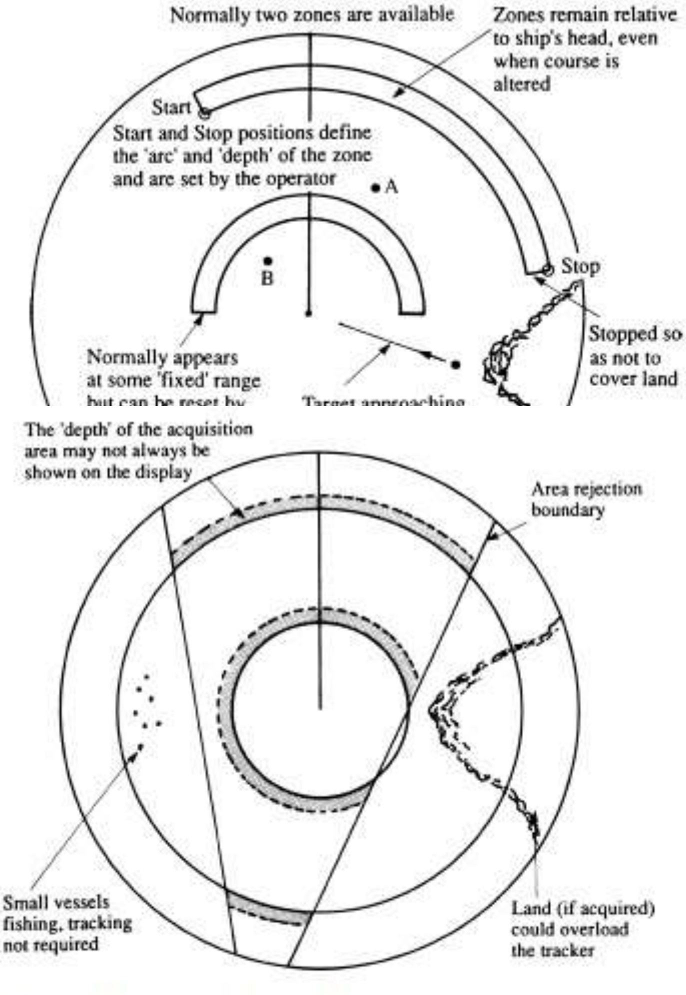


Figure 4.5 Guard rings and ARBs

the number of targets is small and there is the danger of loss of concentration by the officer of the watch due to boredom.

Manual acquisition can be very quick and also selective and hence the perceived need for automatic acquisition has not really materialized.

Guard zones/areas should be regarded as an additional, rather than an alternative means of keeping a proper lookout.

5.6- Tracking capabilities and limitations

.1- Describes target tracking by ARPA

There is a range of facilities available, with an increasing number of factors being taken into account when presenting the trial data. In the simplest form, it is possible to feed in only the intended course, speed and alteration time and observe their effect on the display. In some ARPAs it is possible for the vessel's handling characteristics to be included in the evaluation, but

this will of necessity be restricted to one (or possibly two) conditions of loading.

On some equipment, provision is made for two successive manoeuvres to be displayed. This can be extremely helpful when endeavouring to assess the time for which an alteration must be held.

In order that there should be no confusion between the 'trial' data and the current situation, when trial is in operation the screen will display some distinctive indication such as the word SIM or TRIAL. The use of a 'T' to indicate trial is frequently mistaken for an indication that true vectors are being displayed.

The letter 'T' as it stands is meaningless and has not been particularly helpful. There is the danger that one officer sets up the display and another officer (or the master) observes it without realizing the special nature of the display.

Some systems require the observer to hold down a button, which means that the observer has to make a positive decision to operate the switch and hold it over while he observes the display. Few systems offer such a failsafe control.

Note (i) While trial manoeuvres are being presented on the display, the computer continues its normal task of tracking all acquired targets.

(ii) Where 'predicted areas of danger' are provided, all the possible alterations of course should be simultaneously apparent.

(iii) A 'trial speed' facility is also provided since any given family of PADs is drawn for a specific speed of the observing vessel.

.2- Describes how target are lost and alarm activate

Target loss

The ARPA (or auto-tracking) should continue to track an acquired target which is clearly distinguishable on the display for 5 out of 10 consecutive scans, provided the target is not subject to target swap. (The term *scan* tends to be used rather loosely in radar terminology. Sometimes it is used to describe one line, as in the term 'interscan period', while on other occasions it refers to one aerial rotation. In the above context it refers to the latter.)

It should be noted here that if, for some reason, a response from a tracked target is not received on a particular scan, the ARPA must not immediately declare the target lost. Also it is implied that some form of 'search' for it must take place, e.g. by opening the tracking gate rather than merely looking in the limited area in which it was expected but failed to be detected.

In the IMO Publication "Minimum requirements for training in the use of Automatic Radar Plotting Aids (ARPA)" it is stated that the training for masters, chief mates and officers in charge of a navigational watch should have a knowledge of the criteria for the selection of targets by automatic acquisition".

In the Auto-acquisition mode one has to watch for warning signals that the computer system does not become saturated when new acquisitioning will stop and even the tracking of some targets may be dropped. *Warning signs* are:-

"Tracks Full" notice.

Flashing signals indicating "bad" or *"lost"* echoes.

A dotted ring indicates the area in which automatic acquisition still takes place. This ring expands or contracts depending on the degree of saturation.

.3- States common circumstances leading to target Swop

The possibility of tracking errors, including target swap, should be minimized by ARPA (and auto-tracking) design. A qualitative description of the effects of error sources on the automatic tracking and corresponding errors should be provided to the user, including the effects of low signal-to-noise and low signal-to-clutter ratios caused by sea returns, rain, snow, low clouds and non-synchronous emissions.

Target swap is likely when two targets respond within the tracking gate at the same time. When this happens, the tracker can become confused and the vector(s) may transfer to the wrong target. To minimize this problem, the gate should be made as small as possible, the movement of the target should be predicted and the gate moved on at each scan as described under 'rate aiding

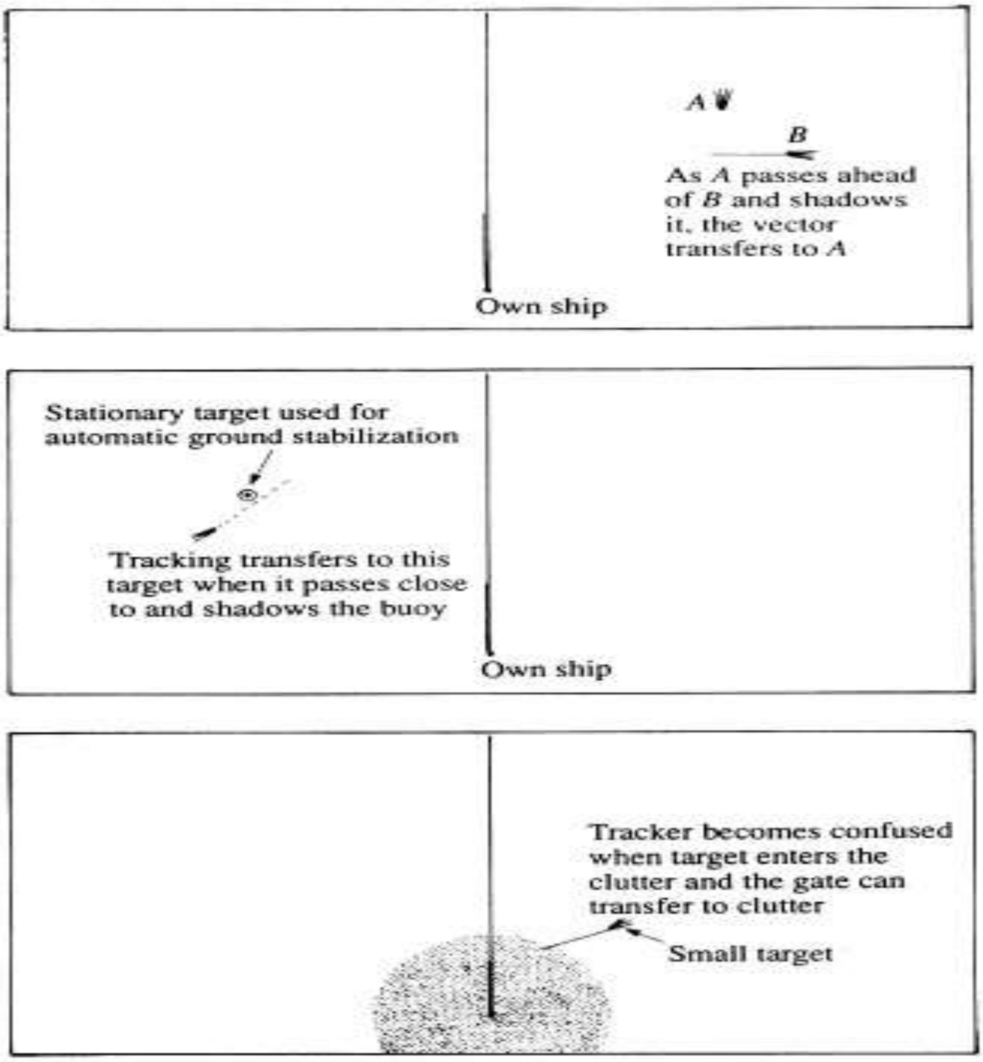


Figure 4.7 Target swap

When two targets are close to each other, it is possible for the association of past and present echoes to be confused so that the processor is loaded with erroneous data.

The result is that the historical data on one target may be transferred to another target and the indicated relative (and true) track of that ship will be composed of part of the tracks of two different target motions.

Target swap can occur with any type of tracker but is least likely in those which use a diminishing gate size as confidence in the track increases and those which adopt rate aiding. It is most likely to occur when two targets are close together for a comparatively long time and one target echo is much stronger than the other, see Figure 9.8. It is particularly likely to occur if one target shadows the other

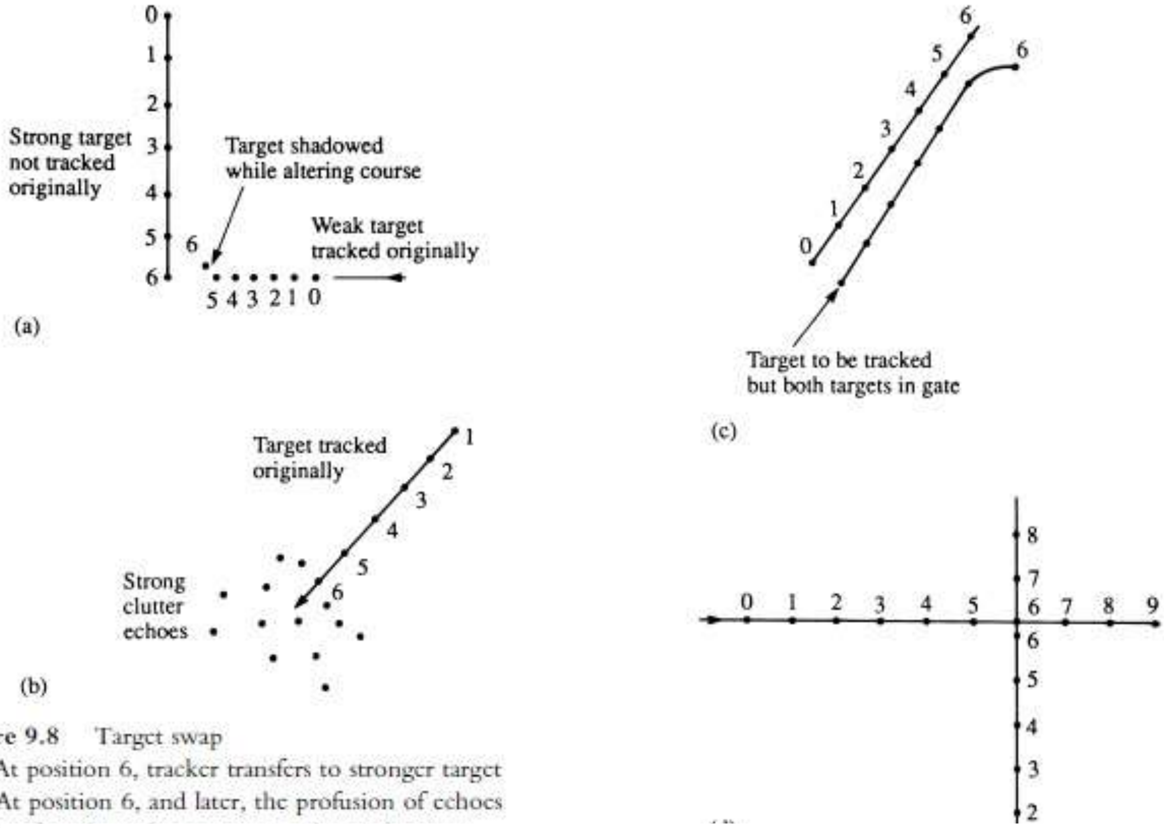


Figure 9.8 Target swap
(a) At position 6, tracker transfers to stronger target
(b) At position 6, and later, the profusion of echoes
(c) … , so that

Item	Symbol	Status	Remarks
Automatically acquired targets	⌜ ⌝ ⌞ ⌟	Initial stage EPVS symbol NO. 3	Broken square around an echo to indicate the target under acquisition and initial stage of tracking, before steady-state tracking.
	⌜ ⌝ ⌞ ⌟ with vector	EPVS symbol NO. 3	Between 20 and 60 scans of antenna after acquisition (vector still unreliable)
	circle with vector	Steady tracking EPVS symbol NO. 4a	Solid circle with vector indicating steady state tracking (60 scans after acquisition)
	triangle with vector (flashing)	CPA alarm EPVS symbol NO. 8	Plot symbol changes to an equilateral triangle flashing to indicate the target is predicted to come into CPA or TCPA.
	triangle with vector	CPA alarm acknowledge EPVS symbol NO. 8	Flashing stops after CPA/TCPA alarm is acknowledged.
	diamond (flashing)	Lost target EPVS symbol NO. 9	Lost target is indicated by flashing diamond symbol. The diamond is formed from two equal triangles.

Item	Symbol	Status	Remarks
Guard zone	(flashing)	On target passing through operator-set guard zone EPVS symbol NO. 7	Plot symbol changes to an equilateral triangle apex down, flashing together with vector if target entering guard zone (guard ring).
Automatic acquisition area		5.5-6.0 nm, 3-3.5 nm or anywhere EPVS symbol NO. 2	Sector or full circle as selected by the operator.
Target selected for data readout	1	On selected target EPVS symbol NO. 12	Target data (range, bearing, course, speed, CPA and TCPA).
Reference target	R (In 60 scans, change to R)	On reference target	Used to calculate own ship's over-the-ground speed (target-based speed) for ground stabilization. Note: Only one point is useable.
Trial maneuver	T (flashing)	Bottom center EPVS symbol NO. 10	Appears during execution of a trial maneuver.
Auto Plotter performance test	XX (flashing)	Bottom center EPVS symbol NO. 11A	Appears during execution of a performance test (Track Test).

Figure 5.19 - ARPA Symbols (continued)

5.7 - Processing delays of target tracking and information delays of AIS reporting

.1- Explain the delay in the display of processed ARPA data after target acquisition

In order to calculate the data required by the Performance Standard, the computer must store sequential positions of each tracked target and then analyse the movement represented by such successive positions so as to evaluate the relative motion and the true motion of each target. The computer is thus required to automate the operation which has traditionally been carried out manually by the recording of successive target positions (either by the plotting of ranges and bearings on a paper sheet or by the use of a reflection plotter) and the subsequent resolution of the *OAW* triangle. Automation of any process normally carried out by an intelligent being is always complex.

The injection of pseudo-intelligence and the difficulty of satisfying conflicting requirements gives considerable scope to the inventiveness of the designer and it is not surprising that various solutions to the problem exist, all of which differ in mathematical detail to a greater or lesser extent. A detailed consideration of the options open to the designer in carrying out the data processing is beyond the scope of this text, but it is important for the observer to have some general knowledge of how the operation relates to the way in which the same task would be tackled by manual plotting. This understanding is relevant not only to the above extract from the Performance

It should thus be appreciated that the ARPA (or auto-tracking) is carrying out a task which could be undertaken manually by an observer, given the time and the inclination, and that there is no reason to believe that the results obtained by an ARPA (or auto-tracking) are any better, or any worse, than those that can be achieved by such an observer. For acceptance by the ARPA (or auto-tracking) data must be in digital form, since the necessary calculations must be performed by a digital computer. Thus, in the first instance, the analogue radar data must be stored, radial line by radial line, in a digital memory. The presence of a response will be registered as a binary 1 in the appropriate range cell(s) and will be associated with the appropriate bearing word.

Filtering techniques are used to establish the likelihood of any particular response being a target and hence whether or not it should be stored for tracking purposes.

During each timebase the detected responses are read into what is known as the *prime register*, which is a group of memory elements of the form shown by one line of the memory matrix illustrated in Figure 2.39.

During the rest (or interscan) period, the contents of the prime register are transferred into the number one register which is the first of a group of N identical registers. At the same time the contents of number one are transferred into number two, and so on down the group. The contents of the Nth register (i.e. the oldest data) are discarded. During the transfer period a comparison is made of the contents of the N cells in each column and if more than M out of N cells in the column contain a binary 1, a hit is registered in the correct location in a further section of the tracker memory which holds only filtered responses. The filtering technique helps to reduce the probability of false echoes reaching the tracker and also improves the chances of a real but weak or intermittent response being tracked.

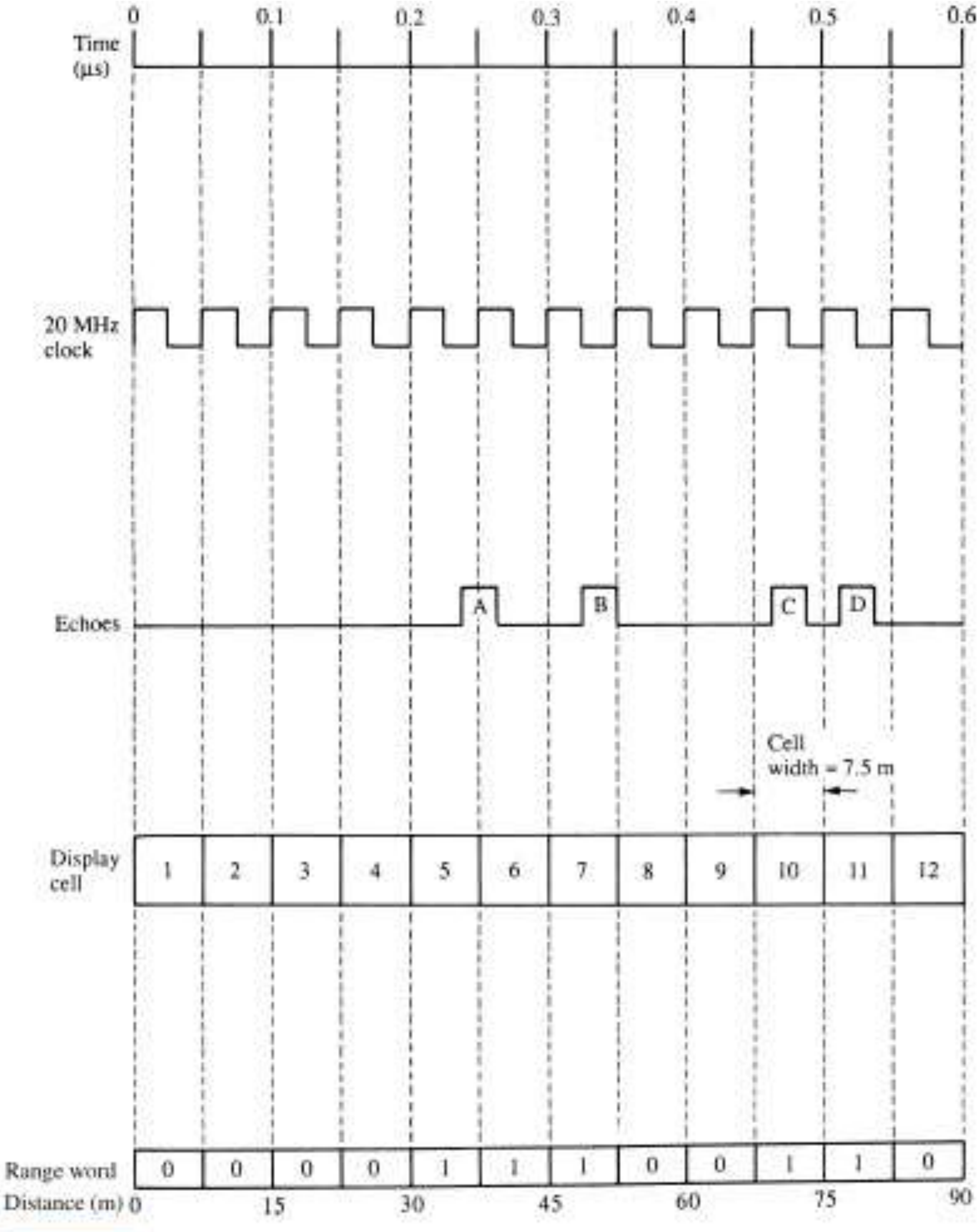


Figure 2.39 Sample rate considerations

Targets within the filtered area of the memory are selected for tracking when, either manually or automatically, a gate is placed over their responses. As the aerial beam sweeps past a ship-target, it will register a number of strikes on successive timebases and it may be that such a target activates more than one successive radial range cell. In the case of picture storage these digitized responses will aggregate in the memory to generate on the display an echo having the outline of the distinctive echo paint. Clearly it is neither necessary nor desirable for the computer to track each individual element present in the resolution cell. For this reason the input responses to the tracker are processed to produce a single registration which represents the location of the target to be tracked and about which the gate will in due course attempt to centre itself. The area of memory which is used to store the assembly of such registrations is known as the *hit matrix*.

If the target has been acquired, and is being successfully tracked, a tracking window will be centred on that particular memory location within the hit matrix which corresponds with the target's range and bearing.

The co-ordinates of the window can be extracted and stored in a further area of the tracker memory. This area is sometimes referred to as the *track file* and there will have to be a separate track file for each tracked target. Thus, rotation by rotation, as the gate moves in steps following the target's position through the hit matrix, sequential positions of each tracked target can be stored in the appropriate track file.

The processor (which is that part of the computer which manipulates the data and carries out the mathematical operations) must operate on the recorded positions to calculate the most probable track of the target. It is difficult to carry out calculations based on positions which are expressed in terms of range and bearing because the rates at which the bearing and range change are not constant for a target on a straight track. Further, the spatial resolution varies with range (i.e. it is geometrical). For these reasons it is usual to convert the target positions into cartesian co-ordinates of northings and eastings.

When laying off observed ranges and bearings on a plotting sheet the effect of inherent errors is that, even for a target on a steady track, the plotted positions do not form a perfectly straight line but are scattered about the correct track; the observer has to attempt to draw the line that is the best fit.

Exactly the same effect occurs with automatic plotting and it is further exacerbated by quantizing errors introduced by the digital storage. Since the data must eventually be displayed as a stable straight line vector, the processor must calculate a length and direction which represents the best fit to the scattered observations. This operation is known as smoothing and involves the application of quite complex mathematical techniques such as Kalman filtering, the mechanics of which are beyond the scope of this text. However, it is important for the observer to appreciate that such smoothing does take place and to understand the implications.

If the smoothing is carried out over too long a period, the tracker will be insensitive to changes in tracks as a result of which small manoeuvres may go undetected and there will be a long delay before large manoeuvres become apparent. On the other hand, if smoothing is carried out over a short period, the output data will fluctuate, rendering decision-making difficult.

Clearly the amount and duration of smoothing is a compromise and the difficulty of reconciling the twin requirements of sensitivity to target manoeuvres and data stability provides the designer with a considerable challenge. As a result, the particular algorithms used for smoothing vary in detail with manufacturer.

.3- States that there may be a delay of up to three minutes before full accuracy of derived information may be attained after acquisition or manoeuvre of the target

When a target is first acquired, the computer will commence storing positions, obtaining updated co-ordinates each time the aerial sweeps across the target (i.e. about once every 3–5 seconds). These positions will have an inherent scatter and initially the mean line will be very sensitive to plots which fall some distance from it. However, as the plotting duration increases and more plots are obtained, the mean line will stabilize and accuracy will improve. During the first minute of tracking the target will normally display only a symbol to indicate that it is being tracked.

In most systems the vector (or other graphical indication of target movement) will be suppressed until sufficient observations have been obtained to produce the indication of the target's motion trend to the level of accuracy required by the Performance Standard.

Some systems were designed to display vectors within a few seconds of acquisition. This should not be seen as a sign of instant accuracy. Accuracy demands a number of successive observations and until the one minute interval has elapsed there is no requirement to meet the Performance Standard accuracy. Any data derived directly or indirectly from these very early indications could be highly misleading. In general, where such early display takes place, a study of the instability of the vector (or other indication of movement) should convince the user that it is based on insufficient observations. After one minute the tracker will have smoothed about 12–20 observations and must then produce data to the lower of the two accuracy levels set out in the Performance Standard.

In some systems a graphic symbol on the target is used to indicate that the data is based on more than one but less than 3 minutes of observation. As long as the target continues to be detected at the location predicted by the rate aiding, the tracking period is allowed to build up to three minutes, at which stage the processor will be able to smooth some 36–60 observations and must then reach the higher accuracy level. Thereafter as each new plot is added the *oldest* is discarded.

If a target response is not detected in the location forecast by the rate aiding, one possible explanation is that the target has manoeuvred. The tracking gate will be opened out and if the target is detected, tracking will continue. If the departure from the three-minute track is not significant, the processor will conclude that the departure was due to scatter and will continue to smooth the track over a period of 3 minutes. On the other hand, if the departure is significant, the processor will treat the situation as a target manoeuvre and will reduce the smoothing period to one minute. This reduction in smoothing period is analogous to the situation in which an observer decides that a target has manoeuvred and therefore discards a previous *OAW* triangle and starts a new plot. If steady state conditions resume, low level accuracy must be obtained within one minute and then the tracking period can again be allowed to build up to 3 minutes, allowing high level accuracy to be regained.

Most systems have two smoothing periods, a short period of about one minute and a long period of about three minutes. For compliance with the Performance Standard the periods must not be more than 1 minute or 3 minutes respectively but in practice manufacturers quite often use slightly shorter periods and hence reach the required accuracy a little more quickly than the standard requires.

6- OPERATE AND ARPA SYSTEM

6.1- Set up and Maintain and ARPA display correctly (0.5 hrs)

.1- Set up an appropriate display presentation for the required task and current situation (stabilized relative motion and true motion display)

Using a true-motion ground-stabilized presentation

(a) *Without automatic ground-stabilization*. In this case stabilization is achieved by the navigator observing a known fixed mark and making adjustments based on these observations .

Moving targets within the vicinity are soon recognized after a small amount of plotting. Their positions and approximate movements with respect to the navigation problem can be deduced. However, it is essential to bear in mind that all targets will exhibit their *ground* tracks.

This limitation is resolved by turning the tidal speed control to zero for long enough to assess the course and speed of the target through the water, i.e. two to three minutes, depending on the range scale. (*Note* The parallel indexing lines on the plotter are now out of position and the origin will need to be reset to restore the parallel indexing plot.)

(b) *With automatic ground-stabilization*. In this case the ground-stabilization is provided by a fixed target reference, dual axis log or position fixing system such as GNSS. Echoes of moving targets can be tracked in the normal manner and their true vectors displayed. The relative vectors or data will provide CPA and TCPA information as required.

However, the true vectors may well represent the movement of the targets *over the ground* and if the tidal component is significant there could be a large discrepancy between the ARPA ground tracks and the target's course and speed *through the water* Since it is the *course through the water* which provides the aspect, the distortion of this piece of information can result in a complete misunderstanding of the situation which is facing the navigator. For example, in clear visibility at night, as a vessel approaches a port and is presented with an array of lights from moving targets against a backdrop of shore lights, unless there is a fairly close correlation between observed aspects and those illustrated on the PPI, the navigator may become disorientated or, alternatively, begin to lose faith in the equipment, all at a critical point in the passage. In reduced visibility, the fact that the data is distorted may go completely unnoticed and result in the navigator having a completely erroneous understanding of the traffic situation. This could lead to the wrong anti-collision action being taken.

The solution to this particular problem is that the navigator should not use a radar presentation that is primarily intended for navigation to deal with an anti-collision problem. The correct information on which to base collision-avoidance action comes from a sea-stabilized display and should always be made use of prior to making an anti-collision decision. The observer should remove the fixed target reference or GNSS input and return to the display of sea-stabilized data. Most of these changes of presentation are simple and quick with modern radars and there is no excuse for attempting to guess the effect that removing the tide would have. Having assessed the relevant information, the navigator can then return to his navigation problem by re-selecting the reference and re-aligning the navigation lines which will have drifted.

.2- Adjust radar controls for the optimum display of echoes

Do you have your marine radar adjusted to give you a crystal clear picture in any kind of ocean weather? Are brilliance, gain, rain and sea clutter tweaked for peak performance? If not, try these fast steps right now:

1. Warm up the Radar

Radars with automatic tuning can be adjusted after a 2-3 minute warm up period. This gives your radar time to settle down for more accurate range and gain adjustments (see below).

2. Adjust the Brilliance

Always start with the brilliance adjustment. If your radar has a contrast knob, use that along with the brilliance knob. Make brilliance and contrast adjustments just like you would with a computer or television. These adjustments affect only the brightness and clarity of the image.

Continue to make fine adjustments to the brilliance control as light conditions change. Dim the brilliance control after dark so that it doesn't interfere with your night vision.

3. Turn off rain clutter

In squalls or heavy downpours, you would use the rain clutter adjustment (AC rain or FTC) knob to clear screen interference. But when adjusting, keep this control all the way down or off.

4. Turn off sea clutter

Sea and swell faces give good reflectivity to a radar signal. This tends to clutter up the center of your radar scope with a fuzzy cluster of dots. You would use the sea clutter (STC) control to clear this up. Again, turn this control all the way down or off before making adjustments.

5. Find a distant object

Look for a large boat, ship, buoy or prominent landmass to use during adjustment. Select an object as far away as possible to give you the best results.

6. Adjust the Gain

Gain amplifies signals received by the radar. Spend a bit of time to get this important setting correct. If the gain is too high, it will wash out targets close to you. If it is too low, you will be unable to pick up distant targets.

First, change the range on your radar to a high setting, so that the signal will reach the object you selected. Turn the gain control clockwise in small increments until you just begin to see a faint speckle of dots across the screen. Fine-tune the gain control so that your object paints onto the scope as a faint, clear image.

7. Make adjustments for rain or sea clutter

In rain or heavy seas, you will want to adjust your radar to reduce interference from rain or sea clutter. Make all adjustments in small increments. The rain clutter control (AC rain or FTC) reduces clutter over the entire scope at once. The sea clutter control (STC) clears clutter from the center of the scope outward.

.3- use log and gyro compass input

Computer technology to predict future situations. An ARPA assesses the risk of collision, and enables operator to see proposed maneuvers by own ship.

While many different models of ARPAs are available on the market, the following functions are usually provided:

1. True or relative motion radar presentation.
2. Automatic acquisition of targets plus manual acquisition.
3. Digital read-out of acquired targets which provides course, speed, range, bearing, closest point of approach (CPA, and time to CPA (TCPA).
4. The ability to display collision assessment information directly on the PPI, using vectors (true or relative) or a graphical Predicted Area of Danger (PAD) display.
5. The ability to perform trial maneuvers, including course changes, speed changes, and combined course/speed changes.
6. Automatic ground stabilization for navigation purposes.

ARPA processes radar information much more rapidly than conventional radar but is still subject to the same limitations. ARPA data is only as accurate as the data that comes from inputs such as the gyro and speed log.

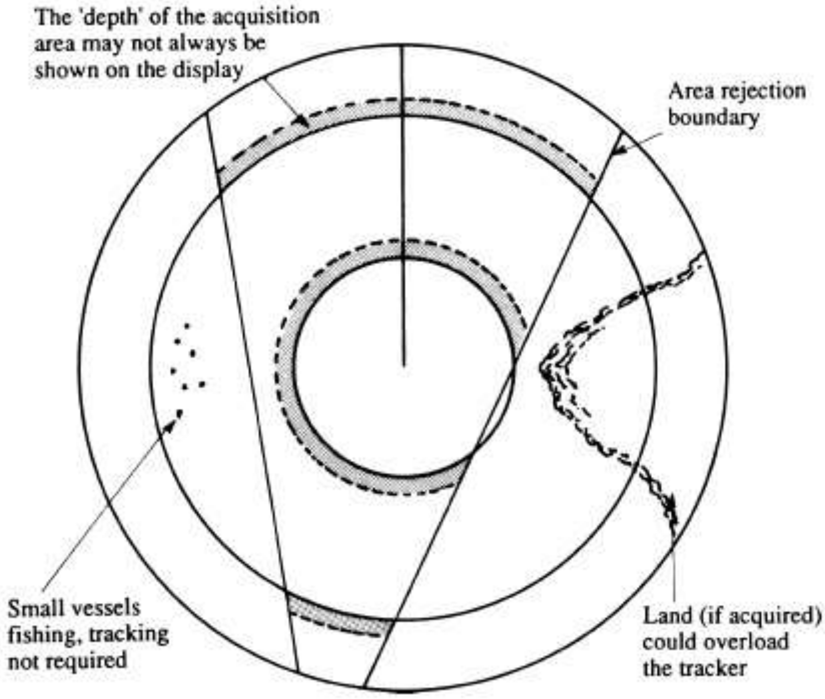
.4- Manually selects, acquires and monitors critical targets

If the ARPA does not track all targets visible on the display, targets which are being tracked should be clearly indicated with the relevant symbol on the display. The reliability of tracking should not be less than that obtainable using manual recordings of successive target positions obtained from the radar display.

.5- Set up automatic acquisition and exclusion areas

Guard rings and area rejection boundaries (ARBs)

With this method of acquisition, the usual provision is for up to two ‘rings’ (of predetermined depth) plus up to two area rejection boundaries (ARBs). The rings and ARBs may be positioned by the operator (Figure 4.5).



When a target is automatically acquired in a guard zone/guard area, it is usual for an alarm to be activated to attract the operator's attention .
The target activating the alarm will be indicated on the screen by, for example, a flashing symbol.
In general, automatic acquisition has not been as successful as was at first predicted. There is a tendency to acquire sea clutter, rain clutter, noise and interference, while disassociated elements of land echoes will very quickly fill up the available tracking channels. Land echoes can be excluded by careful setting of the zones/areas and ARBs, but spurious targets (e.g. clutter), after having been acquired, are quickly lost and the 'lost target' alarm can sound continually.
While it is argued that automatic aquisition will reduce the operator's workload, in practice there is a tendency for it to acquire spurious targets, also to 'over-acquire' and so clutter the screen with unnecessary and unwanted vectors. This has led to auto-acquisition falling out of favour. Enquiries have indicated that it is rarely used in areas of high-density traffic, but can be useful on long ocean passages where the number of targets is small and there is the danger of loss of concentration by the officer of the watch due to boredom.
Manual acquisition can be very quick and also selective and hence the perceived need for automatic acquisition has not really materialized.
Guard zones/areas should be regarded as an additional, rather than an alternative means of keeping a proper lookout.

.6- Use the appropriate time scale for vectors or graphics to produce information required

Pulse-repetition Frequency

The number of pulses transmitted per second is called the *pulse repetition frequency* or p.r.f. The p.d. is generally between 500 and 4000 pulses per second. Most radar sets have a short pulse and comparatively large p.r.f. for the short ranges and a longer pulse combined with a smaller p.d. for the longer ranges. To obtain a good minimum range, it is essential to have a short pulse for the shortest range scale. In order to collect enough echo strength, a great number of these pulses must be sent out per second.
In other words, *the output power is a function of the p.r.f and the pulse-length.*
For longer ranges the minimum distance is not important. The pulse can be made more powerful by extending its length and then the number of pulses per second can be reduced.

.7- Identifies differences between information shown in sea stabilized mode and ground stabilized mode

Ground stabilization:-
In ground stabilization mode true motion display of Radar is used & the Course & Speed is fed from GPS, hence the fixed objects on the PPI remain stationary. The movement of all moving objects is their movement over ground (COG & SOG). It is used for collision avoidance with fixed objects.
Sea stabilization:-
In sea stabilization mode relative motion display of radar is used & the Course is from Gyro course and speed is from log speed. Hence the fixed objects on the PPI appear to have a course & speed equal to the reverse course& speed of own vessel. The movement of own vessel, fixed object & moving object is their movement through

the water.
This is ideal for collision avoidance action.

.8- Select appropriate mode of the circumstances

Display Mode of the Radar Picture

A True Motion display mode should be provided. The automatic reset of own ship may be initiated by its position on the display, or time related, or both. Where the reset is selected to occur at least on every scan or equivalent, this should be equivalent to True Motion with a fixed origin (in practice equivalent to the previous relative motion mode). North Up and Course Up orientation modes should be provided. Head Up may be provided when the display mode is equivalent to True Motion with a fixed origin (in practice equivalent to the previous relative motion Head Up mode).

.9- Set up echo referencing in the true motion mode

TRUE MOTION CONTROLS

The following controls are representative of those additional controls used in the true motion mode of operation. If the true motion radar set design includes provision for ground stabilization of the display, this stabilization may be effected through use of either set and drift or speed and coursemade- good controls.

Operating Mode

Since true motion radars are designed for operation in true motion and relative motion modes, there is a control on the indicator panel for selecting the desired mode.

Normal Reset Control

Since own ship is not fixed at the center of the PPI in the true motion mode, own ship's position must be reset periodically on the PPI. Own ship's position may be reset manually or automatically. Automatic reset is performed at definite distances from the PPI center, according to the radar set design. With the normal reset control actuated, reset may be performed automatically when own ship has reached a position beyond the PPI center about two thirds the radius of the PPI. Whether own ship's position is reset automatically or manually, own ship's position is reset to an off-center position on the PPI, usually at a position from which the heading flash passes through the center of the PPI. This off-center position provides more time before resetting is required than would be the case if own ship's position were reset to the center of the PPI.

Delayed Reset Control

With the delayed reset control actuated, reset is performed automatically when own ship has reached a position closer to the edge of the PPI than with normal reset.With either the normal or delayed reset control actuated, there is an alarm signal which gives about 10 seconds forewarning of automatic resetting.

Manual Reset Control

The manual reset control permits the resetting of own ship's position at any desired time.

Manual Override Control

The manual override control when actuated prevents automatic resetting of own ship's position. This control is particularly useful if a critical situation should develop just prior to the time of automatic resetting. Shifting from normal to delayed reset can also provide more time for evaluating a situation before resetting occurs.

Ship's Speed Input Selector Control

Own ship's speed and course being necessary inputs to the true motion radar computer, the ship's speed input selector control permits either manual input of ship's speed or automatic input of speed from a speed log. With the control in the manual position, ship's speed in knots and tenths of knots can be set in steps of tenths of knots.

Set and Drift Controls

Set and drift controls, or their equivalent, provide means for ground stabilization of the true motion display. When there is accurate compensation for set and drift, there is no movement of stationary objects on the PPI.

Without such compensation, slight movements of stationary objects may be detected on the PPI. The set control may be labeled DRIFT DIRECTION; the drift control may be labeled DRIFT SPEED.

Speed and Course Made Good Controls

The radar set design may include speed and course made good controls in lieu of set and drift controls to effect ground stabilization of the true motion display. The course made good control permits the input of a correction, within limits of about 25° to the course input to the radar set. The speed control permits the input of a correction to the speed input from the underwater speed log or from an artificial (dummy) log.

Zero Speed Control

In the ZERO position, the zero speed control stops the movement of own ship on the PPI; in the TRUE position own ship moves on the PPI at a rate set by the speed input.

6.3- Operate ARPA or TT and AIS reporting to obtain target information

.1- Operates displays in true and relative modes to obtain true and relative vectors in each display

True vector

Vector mode, True or Relative, is selected with the [VECTOR] key. True vectors are the predicted true motion of a target as a result of own ship's direction and speed input. With true vectors the radar display will look like the one in (a) in the figure below.

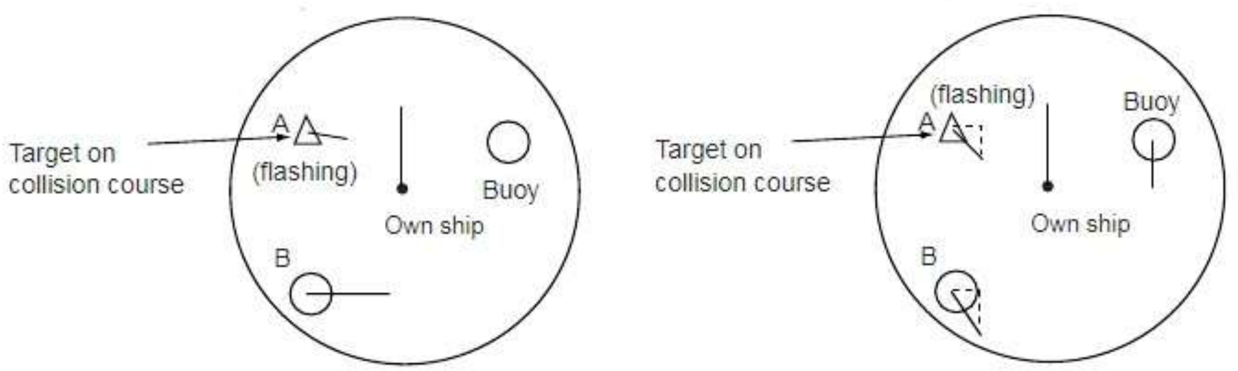
In the true motion mode, all fixed targets, such as land, navigational marks and ships at anchor, remain stationary on the radar screen with vector length zero. But in the presence of wind and/or current, vectors appear on fixed targets representing the reciprocal of set and drift affecting own ship unless set and drift values are properly entered.

Relative vector

True vectors are the predicted movement of a target relative to own ship. With relative vectors the radar display will look like (b) in the figure above.

Relative vectors on targets which are not moving over the ground, such as land, navigational marks and ships at anchor, will represent the reciprocal of own ship's ground track.

A target of which vector extension passes through own ship is on the collision course. (Dashed lines in the figure are for explanation only.)



(a) True vectors in head-up mode (b) Relative vectors in head-up mode

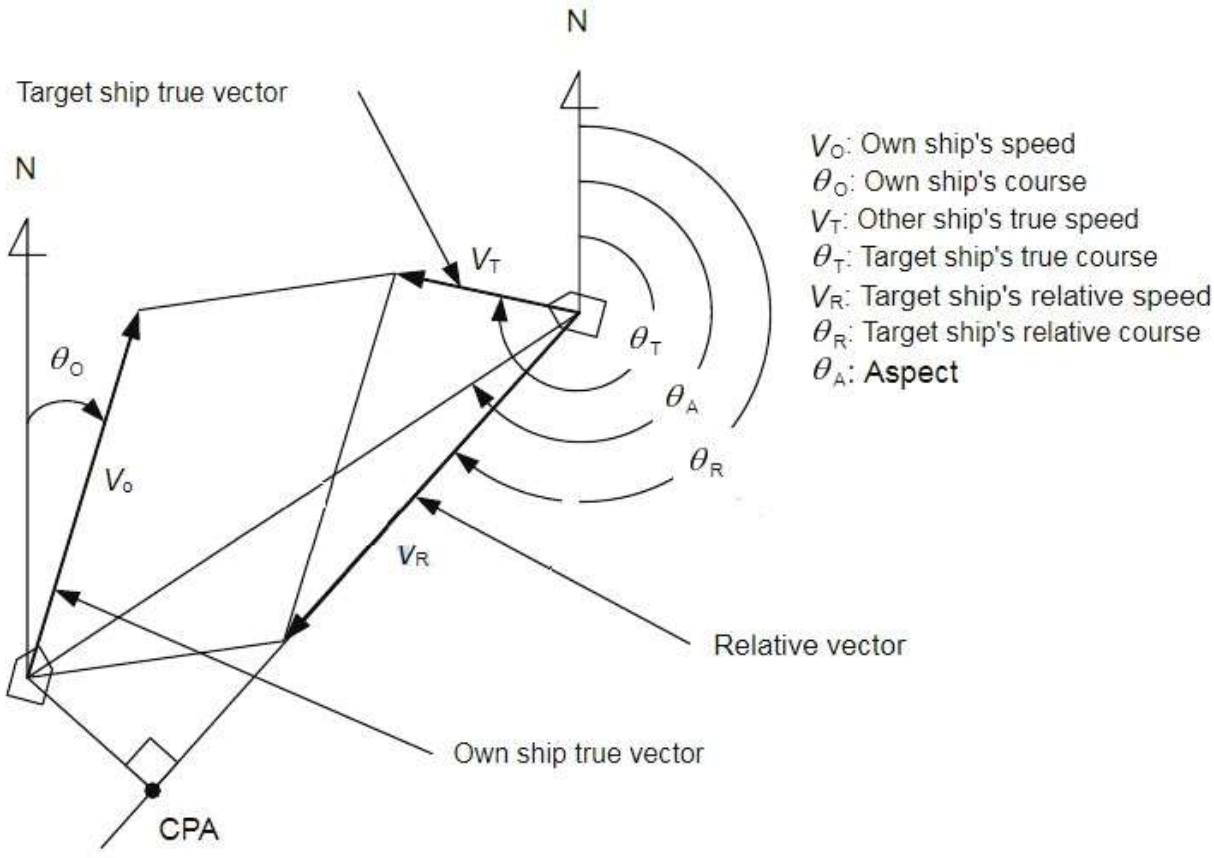


Fig. 5-3 Relative Vector and True vector

.4- Determine Threat of collision by forward extrapolation of vectors and by the use of pads

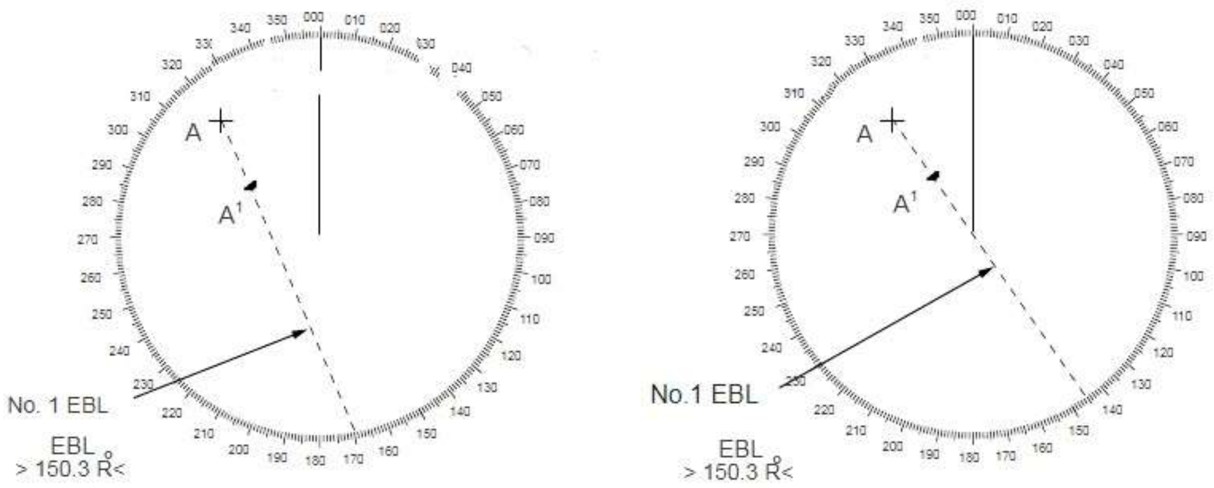
Collision Assessment by Offset EBL

The origin of the EBL can be placed anywhere with the trackball to enable measurement of range and bearing between any two targets. This function is also useful for assessment of the potential risk of collision. To assess possibility of collision:

1. Press the [EBL ON] key to display or activate an EBL (No. 1 or 2).
2. Place the cursor (+) on a target appearing as threatening (A in the illustrated example) by operating the trackball.
3. Press the [EBL OFFSET] key on the mode panel, and the origin of the active EBL shifts to the cursor position. Press the [EBL OFFSET] key again to anchor the EBL origin.
4. After waiting for a few minutes (at least 3 minutes), operate the EBL control until the EBL bisects the target at the new position (A ship's course, which may be true or relative depending on the settings on the RADAR 1 menu.

If relative motion is selected, it is also possible to read CPA (Closest Point of Approach) by using a VRM as shown below (Figure (a)). If the EBL passes through the sweep origin (own ship) as illustrated (Figure (b)), the target ship is on a collision course.

5. To return the EBL origin to the own ship's position, press the [EBL OFFSET] key again.



(a) Evaluating course of target ship in RM

(b) Target ship on collision course

Figure 1-22 Collision assessment with the offset EBL

The trails should be distinguishable from targets.

Either scaled trails or past positions or both, should be maintained and should be available for presentation within 2 scans or equivalent, following:

– the reduction or increase of one range scale;

– the offset and reset of the radar picture position; and

– a change between true and relative trails.

.6- uses trial manoeuvre (approximation depending on the model of own ship Manoeuvring characteristic)

The system should, where required by Table 1, be capable of simulating the predicted effects of own ship's manoeuvre in a potential threat situation and should include own ship's dynamic characteristics.

A trial manoeuvre simulation should be clearly identified. The requirements are:

• The simulation of own ship course and speed should be variable.

• A simulated time to manoeuvre with a countdown should be provided.

• During simulation, target tracking should continue and the actual target data should be indicated.

• Trial manoeuvre should be applied to all tracked targets and at least all activated AIS targets.

.7- Refers to equipment manual for a description of the Manoeuvring characteristics model use

This equipment is referred to Trial manoeuvre:

Graphical simulation facility used to assist the operator to perform a proposed manoeuvre for navigation and collision avoidance purposes, by displaying the predicted future status of at least all acquired or activated targets as a result of own ship's simulated manoeuvres.

.8 Sets and acknowledge operational warning

Performance tests and warnings

The ARPA (or auto-tracking) should provide suitable warnings of ARPA (or auto-tracking) malfunction to enable the observer to monitor the proper operation of the system. Additionally, test programmes should be available so that the overall performance of the ARPA (or auto-tracking) can be assessed periodically against a known solution.

When a test programme is being executed the relevant test symbols should be displayed.

In the case of conventional radar, there was always a basic requirement to ensure that the radar controls were properly adjusted and that correct operation of the radar had been established by means of a performance check.

All ARPA and ATA equipments incorporate some form of self-diagnostic routine which monitors the correct operation of the various circuits. This check is repeated at regular intervals (which may range from once per hour to many times per second) or on request from the operator. In the event of a fault, a warning is given to the operator and, in some cases, an indication of the cause or location (e.g. printed circuit board No. 6) of the fault is also given.

However, it must be appreciated that some faults cannot be detected internally, e.g. a failure of certain elements in a numeric read-out can cause an 8 to appear as a 6 or a 9 to appear as a 3 etc. In such cases, a typical test may provide for the operator to switch all of the elements on so that each indicator should display an 8.

To ensure that the processor which deals with data has sufficient overall accuracy, four test scenarios are specified together with the tolerances within which the output must fall. All ARPAs and ATAs should be able to conform to this level of accuracy.

Where the effect of a fault is confined to certain facilities, those facilities may be 'shut down' (e.g. true motion not available), while allowing the remainder of the system to continue to be used.

.9- States benefits and limitations of operational warning

Operational Warnings

There are six main situations which cause the Auto Plotter to trigger visual and aural alarms:

- CPA/TCPA alarm
- Guard zone alarm
- Lost target alarm
- Target full alarm for manual acquisition
- Target full alarm for automatic acquisition
- System failures

.10- Set area rejection boundaries to avoid spurious interference

INTERFERENCE REJECTOR

Mutual radar interference may occur in the vicinity of another shipborne radar operating in the same frequency band (9GHz for X-band, 3 GHz for S-band). It is seen on the screen as a number of bright spikes either in irregular patterns or in the form of usually curved spoke-like dotted lines extending from the center to the edge of the picture. The type of interference can be reduced by activating the interference rejector circuit.

The interference rejector is a kind of signal correlation circuit. It compares the received signals over successive transmissions and suppresses randomly occurring signals. There are three levels of interference rejection depending on the number of transmissions that are correlated. These are indicated by the legends lR1, lR2 and lR3 at the upper left position of the screen.

Press the INT REJECT key to activate the interference rejector circuit.

Successive presses of the key increase the effect of interference rejection, up to level 3. A fourth press deactivates the interference rejector. Switch off the interference rejector when no interference exists; otherwise weak targets may be lost.

Note: For stable reception of certain types of radar beacons (racons) or SART (Search and Rescue Radar Transponder) as required by SOLAS 1974 as amended 1988 (GMDSS), it is recommended to turn the interference rejector off.

6.4- Possible errors of interpretation of target data

.1- Identifies consistently vectors in the wrong mode (a common error)

Shipboard radar displays can be configured in a range of orientation modes (head-up, North-up, course-up) each offering benefits and hazards. Head-up display allows easy association with views from the bridge windows or from electronic charts in headup mode, whereas North-up gives easy association with paper charts or electronic charts in North-up mode. These choices may also be affected by the area the ship is in, such as pilotage waters or open ocean, and should always be coordinated with all members of the bridge team. As one experienced pilot advises, "learn how to use a head-up unstabilised display, so that if/ when all the secondary inputs fail, you still have a useful tool."

Two motion modes are provided – True and Relative. In True Motion the displayed position of own ship moves at a scaled speed across the display that corresponds to the vessel's actual motion. In Relative Motion mode the displayed position of own ship is static. When off-centred, this provides maximum lookout ahead, as well as possible early warning of rain showers/ squalls, landmarks, wheel over points and, of course, traffic.

.2- Derives information from vectors with numeric displays

The series of illustrations which follow, shows various steps in evaluating the results of own ship's maneuvers using only the direction of relative motion as presented, and demonstrates the immediate readability of information sufficient to make risk of collision assessment and maneuver.

These photographs were taken of a 16 inch stabilized north up relative motion radar, the range setting is 6 miles. Views A and B show the situation up to the decision time of 3 minutes. Views C thru J show the results of four simulator runs demonstrating each basic maneuver.

These illustrations show that it is possible for the maneuvering officer to have instantaneous, readily available, at-a-glance information which will "hang in" when the going gets rough and when orientation seems to be the most threatened. This is important, for it is difficult to assess a maneuver by reading a list of numbers concerning the threat and then mentally trying to associate those numbers with what own ship is doing.

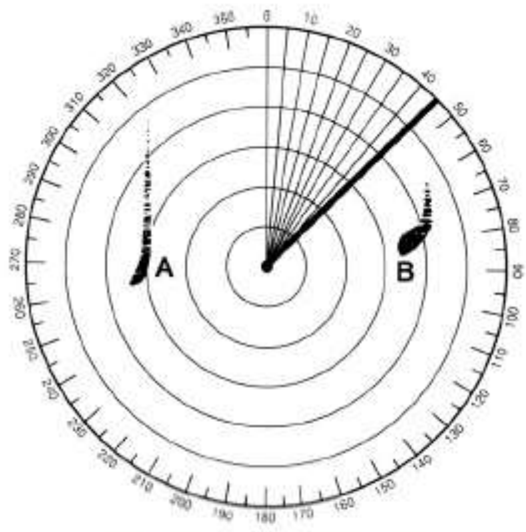


Figure 3.52 - Effects of a course change against targets with different speeds of relative motion.

.3- Explain that ... show a course and speed suggesting ...

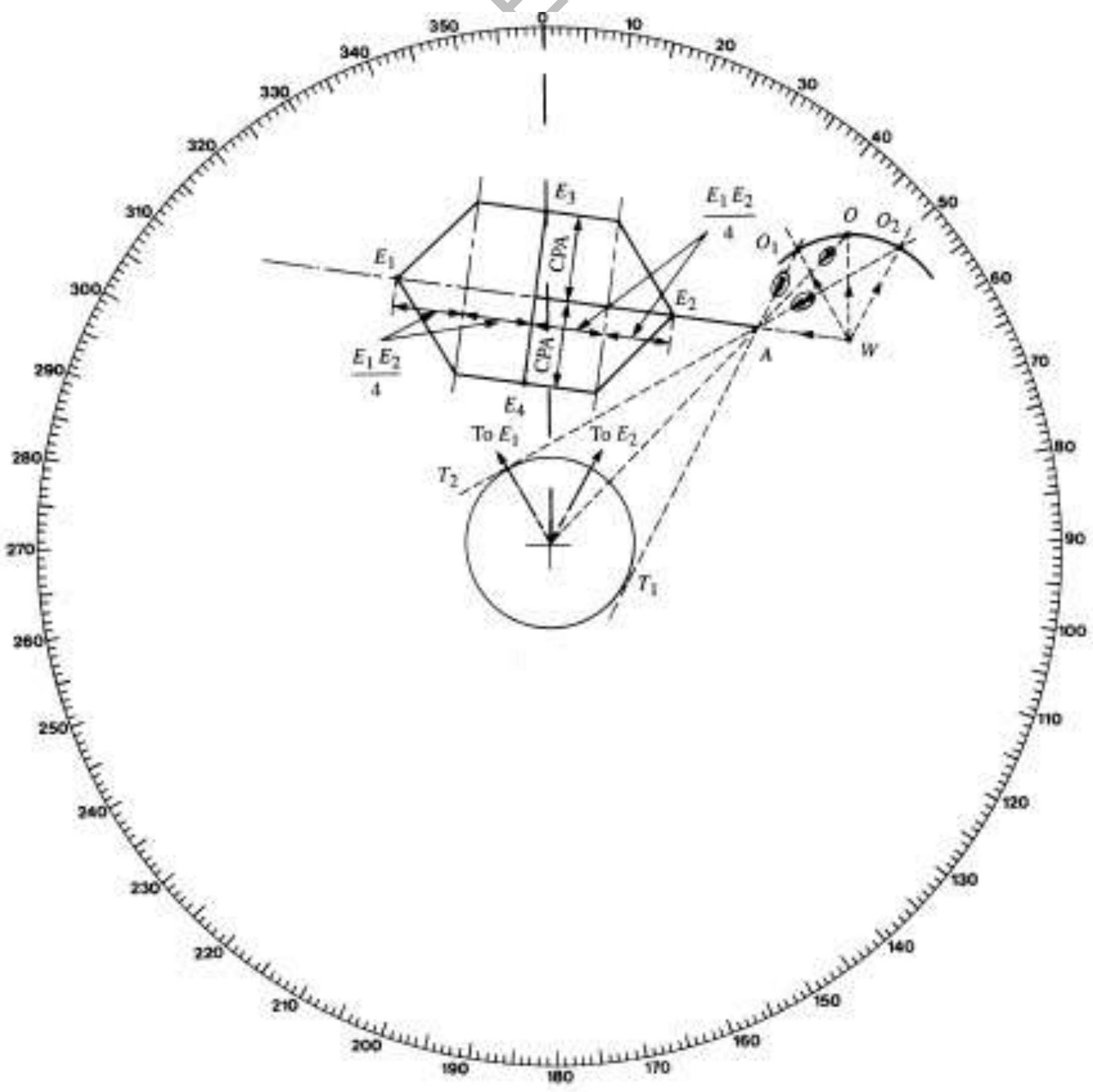
If a target once plotted i... arming "UPDATE PLOT NO" will appear c... plot symbol of the target flashes. If you wan... within five minutes. Otherwise, the target wil... mbol and target data will be erased. The larger the plotting interval, the less accurate the plotted target data. Plotting of each target should normally be made every 3 or 6 minutes as far as possible.

When a target has been plotted more than once, the radar calculates its motion rend and automatically displays a vector on the target.

.4- State data from PADs and PPCs display apply only to own ship and targets do not indicate mutual threats between target

The construction of the PAD

(a) Plot the target and produce the basic triangle.
(b) Draw lines AT1 and AT2 from the target's position A, tangential to a circle of radius equal to the required CPA. Extend beyond A.
(c) With compasses at W and radius WO, scribe an arc to cut T1A and T2A at O1 and O2 respectively.
(d) JoinWO1 andWO2. These represent the limiting courses to steer to clear the target by the required CPA.
(e) Draw CE1 and CE2 parallel to WO1 and WO2 respectively, to cut WA produced at E1 and E2 respectively.
(f) At the mid-point of E1E2, draw the perpendicular to E1E2 and extend it in both directions. In each direction, mark off the 'required CPA' and label the points E3 and E4.
(g) Draw in the ellipse passing through the points E1_ E2_ E3, and E4 (or the hexagon as indicated in Figure 7.18(b)). In the interest of simplicity, the ellipse was replaced by the hexagonal PAD in later equipment.
For a clearer appreciation of the PAD, Example 7.8 should be drawn out full size and to scale on a plotting sheet.



Exam
as fol
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1006
1012

Plot the target and draw in the PAD for a 2.0 n mile clearing.
Answer See Figure 7.18(b).

The construction to find the PPC

The plot is constructed as follows:
(a) Plot the target and produce the basic triangle.
(b) Join the own ship position ‘C’ to the target’s position ‘A’ and extend beyond ‘A’.
(c) With compasses at W and radius WO, scribe an arc to cut CA produced at O1 or, if own ship is the slower (i.e. WO<WA), at O1 and O2.
(d) Join WO1 (and WO2).
(e) Draw CP1 parallel to WO1 to cut WA produced at P1 (and CP2 parallel to WO2 to cut WA produced at P2).
(f) P1 (and P2) is the PPC.
For a clearer appreciation of the determination of the PPC, Example 7.7 should be drawn out full size and to scale on a plotting sheet.

Example 7.7 With own ship steering 000_(T) at a speed of 10 knots, an echo is observed as follows:
0923 echo bears 037_(T) at 10.3 n mile
0929 echo bears 036_(T) at 8.5 n mile
0935 echo bears 034_(T) at 6.7 n mile
Determine the bearing and range of the PPC(s).
Answer (Figure 7.17(b))
(a) P1 bearing 337_ at a range of 4.4 n mile.
(b) P2 bearing 270_ at a range of 18.0 n mile.

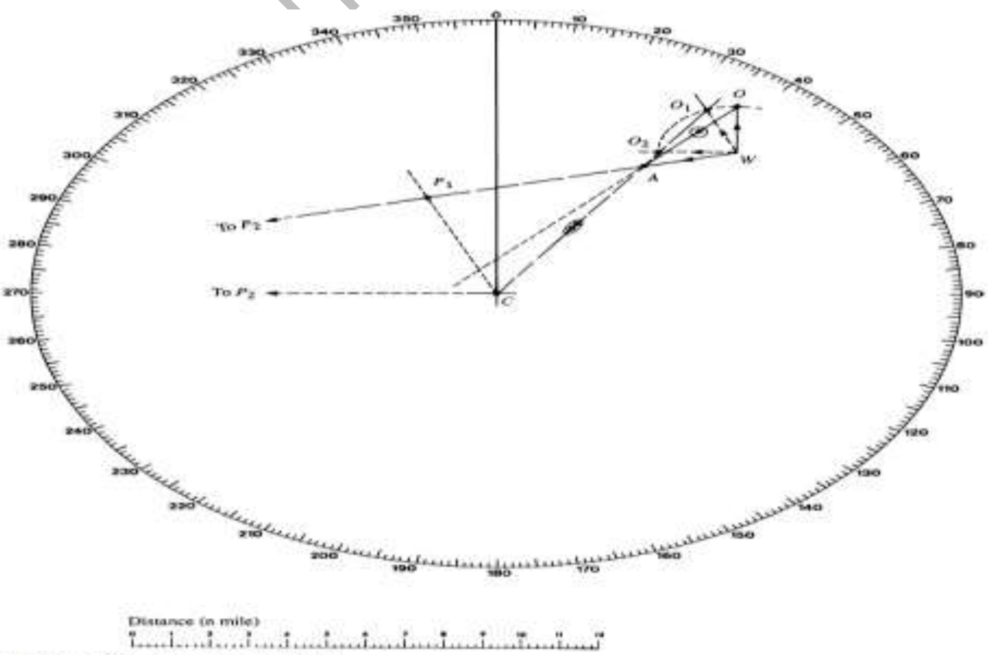
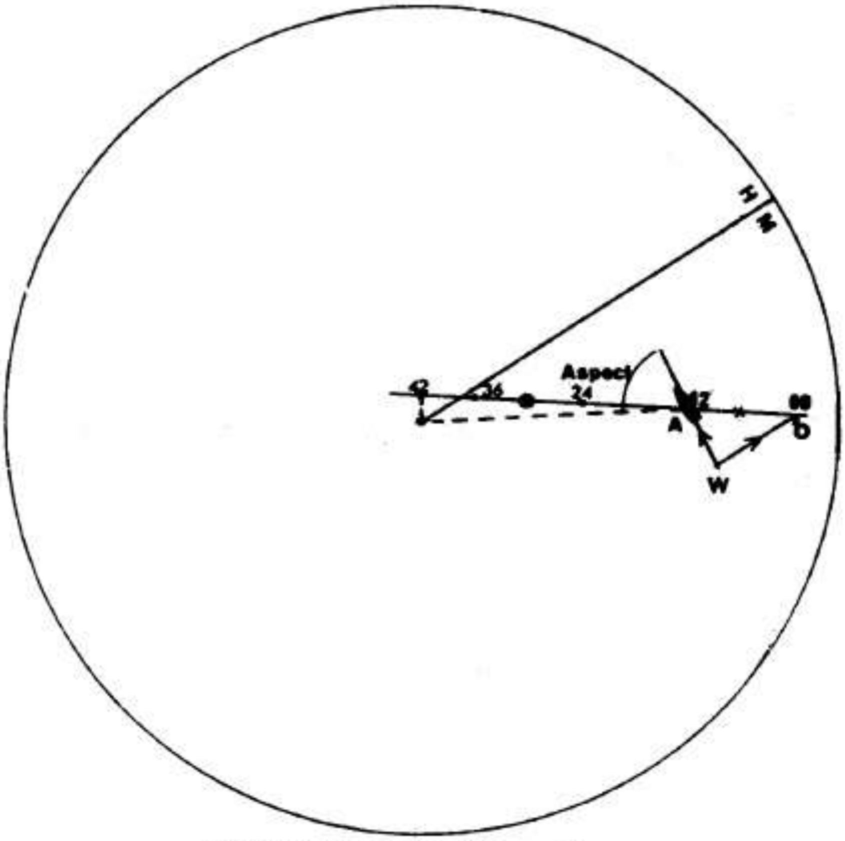


Figure 7.17(b) Answer to Example 7.7

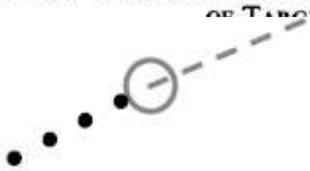
.5- States that the length of line from target to PAD or PPC is not an indicator of target speed

The indicatos of target Speed. If the *WO* component is plotted *during* the time interval, then nearest approach, course and speed of the target are obtained *simultaneously*.



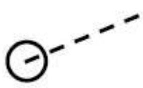
.6- States

FIG. 13.3 DETERMINATION OF COURSE AND SPEED OF TARGET

Target past positions		Dots, equally spaced by time.

vector looks in the same display

Table 2 Tracked radar target symbols

Topic	Symbol	Description
Tracked target including dangerous target		Solid filled or unfilled circle located at target position. The course and speed vector should be displayed as dashed line, with short dashes with spaces approximately twice the line width. Optionally, time increments, may be marked along the vector. For a **'Dangerous Target'**, bold, red (on colour display)

.7- States that a change of direction in the relative history display does not necessarily imply that the target has altered course

It is important to select *relative vectors* when assessing the effect of a manoeuvre as this will give an indication of how far the target will pass clear (Figure 4.12). It is also possible to vary the inputs while observing this display and note the effect on the CPA.

There is a range of facilities available, with an increasing number of factors being taken into account when presenting the trial data. In the simplest form, it is possible to feed in only the intended course, speed and alteration time and observe their effect on the display. In some ARPAs it is possible for the vessel's handling characteristics to be included in the evaluation, but

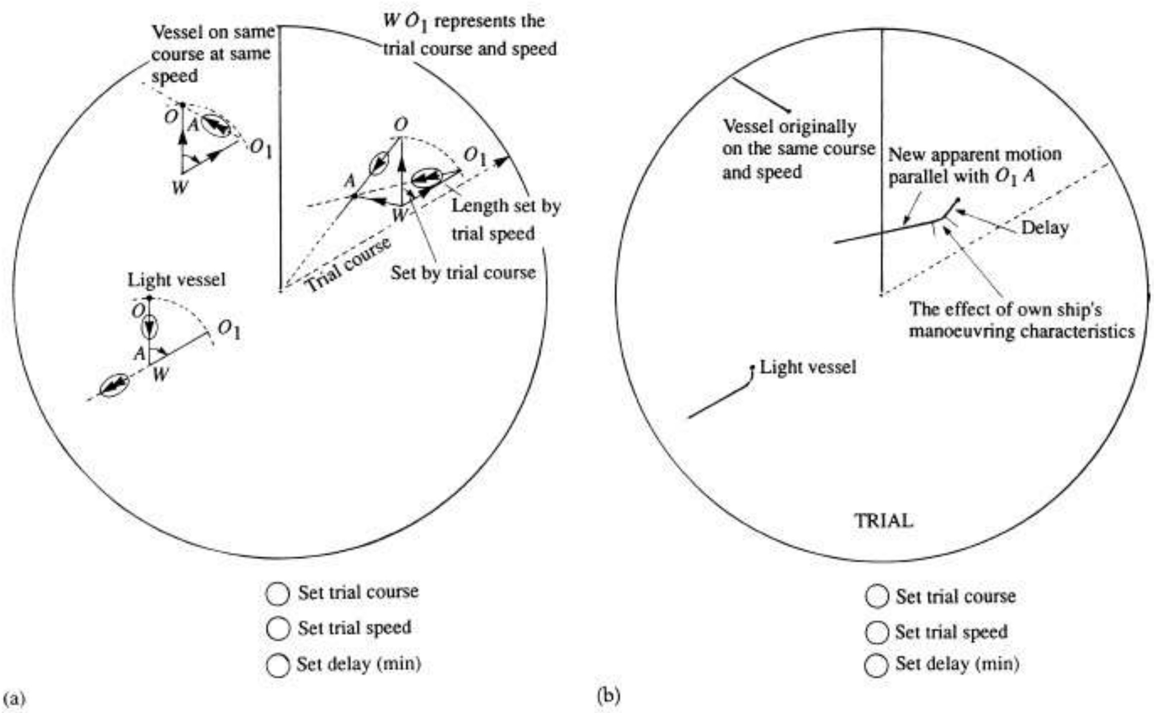


Figure 4.12 Trial manoeuvre display in the relative vector mode
(a) Construction of relative vectors
(b) The trial manoeuvre display

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it without realizing the special nature of the display.

Some systems require the observer to hold down a button, which means that the observer has to make a positive decision to operate the switch and hold it over while he observes the display. Few systems offer such a failsafe control.

.8- Explain that incorrect interpretation of ARPAmay lead to dangerous misunderstanding

(*Misinterpretation of the Trial Manoeuvre (Simulation).*

Here, also, the type of display presentation has to be appreciated. With static simulation, showing the predicted situation immediately after the manoeuvre, it seems best to use a Relative Motion Display with Relative Motion vectors of moderate length. With dynamic simulation, showing the predicted developing situation up to thirty minutes *after* the

manoeuvre has been carried out, it will be better to have a True Motion Display, for good understanding, plus Relative Motion vectors (if possible).
Although "Simulation" will give guidance for a predicted safe manoeuvre, the observer should keep the "Rule of the Road" in mind, especially Rule 19, during poor visibility. The former prediction, which is based merely upon the other vessel keeping her course and speed, may clash with the latter requirement.

Misinterpretation of the Input Speed (Velocity).

In open sea the input speed to ARPA is generally manual sea speed or one-axis "water-locked" speed. In calm water - which is often the case during fog conditions - one can be reasonably certain from the true motion vector what the target's aspect will be.
Near the coast or in estuaries, it is often advisable to use the *"Auto-Track"* or *"Echo-Reference"* facility, if these are available. The true motion vectors will then show the ground velocity giving a good idea where the ships are *going* to (this arrangement, under restricted visibility conditions does *not* clash with Rule 19 COLREG). This facility can be used with a True Motion *or* a *Relative* Motion Display.
Whatever the speed input, one must make certain what the type is - sea or ground speed, one-axis; sea or ground speed dual axes (sea or ground velocity) - to appreciate the meaning of and to understand the interpretation of the true motion vectors. Also, during rough weather, one should realise that some vessels will have wind drift (leeway) superimposed on their directed motion and their real aspect may differ from the one shown on the display or read out digitally. Error in the speed or velocity input does not affect the accuracy of range, bearing and RM past track.

Misinterpretation of Display Symbols.

One has to be careful with older ARPA sets where different manufacturers used different symbols (circles, triangles, squares, diamonds etc.) for the same message. For example, depending on the .ARPA make, a square symbol may indicate "Acquired", or "Stationary Target" or "Passing within the set CPA distance".

6.5 - Cause errors in displayed data

.1- Identify bearing errors in the radar installation due to:

Errors in the radar, gyro compass and log which feed data to the ARPA or ATA system will result in errors in the output data. Range and bearing errors which remain constant or nearly so during the encounter, e.g. a steady gyro compass error of a few degrees, will introduce an error into the predicted vectors of other ships, but are unlikely to cause danger since all data will be similarly affected, including own ship.
The effect of errors on the predicted data depends on the kind of error, the situation and the duration of the plot for which the data is stored for processing and prediction. This time is typically in the range of 1 to 3 minutes and in this respect it must be appreciated that errors which in the past could be considered to be negligible may have a significant effect on derived data. In the following examples, the situation is assumed to be a near miss or a collision

- **backlash**

Backlash in gearing

Backlash can occur between the rotating antenna and its azimuth transmitter. Air resistance on the rotating antenna will tend to maintain geartooth contact, but bounce and reverse torque due to aerodynamic forces will break the contact and allow some backlash to occur. This problem has been to a large extent overcome by the use of more modern forms of bearing transmission.

- **ship motion**

Unstable platform or antenna tilt Ship motion causes the axis of rotation of the radar antenna to tilt. When the ship is heeled to an angle of B radians, a bearing error of $-\left(\frac{1}{2}B^2 \sin\theta \cos\theta\right)$ is produced, where is th θ bearing of the target off own ship's bow. This l, i.e. zero ahead, astern and abeam, rising to alternate plus and minus maxima at 45° and 135° etc. It will not be reversed by the opposite roll since B is squared. When the ship is rolling, the tilt has two components, a random variation between zero and a maximum, according to the value of B (i.e the actual roll angle which happens to be present when the aerial is directly on the bearing) and a rise and fall of the maximum over periods of about one or two minutes with wave height variation. For a relative bearing of 45° and a roll of 7.5° toward or away from the other ship, the error is −0.25° maximum.

- **Asymmetrical antenna beam**

Asymmetrical antenna beam

The ARPA should take the bearing of the target as that of the centre of the echo. If the antenna beam is asymmetrical, the apparent position of the echo may change with the echo strength. Errors due to this cause can become very large in some systems if the echo strength is sufficient for the close-in side-lobe pattern of the antenna to become apparent. At least one system employs special techniques to eliminate this problem.

- **Azimuth quantization**

Azimuth quantization error (Figure 9.6)

The antenna position must be converted to digital form before it can be used by the computer, for example, by using a shaft encoder (see Section 2.6.6.4).
A 12-bit shaft encoder has a least significant bit (LSB) equivalent to 0.09° (i.e. 360 °/4096) so that the restriction to 12 bits introduces a quantization error of 0.045°. The same error will arise if the computer truncates the input azimuth information to 12 bits.
Antenna azimuth is often taken to a resolution of either 12 or 13 bits.
Note Since gyro compass error is of the order 0.1° to 0.5° at best, there is no real point in making the antenna encoder bit size very much smaller.

.2- Explain error in range generated by

- **rolling of own ship**

Parallax due to roll of own ship (Figure 9.5)

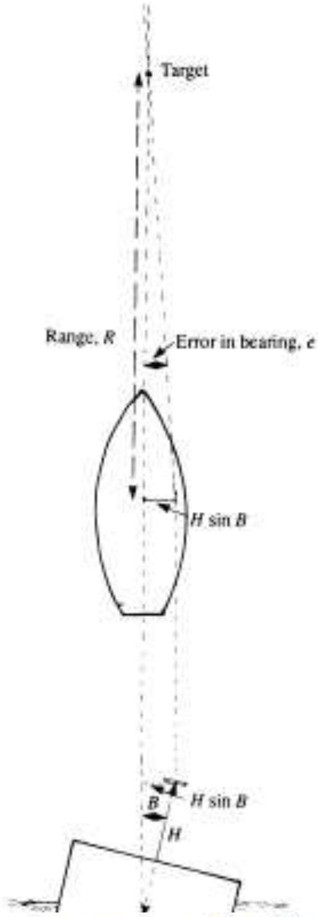
If the radar antenna is mounted at a height H above the roll axis of the ship and the ship rolls to an angle *B*, the antenna moves transversely by H sin *B*. The measured bearing of a target at a bearing of _ from the ship's head and at a range R will be in error by an angle e which is given by

$$\tan e = \frac{H \sin B}{R} \times \cos\theta$$

(*Note* H and R must be in the same units and is the θ ·lative bearing.) Since e is small,

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

This error will vary sinusoidally qual to the roll period.



The error is maximum when $\theta = 0°$ and $180°$ minimum when $\theta = 090°$ and $270°$ i.e. it varies with $\cos\theta$.

- **Range quantiz**

Figure 9.5 Parallax due to roll of own ship

Azimuth quantization error (Figure 9.6)

The antenna position must be converted to digital form before it can be used by the computer, for example, by using a shaft encoder .

A 12-bit shaft encoder has a least significant bit (LSB) equivalent to 0..09° (i.e. 360°/4096) so that the restriction to 12 bits introduces a quantization error of 0.045°. The same error will arise if the computer truncates the input azimuth information to 12 bits. Antenna azimuth is often taken to a resolution of either 12 or 13 bits.

Note Since gyro compass error is of the order 0.1° to 0.5° at best, there is no real point in making the antenna encoder bit size very much smaller.

.3- Explain that unreliable indications are given when smoothing

Where only the target manoeuvres there will be a finite response time in which the displayed vector will seek to follow the change and to stabilize on the new track. Under such circumstances, irrespective of whether the tracker smoothes relative or true tracks, there should in theory be no difference in the tracker performance when measured in terms of the accuracy with which it provides output of both relative and true vectors. In both cases the vectors may be erratic when the processor reverts to smoothing over the short period.

Where only the observing vessel manoeuvres, the method of storage is significant because the relative tracks of all targets will be curves for the duration of the manoeuvre. If the smoothing is applied to relative tracks, the tracker will be faced with the task of trying to produce a straight line from a curve and will hence obtain a mean track. Errors in the relative track will result and the relative vectors of all targets may be erratic in the short term. True-motion data derived from this will also be in error, just as where a manual plotter constructs an OAW triangle on the basis of an apparent motion which is not consistent. The effect may be exacerbated by the fact that, during the vessel's manoeuvre, the path traced out by the mass of the vessel, and hence the aerial, may differ significantly from that indicated by the gyro compass and log. Systems which smooth true tracks should derive a more accurate indication of the target's true track during the observing vessel's manoeuvre, as the true track is in theory rendered independent of changes in the observing vessel's course and speed.

This independence will be reduced by any difference between the velocity of the ship's mass during the manoeuvre and the direction and speed fed in by the gyro and log. Again, all errors must fall within the limits of the Performance Standards but the prudent observer can assess the effect of manoeuvres on the performance of the tracker by observing a known stationary target during a manoeuvre. In this connection it must be remembered that, even in steady-state conditions, a land-stationary target may display some component of motion due to the effect of tide, and water-stationary targets may have small non-zero vectors due to system errors.

Where both observing vessel and target manoeuvre at the same time, it is unlikely that any system will commence to provide a reliable indication of any target data until either the observing vessel or the target ceases to manoeuvre.

If targets are tracked down to very close ranges, the relative motion will give rise to very rapid bearing changes and this may make it impossible for the tracker to follow the target; thus the 'target lost' condition may arise, not because the echo is weak, but because the gate cannot be moved fast enough or opened up sufficiently to find it. It is also worth remembering that the use of true vectors as an indication of target heading is based on the assumption that the target is moving through the water in the direction in which it is heading. Leeway is the prime example of a case where this may not be correct. Unless one can see the target it is impossible even to begin to make an estimate of leeway. In poor visibility and high winds the observer must be alert to the possibility and use the displayed data with additional caution.

In summary, it must be remembered that whenever the steady-state conditions are disrupted there will be a period in which the data will be particularly liable to the track errors described above, in the same way as is the case when a target is first acquired. When the steady state is regained, accuracy and stability will improve, first over the short smoothing period and then over the long period. Any track data extracted during periods of non-steady-state conditions must be viewed with suspicion.

.4- Explain the effects of heading and speed errors on derived information

From the theory of manual radar plotting it is evident that it is possible to deduce the relative motion of a target without using a knowledge of the true motion of the observing vessel (other than to produce stabilized bearings). Deduction of the true motion of the target requires a knowledge of the true motion of the observing vessel to allow resolution of the *OAW* triangle and the accuracy of the result depends largely on the accuracy of the course and speed data used. Extrapolation of this reasoning suggests that the accuracy of relative vectors and the associated CPA data are independent of the accuracy of the course and speed input, whereas the accuracy of true vectors and the associated data are dependent on the accuracy of the input course and speed. In the case of systems which smooth relative tracks, this is invariably correct; in the case of systems which store true tracks, it is correct subject to the qualification that the input errors are constant. In the case of a fluctuating error input, the two storage approaches will produce different results. Whatever approach the tracker uses, it is essential for the observer to ensure that the correct course and speed inputs are fed in when setting up and that regular and frequent checks are made to ensure that the values remain correct. Failure to do this will in general result in the erroneous display of true data which may seriously mislead the navigator when choosing a suitable avoiding manoeuvre strategy.

.5- State that smoothness of the displayed history tracks is an indication of satisfactory tracking by ARPA

When ARPA is being used, the true vector data may be obtained in alphanumeric form and cross-checked by interpretation of the graphical presentation but, since these are often generated from the same database, a good comparison should not be taken as an assumption of accuracy of the information. It is important to remember that the success of the action by own ship may be influenced by recent changes in the target's true vector. It is thus useful to check, by using the *history* presentation on the ARPA, whether such changes have occurred, although there is *no* requirement to have this facility on an ATA.

7.5- Use system operational test to determine data accuracy (1 hour)

.1- Uses self-diagnostic routine

Performance check

Means should be available, while the equipment is used operationally, to determine readily a significant drop in performance relative to a calibration standard established at the time of installation, and that the equipment is correctly tuned in the absence of targets.
When using the ARPA the following points should be considered:
Review the operating manuals for all of the different makes and models of ARPA on board and be familiar with their capabilities and limitations

For collision avoidance purposes an ARPA should be sea stabilised with a log input delivering the vessel's speed through the water. The resulting true vectors will provide a more accurate indication of the aspects of tracked targets. If speed through the water is set manually, the details should be checked regularly and updated as necessary. Remember that GPS speed is the vessel's speed over the ground

If two or more ARPAs are in operation, it is recommended that these be set with different vector and trail types so that a comprehensive display of all information regarding traffic in the vicinity is readily available

When sea stabilisation is selected and considerable set and drift exist, land and other fixed objects will have true motion trails, possibly causing screen clutter. In such circumstances consideration should be given to selecting ground stabilisation to differentiate more easily between fixed and moving targets. However, for collision avoidance purposes sea stabilisation is preferable

It should be borne in mind that the relative motion of a target, and therefore its Closest Point of Approach (CPA), Time to Closest Point of Approach (TCPA), Bow Crossing Range (BCR) and Bow Crossing Time (BCT) should remain the same regardless of radar set-up, provided the vessel and the target maintain their course and speed

Compass heading and speed errors will produce inaccurate target true vector data, particularly when another vessel is on a reciprocal or near reciprocal course. This may lead to an incorrect interpretation of the other vessel's true heading and the necessary collision avoidance action

When using a transmitting magnetic compass to provide radar heading data, be aware that rolling may cause the magnetic compass to oscillate resulting in inaccurate ARPA information

Ensure visual and audible alarms are switched on when required

The CPA and TCPA alarms should be switched on and adjusted as necessary according to the prevailing navigational situation

The BCR and BCT alarms should be switched on and adjusted as necessary according to the prevailing navigational situation, remembering that the distance from the radar scanner to the bow may be considerable

If guard zones or target acquisition areas are used, bear in mind that these features are no substitute for maintaining a proper lookout by sight, hearing and all other available means to ensure the early detection of other vessels

In order for accurate target information to be displayed, an APRA will need to track a target for at least 3 minutes. Should either vessel change course or speed it will take time for the target data to reflect such details

Although ARPA target data may appear to be accurate, always treat such information with caution When selecting a vector length, ensure that it is appropriate to the prevailing circumstances and conditions

.2- Operates test programmes to check performance against know solution

These test scenarios are generated by a simulator and fed to the ARPA or ATA which must give the results specified in Tables 9.1 and 9.2.

In the scenarios, the target's motion is specified in terms of its *relative* course and speed, neither of which is particularly helpful to the practical ARPA operator; in fact, the use of these terms on the bridge

Table 9.1 Plotting accuracy values (95% probability) required after one minute

Scenario	*Relative course (degrees)*	*Relative speed (knots)*	CPA *(nautical miles)*
1	11	2.8	1.6
2	7	0.6	

Table 9.2 Plotting accuracy values (95% probability) required after three minutes

Scenario	*Relative course (degrees)*	*Relative speed (knots)*	CPA *(nautical miles)*	TCPA *(min)*	*True course (degrees)*	*True speed (knots)*
1	3.0	0.8	0.5	1.0	7.4	1.2
2	2.3	0.3			2.8	0.8
3	4.4	0.9	0.7	1.0	3.3	1.0
4	4.6	0.8	0.7	1.0	2.6	1.2

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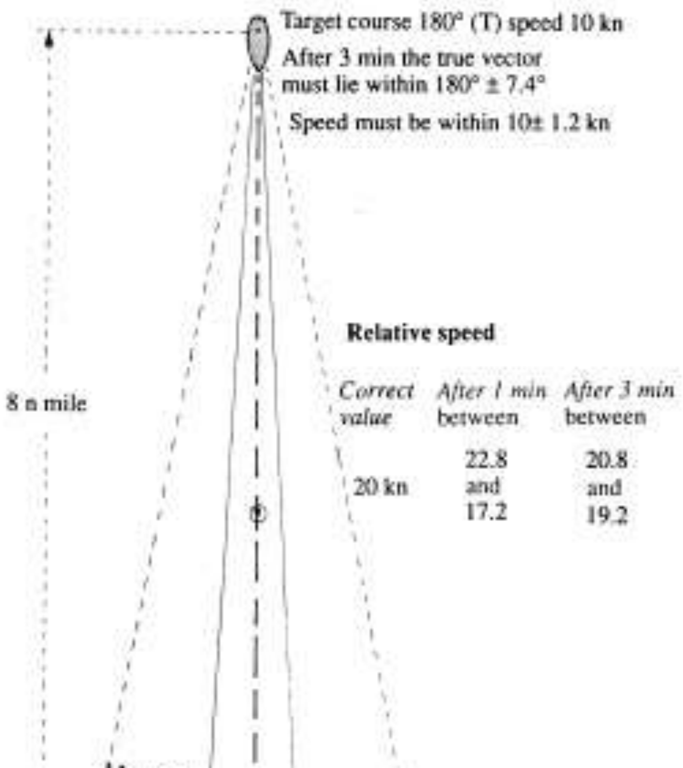
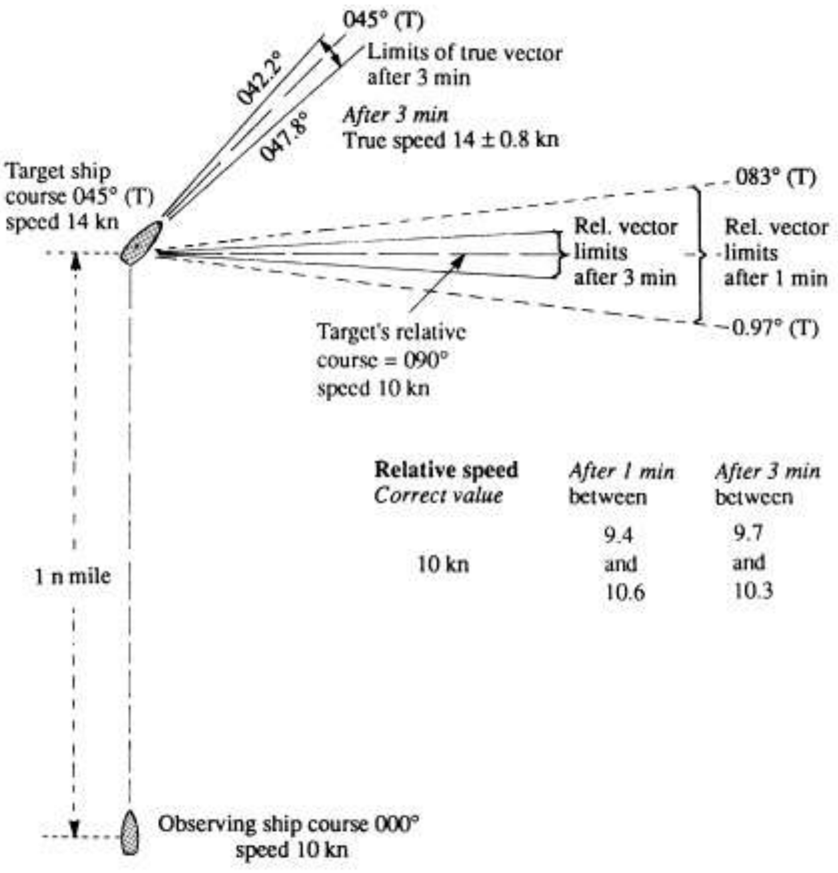
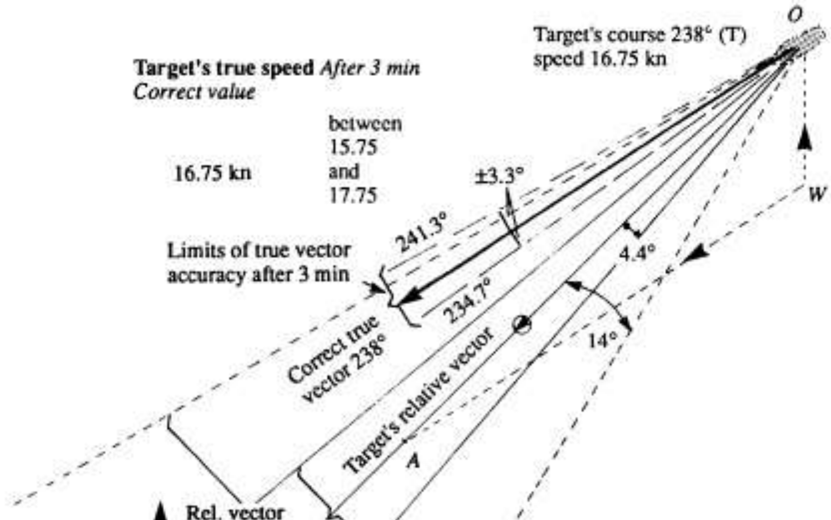


Test scenario 1 (Figure 9.1)
Own ship course 000_; own ship speed 10 kn; target range 8 n mile.
Target: bearing 000_; relative course 180_; relative speed 20 kn.



Test scenario
Own ship cou
Target: beari

Figure 9.2 Test scenario 2



Test scenario 3 (Figure 9.3)
Own ship course 000_; own ship speed 5 kn; target range 8 n mile.
Target: bearing 045_; relative course 225_; relative speed 20 kn.

Test scenario 4 (Figure 9.4)
Own ship course 000_; own ship speed 25 kn; target range 8 n mile
Target: bearing 045_; relative course 225_; relative speed 20 kn.

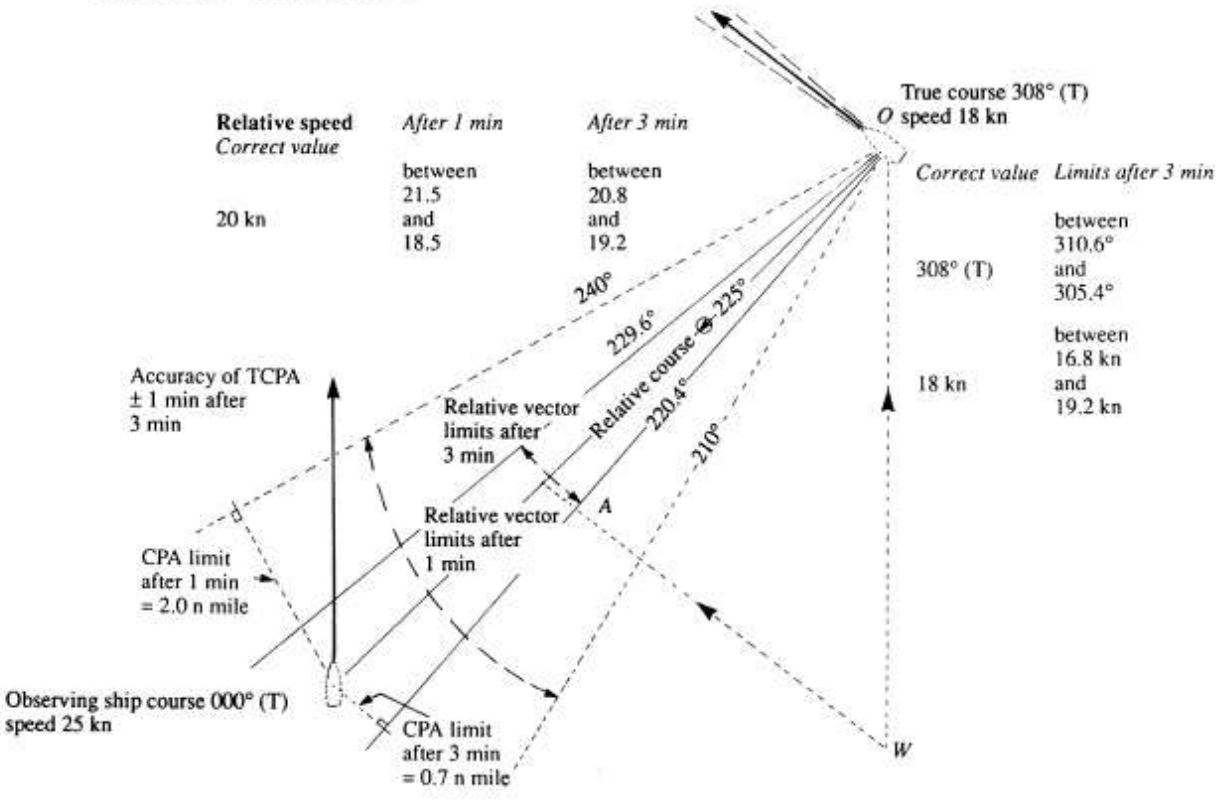


Figure 9.4 Test scenario 4

2. Enter own ship speed of 0 knots.
3. Press the [PLOT MENU] key followed by the [0] key to show the ARPA 2 menu.
4. Press the [9] key to select ARPA TRACK TEST.
5. Press the [ENTER] key.

An alert XX flickers during the test. It takes approximately three minutes for all vectors to be displayed. The test does not need echo signals, gyro nor speed log input. Seven targets having different speeds and courses, as shown in the table below, are simu- lated automatically.

6. The test continues for five minutes and then repeats.

To terminate the track test, press the [STBY/TX] key. The STBY display appears.

Select any target with the cursor and check that the selected target shows the course and speed as in the table. CPA and TCPA shown below are initial values which change with time.

Ta^{grte}	Cou^{sr}e	Speed $^{k()t}$	CPA $^{n(}$m)	TCPA (mi$^{)n}$
Ta^{grte} A	9 $^{0°0}$ T	10^{0}	1^{0}	10^{4}
Ta^{grte} B	$^{0°0}$ T	0^{0}	4^{0}	—
Ta^{grte} C	18 $^{0°0}$ T	10^{0}	1^{7}	28^{2}
Ta^{grte} D	21 $^{6°5}$ T	23^{8}	0^{9}	15^{0}
Ta^{grte} E	27 $^{3°5}$ T	14^{2}	6^{0}	22^{5}
Ta^{grte} F	18 $^{0°0}$ T	20^{0}	0^{0}	30^{0}
Ta^{grte} G	2 $^{4°6}$ T	15^{6}	4^{0}	43^{6}

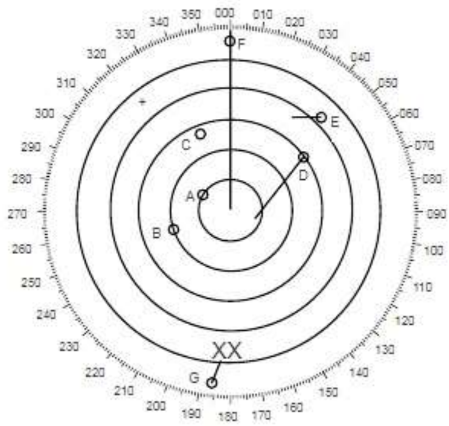


Figure 5-16 ARPA performance test values

1. The first thing we need to do is to try to calm. There's no room for panic because lives of many are in your hand when you are at the duty.

2. Protect yourself and the ship from the result of failure. You must be prepared ahead of time before the actual failure happens. Look for possible danger while ARPA is not functioning. You can use the radar, navigational charts, GPS receiver, sextant or any alternatives to sure the safety of the ships and the crew.

3. Record your position at a regular basis using manual plotting.

4.Maintain a look out.
5. Try to trouble shoot the arpa.

- Restart
- Shut down the breakers then turn on again after few minutes
- Turn on Radar and observe it
- Consult the manual
- Perform diagnostic test
- Refer to the flow chart
- Determine the damaged parts

6. Inform and consult the captain.
7. Call for a technician to the port that you are heading.
8. Maintain manual plotting until you arrive at the port.

7- Application of COLREG'S when using RADAR

.1- Uses a radar as a mean of look out, and state importance of continuous plotting.
Operational warnings. Audible and / or visible warning signals should be provided:-

(a) When any target closes to a range or crosses a zone selected by the observer. This is important in connection with the concept "keeping a proper look-out", and also, if manual acquisition only is provided, it warns the observer to start the tracking process in relation to (b) below.
(b) When any target is predicted to pass within a minimum range and time chosen by the observer.
An indication should also be given if any tracked target is lost other than by getting out of range. In all the cases mentioned above, warnings should also be clearly indicated on the display.
Radar for the Merchant Service is designed for what is known as "Surface Warning" and for anti-collision purposes its main use was during reduced visibility. With the faster ships, radar, however, is also now extensively used in clear weather as an extra aid for the look-out man. With the range-scale on 12 miles and the electronic centre off-set, strong echoes of ships can be detected up to 16 miles for an average bridge height and at a time when the ship has not yet been sighted visually. Another reason for earlier detection by radar is that the white echo pip against the dark background is often more conspicuous than the appearance of a ship against a grey sky and seas. By placing the curzor over the echo, a timely check can be kept on the bearing change.
When fog-banks are expected the radar set should be at least on "Stand-by" during daytime, making it ready for immediate use; but at night the set should be left on "Transmit", as the vessel could well be steaming along near a fog bank which is giving no visual indication of its presence.
When approaching a fog-bank Rule 35 (Sound Signals in Restricted Visibility) must be adhered to and radar must be used to see what is inside the fog-bank. Failure to employ the radar in such a case contravenes Rule 2 and blame accordingly has been attached to ships which did not comply with this rule near a fog-bank. Upon approach of the fog-bank, radar watch routine should be started, and inside the fog-bank, the observer should realize that some echoes on the screen might represent ships which are not in fog and may not exercise the same caution as his own ship.
Unexplained manoeuvres by other vessels as observed from the radar screen might indicate the existence of a small vessel or vessels undetected by the ship's own radar, and a close watch should be kept on the suspected area.
Shipmasters have been blamed for not keeping a proper "look-out" because they were not using their radar on clear nights to detect the presence of the unlit oil-rigs with which their vessels collided.
It may, therefore, be said that it is always good practice, especially for fast ships, to keep the radar working. This also offers an opportunity to the officer of watch to maintain his plotting expertise, which is so important in cases when the visibility deteriorates and plotting becomes really essential.
At night, when in a region where fog-banks and/ or unlit obstructions can be expected, the radar must be in continuous operation. Previous Court Cases, by the way, have stressed that a shipmaster is considered to be at fault for not using radar provided for his ship and also for allowing the radar installation on his ship to remain in a defective condition for a prolonged period. At present the U.K. Government has made radar compulsory for all British ships of 500 gross tons or more, following an IMO

recommendation that at least one radar must be fitted in ships of 500 g.r.t. or more (300 g.r.t. after 1st February 1995), and at least two radars must be fitted to all ships of 10,000g.r.t. or more, each capable of operating independently of the other.

Some important points to be kept in mind when using radar in reduced visibility, are the following:- .

(a) The setting of the anti-clutter control on raw radar displays. Adjust, if possible, in such a way that echoes can be traced near the spot representing own ship. Be aware of over-suppression, as this will wipe off most of the echoes of ships nearby.

(b) The existence of blind and shadow sectors caused by objects on the ship itself. A slight "weaving" around the course is recommendable in such a case.

(c) The selection of range scale, taking account of:

(i) The speed of own ship (the faster the ship, the greater the range scale).

(ii) The accuracy of bearing and range observations (shorter range scales with the echo in the outer half of the screen yields an increased accuracy).

(iii) The length of the "tadpole" tails (the shorter the range scale, the longer the tails). If a True Motion Display is available, this might entail off-centring the time-base and use of the Zero- Speed switch.

(iv) The possibility of encountering small craft or ice growlers (easier discernable on the shorter range scales and, if possible, with long pulse selected).

(v) The number of ships in the vicinity of own ship (a long-range scale can produce a confusing array of closely-packed echoes).

(vi) The range at which most merchant ships are first detected (generally about 10-15 miles).

In addition to the above considerations, it should be remembered that a plot on a reflection plotter mounted on a True tdotion Display will become distorted if the range scale is altered during the plotting interval (see Fig. 14.5). This problem does not arise with Relative Motion radar.

Summarizing on this problem of selecting a range scale, it is generally best to relate the range-scale used most of the time to the vessel's speed - changing to shorter range scales now and again to obtain more accurate observations of bearings and ranges of any nearby objects and also to conduct a search for smaller objects.

(d) The obeyance of Rule 35 (Sound signals in restricted visibility) even if the screen is free from echoes on the longer range scales and one knows that the set is fully efficient.

(e) The obeyance of Rule 34 (a) (Manoeuvring signals) only when the other vessel is in sight.

.2- List the factors which determine a safe speed, with emphasis on factors related to radar

Rule 6 introduces a new concept, namely Safe Speed. When, about 45 years ago radar was introduced on board ships, one of the greatest difficulties with which Mariners were confronted, was the term "Moderate Speed". What, in fact, was a moderate speed using radar? A concise answer was not possible. It could be argued that a moderate speed, using radar, could in some cases mean "Full speed with engines on Stand-by", but in other cases could mean a slower speed than a Mariner without radar might consider "moderate". From

the legal and philosophicaI point of view these arguments are quite correct but in the literary sense they are unsatisfactory.
A Safe Speed as defined in the 1972 Rules is not based only on the state of visibility (as in the 1960 Rules) but "Every vessel shall at all times proceed at a safe speed so that she can take proper and effective action to avoid collision and be stopped within a distance appropriate to the prevailing circumstances and conditions".
Besides the state of visibility (i) the following factors should be taken into account in determining a safe speed:-
(ii) "the traffic density, including concentrations of fishing-vessels or any other vessels";
(iii) "the manoeuvrability of the vessel with special reference to stopping distance and turning ability in the prevailing conditions";
The manoeuvrability depends on the stern power of the vessel, the number and type of screws, the provision of a bow-thruster, the size of the ship and her loaded condition while the prevailing conditions are mainly governed by the wind and wave directions, wind force and wave height, and current and tidal conditions.
(iv) "at night the presence of background light such as from shore lights or from back scatter of her own lights";
(v) "the state of wind, sea and current, and the proximity of navigational hazards";
(vi) "the draught in relation to the available depth of water" .
These factors, which determine a safe speed in general, are applicable to all ships. Vessels which use their radar need, in addition, take the following conditions into account:-
(i) "the characteristics, efficiency and limitations of the radar equipment"; The age and reliability of the equipment, the number of radars and displays, interswitching facilities, types of display presentations, plotting devices and facilities for automatic plotting etc., are all factors to consider.
(ii) "any constraints imposed by the radar range scale in use"; A constraint may be imposed on a particular range scale owing to strong radar or electrical interference, or for a very fast vessel the use of the 12-mile range scale (the 24-mile range scale is too small for effective plotting on a reflection plotter) for echo observation, might compel her to reduce speed.
(iii) "the effect on radar detection of the sea state, weather and other sources of interference"; Excessive "noise" due to wave, sea, rain-drops, snow crystals, other ships' radar pulses or electrical interference may swamp the signal and essential information may be lost.
(iv) "the possibility that small vessels, ice and other floating objects may not be detected by radar at an adequate range". This "possibility" can be a result of atmospheric conditions such as sub-refraction or it might be caused by a small reflection coefficient of the object.
(v) "the number, location and movement of vessels detected by radar".
(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".
In addition, we may say that the number of men for keeping radar watch and a plot, and their efficiency could influence the master's opinion about what is, or what is not a safe speed

.3- List factors which provide a good plot to avoid collision/close encounter

Rule 7 deals with the "Risk of Collision". The Rule stresses again the use of "all the available means appropriate to the prevailing circumstances and conditions to determine if the risk of collision-exists". This includes the listening to V.H.F. R/T messages of other ships and shore radar stations, but no guidance is give about actual active participation.
There is a very important last sentence in the first paragraph: "If there is any doubt such risk shall be deemed to exist". This might remove the possible element of indecision in a radar encounter.
Rule 7 (b) stresses the importance of making proper use of radar equipment, including early warning of collision risk on the longer range scales. It furthermore emphasizes the practice of radar plotting or "equivalent systematic observation of detected objects" (recording in writing and tabulation, automatic plotting aids).
Rule 7 (c) statp.s:"Assumptions shall not be made on the basis of scanty information, especially scanty radar information". The omission of a plot, an incomplete plot or a plot based on an insufficient number of observations, in short the determination of the position of another vessel without finding her movement, might be termed as "scanty". ARPA provides a solution here.
The last paragraph of Rule 7 states how risk of collision can be obtained from compass bearings and gives a warning that an appreciable change in bearing does not always indicate a safe passing (large vessel, or a tow, or a ship at close range; see also Fig. 14.4). Bearings should be recorded as compass bearings and not as relative bearings as is so easily done on an unstabilized display. It is not possible to compare relative bearings when own ship is subject to yaw or makes alterations of course, and often the Master has been led to believe, that, by making a small alteration of course, the situation improved because the relative bearing changed and he did not realize that the change in the relative bearing was mainly due to own ship's alteration of course. If he had converted the relative bearings to compass bearings, he would have noticed that danger of collision after the alteration had become greater instead of less.

Rule 8 is headed "Action to avoid Collision".

Paragraph (a) states that, if the circumstances of the case admit, any action shall "be positive, made in ample time and with due regard to the observance of good seamanship". The word "positive" in this connection means "effective" and bears no relationship to the conventional adaptations "positive and negative actions", mentioned in certain papers about collision-avoidance (more about these later).

Paragraph (b) is an extension of paragraph (a), stating that "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". The Rule requires substantial action in order to make clear one's intention to all vessels in the neighbourhood ("another vessel" is not necessarily the vessel for which avoiding action was taken) both in clear weather as well as in fog. This requirement should be kept in mind when an agreement is reached about collision-avoiding tactics between two vessels via V.H.F. R/T and also when using the 'Trial Manoeuvre' facility on ARPA.

The remainder ofthe Rule (paragraphs (c), (d) and (e» emphasizes that an alteration of course, provided there is sufficient sea room, may be the most effective action to avoid a close quarters situation on condition that it is made in good time, is substantial and does not result in another close-quarters situation. It stresses the safe passing distance and warns that effectiveness of the action shall be carefully checked until the other vessel is finally past and clear. If necessary, or to allow more time to assess the situation, a vessel shall slacken her speed or take all way off by stopping or reversing her means of propulsion.

In short, what this Rule is saying is that if avoiding action for another vessel is going to be taken such action should be bold both in clear weather and in conditions of restricted visibility so that the intention of the vessel taking the action becomes readily apparent to. other vessels in the vicinity.

Seen in this light, an alteration of course is generally more effective than an alteration in speed.

each forward of the other's beam - an alteration of course or speed by one of the vessels shows up far less pronounced in the relative track (direction or rate) on the other vessel's display or plot when a relative presentation is used than if a true motion presentation were used. This is understandable when one remembers that the relative motion line is produced as the result of two vectors, of which only one is changed in this case.
Fig. 16.1 shows the effect of an alteration of course by another vessel on the relative motion display of own ship. The vessel on the port bow is on an opposite course and has the same speed as own ship. If she alters 45 degrees to starboard, then the OA line will change its direction by 22~ degrees. The vessel on the starboard bow, also on a reciprocal course, but having a speed half of that of own ship, will cause a change of 27 degrees in the OA line if she makes an alteration of course of 90 degrees. It is quite obvious that the change in the direction of the OA line depends on the ratio of the ships' speeds. If the speeds are the same, then the change in the direction of the relative motion shown on own ship's plot is about one-half the alteration of course of the other ship.
The reverse is also true. If our own ship, for example makes an alteration of course of 30 degrees, another crossing vessel, with approximately the same speed, forward of the beam, involving risk of collision, will observe a change in her relative motion line of about 15 degrees. To make, therefore, a course alteration - and this holds also for alterations in speed - readily apparent and on the assumption that other vessels in the vicinity use a relative motion display presentation, a substantial alteration is required by own ship.
The second reason for making substantial alterations is that errors in plotting and a wrong estimation of the direction of the relative motion line can easily take place (Chapter 14) especially when the display is unstabilized. The observer may, for example, conclude that the other vessel is on a collision course or will be passing on her port side while, in fact, the other ship, if she maintains her course and speed will be passing on her starboard side. If, in this case, own ship makes a small alteration to starboard, then, instead of improving

the situation, the nearest approach between the two vessels will become even smaller. If later on, own ship makes a second alteration to starboard, and perhaps even a third one, then this may lead to collision. This type of action whereby one ship makes a succession of small alterations of course has become known as The Cumulative Turn and the majority of collisions in fog have been caused by this type of action. See Fig. 16.2.
In many of these collision cases, while one ship carried out the cumulative turn, the other vessel maintained her course and speed, simply because she had not detected the effect of the turn on her display.
Although, for her, the bearing opened out it did not open out sufficiently (Rule 7 (d) (ii) and Fig. 14.4) and in the final stages of the encounter it became steady. Hence the warning in Rule 8 (b) against a succession of small alterations of course and/ or speed.

Rule 8 (c) states that if there is sufficient sea room, alterations of course alone may be the most effective action to avoid a close-quarters situation.
The sea room, however, could be restricted by navigational dangers or a fair amount of traffic with ships crossing from different directions. In such cases substantial alterations of course may not be possible and may make the situation even more dangerous when ships which, before the alteration, were not on collision courses, may after the alteration, involve a risk of collision. If it becomes necessary to avoid collision, a substantial reduction in speed must be made (Rule 8 (e)) ..
Paragraph (d) of Rule 8 emphasizes that the effectiveness of any action shall be carefully checked until the other vessel is finally past and clear.
During restricted visibility and using one's radar, this means that after an alteration of course and/ or speed, observations of the target should be taken at frequent intervals to see if the echo follows the predicted track at the predicted rate. If the echo deviates from the predicted track away from the centre of the plot, then the other vessel has taken action contributing to safety, but, if on the other hand the echo deviates from the prediction line towards the centre of the plot, then the other vessel has taken action which has cancelled out or partly cancelled out our avoiding action and in the majority of cases, fhe wisest thing to do is to reduce the speed of own ship to a minimum at which she can be kept on her course, or to alter course and to put the other ship right astern. On ARPA the history track should be watched for alterations of course or/and speed of targets.
Finally, Rule 8 makes a mention of "close-quarters situation" and "safe passing distance". These concepts cannot be concisely formulated. It is obvious that their extent depends on many factors, such as weather conditions, state of visibility, type of vessel, manoeuvrability and if observations are carried out by visual means or by radar - which is far less discriminating than the naked eye in discerning changes in aspect. But even, when considering radar navigation in fog only, formulation does not come easily. For example, to pass another vessel at half a mile at three knots could be considered just as safe as passing a vessel four miles off at 15 knots. One must also take into account, when deciding what is a safe distance to pass, the direction in which vessels are shaping to pass. For instance, it could be quite reasonable and safe when overtaking a vessel to pass two miles off, whereas this could be unwise when passing a vessel on a reciprocal course with speed. In other words, it is really the relative speed and the direction of the target which should be considered when judging what is a close-quarters situation.

In thick fog, however, when there is plenty of sea room, it is practical to keep the minimum radius of the close-quarters situation at about three miles in order to allow for bearing errors, unsuspected manoeuvres of the target and to keep out the range of audibility of the other ship's sound signals so that delays owing to the application of Rule 19(e) can be avoided.

Really, in order to assess the radius of the close-quarters situation, the master must rely on intuition based on experience to give him the right answer (radar simulator courses are generally useful to accelerate this experience). CPA and TCP A data should be set on ARPA so that sufficient warning can be given to the O.O.W. when a close-quarters situation is approaching.

.4- Make substantial alteration of course or speed to avoid collision/close encounter

Own vessel’s change in speed.

To minimize collision risk by increasing CPA a vessel could stop, slow down or (often less achievable) speed up. In seeking this improved CPA a new vector plot is first drawn. In the examples below we altered speed at A, so this is effectively also a new position O^1. The W^1A (our speed) is the vector that changes while the W^1A^1 vector (another’s speed) stays constant.

Stopping, slowing down or speeding up:

Plots for our vessel on initial course 030ºT and speed 20 kts plots with 0.5 mile CPA and the consequence of altering speed are shown below. If our vessel stops WO vector stops increasing while the W^1A vector keeps going to extend past the new CP^1A (3.8 miles). In this case relative motion and true motion are identical as only one changing vector is in play, the other vessel.

In the examples above we changed speed at A, so this is also a new position O^1 for the new vector plot. If our 20 knots vessel slows to10 knots or speeds up 30 knots, the W^1O^1 own speed vector is drawn proportionally shorter or longer but in the same direction of the initial WO vector. After finding W^1 the constant WA length and direction can be repeated as W^1A^1, thus providing the line A/O^1 A^1 and its extension to CP^1A (2.3 miles ahead and 0.5 miles behind).

Plotting own vessel’s change in speed.

Plot 1a. Own vessel’s slows its speed.

Our vessel while on a course of 030ºT at a speed of 20 kts plots a target ahead with 0.5 miles predicted CPA requiring avoidance speed change.

Finding the CP^1A resultant on decreased speed to13 knots:

Calculate the new speed vector of 13 knots x 6” interval (1/10th hour) =1.3 nm. Draw this shorter speed vector line from W to a new position O^1. A new O^1 line extended through and past A will provide the new CP^1A.

Finding speed change required to increase CPA from 0.5 to 2 miles:

Draw a line from P^1 (the chosen 2 miles CP^1A^1) to A (the 2:09 position) and extend it to cross the initial WO line at new position O^1. From this vector WO^1 the required speed can be calculated from the length times the interval period:

Measured 1.3 nm x 10 = 13 kts

Plot 1b. Own vessel's change in speed after a delay.
Our vessel while on a course of 030ºT at a speed of 20 kts plots a target ahead with 0.5 miles predicted CPA requiring avoidance speed change.
Finding speed change required to increase CP^1A^1 from 0.5 to 2 miles.
From the (current) target position after the delay, in this case 12:12 draw a line to P^1 as the required 2 miles CP^1A. Transfer a line parallel to this extending through A to cross the initial WO to find O^1. Measure the new WO^1 to find our vessel's travel over the initial between 12:30 -12:09 interval. Calculate the speed from the multiples of this distance that would be covered in 60 minutes, in this case:
Measured 1 nm x 10 (6 mins) = 10 kts
Finding the CP^1A resultant on slowing to 10 knots.
Calculate the distance that would be covered in 6 minutes at ten knots, in this case, 1 nm. Mark this distance from the initial W to find the new WO^1 vector. From O^1 draw a line through A and extend towards the centre. Transfer a line parallel to this from the current target position (12:12). Where this line passes closest to the centre is the new CP^1A.

Plotting own vessel's change in course.
Plot 2a. Own vessel's change in course.
Our vessel while on a course of 030ºT at a speed of 20 kts plots a target ahead with 0.5 miles predicted CPA requiring avoidance course change.
Finding the CP^1A resulting from chosen 37º to Stb course change.
Transfer the avoidance course (030ºT + 37º Stb = 067ºT) from the outer bearing scale and draw as a line from W extending in the avoidance course direction. With dividers spanning WO, swing arc from O to cross the avoidance course line. Call the crossing point O^1. Draw a line from O^1 back through A and extend past the centre. A perpendicular from the centre crosses at P^1, the new CP^1A.
Finding course required to increase the 0.5 miles CP^1A to 2 miles.
Draw line from P^1 (new 2 miles CP^1A) through A (the 2:09 position) and extend. With dividers spanning line WO, swing an arc from O to new position where the extended P^1A line is crossed. Call this O^1. Draw line WO^1 and transfer it to the outer bearing scale to read off the avoidance course, in this case 067ºT.

Plot 2b. Own vessel's change in course after a delay.
Our vessel on 030ºT and speed 20 kts plots a target ahead with 0.5 mile CPA requiring avoidance course change actioned after 3 minutes delay.
Finding the CP^1A^1 with delayed 54º to Stb course change:
Calculate the new avoidance course from the current course plus or minus the turn away from it (in the example, 030ºT + 54º Stb = 084ºT). From initial W to O^1. draw this directional vector the same length as initial WO. From O^1 draw a line
back through A and past the centre. Transfer a line parallel to this to pass through A^1 (the 12:12 position) and past the centre. This gives the new CP^1A^1 of 2 miles.
Finding course required to increase 0.5 miles CPA to 2 miles after delay:
Draw a line from P^1 (the chosen new 2 miles CP^1A^1) to A^1 (the 12:12 position). Draw a line parallel to this and extend through the initial A to well past the initial WO line. With dividers spanning the initial WO line, sweep an arc from W to find new position O^1 where

the previously drawn line is crossed. Line WO¹ is the new avoidance course, in this case 084ºT.

.5- States times when radar is to be used in clear weather by day, at night when there are indications that visibility may deteriorate, and all time in congested water
Rule 19 Conduct of vessels in restricted visibility
(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.
(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). an alteration of course towards a vessel abeam or abaft the beam.
(e). Except where it has been determined that a 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.
Rule 20 Application
(a). Rules in this part shall be complied with in all weathers.
(b). The Rules concerning lights shall be complied with from sunset to sunrise, and during such times no other lights shall be exhibited, except such lights as cannot be mistaken for the lights specified in these Rules or do not impair their visibility or distinctive character, or interfere with the keeping of a proper look-out.
(c). The lights prescribed by these Rules shall, if carried, also be exhibited from sunrise to sunset in restricted visibility and may be exhibited in all other circumstances when it is deemed necessary.
(d). The Rules concerning shapes shall be complied with by day.
(e). The lights and shapes specified in these Rules shall comply with the provisions of Annex I to these Regulations.
6- Operation of ARPA or Radar target tracking (TT) and AIS reporting functions
6.1- Setting up and maintaining ARPA or TT display
.1- Describes different display characteristics
The course and speed information generated by both ATA and ARPA for acquired targets should be displayed in a vector or graphic form which clearly indicates the target's predicted motion. In this regard:

1 ARPA (or auto-tracking) presenting predicted (extrapolated) information in vector form only should have the option of true and relative vectors.
There should be an indication of the vector mode selected and, if true vector mode is selected, the display should show whether it is sea or ground stabilized.
2 An ARPA (or auto-tracking) which is capable of presenting target course and speed information in graphic form should also, on request, provide the target's true and/or relative vector.

(Note This means that vectors of some kind must be provided, irrespective of the availability of any other method such as PADs, used to display collisionavoidance information.)
3 Vectors displayed should be time adjustable.
4 A positive indication of the time-scale of the vector in use should be given.
Vectors must be capable of indicating the rate and direction of the target's relative motion (relative vectors), or indicating the rate and direction of the target's proper motion (true vectors). The direction and rate forecast by a true vector will only be fulfilled if the tracked target maintains its course and speed. In the case of a relative vector, the fulfilment depends additionally on the observing vessel similarly maintaining course and speed.

- Graphics

In all cases, the displayed vector length is time related and normally can be adjusted by using a 'vector length' control. An alternative approach is to have a fixed physical length which remains the same irrespective of the range scale, e.g. 3 minutes on the 6 n mile range scale, 6 minutes on the 12 n mile range scale, etc.
Note Vectors of either of the two types can be displayed on a true- or relative-motion radar picture presentation, i.e. true vectors can be selected to appear on a relative-motion presentation and vice versa. It was originally considered in some quarters that this might result in confusion and at least one manufacturer provides a default condition where relative vectors are displayed when relative motion is selected and, likewise, true vectors on the true-motion presentation, with the alternative vector mode being temporarily selectable in each case by the user holding down a 'spring-loaded' control (see also Section 9.7,1, incorrect interpretation).

Relative vectors
The ARPA or ATA must track the target(s) for a period of time, after which a vector can be displayed as in Figure 4.11(a).
Using the vector length control, the vectors can be extended to determine the CPA by observation against the background of the range rings and the TCPA can be read off from the vector length control.

Figure 4.11(a).

True vectors

As an alternative, the observer may request that the true vector(s) be displayed (Figure 4.11(b)). In this case, own ship will also have a vector which will increase in length as the time control is increased.

The likelihood of a close-quarters situation developing can be ascertained by running out the true vectors progressively to show the predicted development of the encounter. The dynamic nature of this technique appeals to many users but it must be borne in mind that any evaluation of CPA/TCPA is a matter of trial and error and thus better avoided. It is essential to appreciate that the CPA is not represented by the point at which the target's true vector intersects own ship's true vector, except in the case of zero CPA.

-Digital read out

The ARPA should be capable of simulating the effect on all tracked targets of an own ship manoeuvre with or without time delay before manoeuvre without interrupting the updating of target tracking and display of actual target alphanumeric data. The simulation should be indicated with the relevant symbol on the display.

The feature is not included in the standards for an ATA and nor is it a requirement for vessels below 10 000 grt in the new 2008 standards.

With the availability of computer assistance, the problem of predicting the effect of a manoeuvre prior to its implementation by own ship is much simplified.

While it is relatively easy to visualize mentally the outcome of a manoeuvre where two ships are involved, in dense traffic this becomes very difficult. In particular, with large ships and limited sea room, it is necessary to plan and update the whole collision avoidance strategy as quickly as possible in light of the continually changing radar scene. While planning, it is important to bear in mind the following points.

(a) Own ship may temporarily need to be on a 'collision course' with more distant vessels, i.e. collisions may require sequential avoidance since it is unlikely that a single manoeuvre will resolve all the problems.

(b) Extrapolation of the present situation using the trial manoeuvre facility with current course and speed as inputs can provide valuable information on which of the 'other' vessels in the vicinity may have to manoeuvre in order to avoid collisions between each other. Obvious avoiding manoeuvres may present themselves and should be watched for.

(c) Constraints imposed by navigation may dictate the manoeuvre of 'other' vessels. This should be taken into account when planning strategy and watched for when carrying out the plan and assessing its effectiveness.

(d) The ease with which this facility allows the navigator to establish the course to steer for a given passing distance may encourage the choice of a small alteration. This temptation must be avoided at all costs as it loses sight of the need to make a substantial alteration. The rules require the latter in recognition of the fact that other vessels may be using much more rudimentary methods of data extraction and may not be able to detect a small manoeuvre.

Unfortunately, although there is a single requirement for all approved ARPAs to possess a facility for simulating a trial manoeuvre, different methods of providing this have been devised by the various manufacturers.

When information relating to the proposed manoeuvre is fed in, the true or relative vectors which would result from such a manoeuvre are displayed on request. This, combined with the ability to adjust the vector length, can give a clear presentation of potential close-quarters situations between other vessels as well as with the observer's vessel.

It is important to select relative vectors when assessing the effect of a manoeuvre as this will give an indication of how far the target will pass clear (Figure 4.12). It is also possible to vary the inputs while observing this display and note the effect on the CPA.

There is a range of facilities available, with an increasing number of factors being taken into account when presenting the trial data. In the simplest form, it is possible to feed in only the intended course, speed and alteration time and observe their effect on the display. In some ARPAs it is possible for the vessel's handling characteristics to be included in the evaluation, but this will of necessity be restricted to one (or possibly two) conditions of loading.

On some equipment, provision is made for two successive manoeuvres to be displayed. This can be extremely helpful when endeavouring to assess the time for which an alteration must be held.

In order that there should be no confusion between the 'trial' data and the current situation, when trial is in operation the screen will display some distinctive indication such as the word SIM or TRIAL. The use of a 'T' to indicate trial is frequently mistaken for an indication that true vectors are being displayed.

The letter 'T' as it stands is meaningless and has not been particularly helpful. There is the danger that one officer sets up the display and another officer (or the master) observes it without realizing the special nature of the display.

Some systems require the observer to hold down a button, which means that the observer has to make a positive decision to operate the switch and hold it over while he observes the display. Few systems offer such a failsafe control.

- Potencial point of collision

The predicted point of collision (PPC) is that point towards which the observing ship should steer at her present speed (assuming that the target does not manoeuvre) in order for a collision to occur.

Some designers have recognized that the positions of these points can be quickly calculated and displayed for all tracked targets. The argument made for displaying the PPCs is that they assist in developing a collision avoidance strategy by showing the navigator, at a glance, the courses which are completely unacceptable because they intersect a collision point. This is the only contribution which can be claimed for PPCs. They do not give any indication of miss distance (other than in the zero CPA case) and any attempt to extrapolate the clearing distance either side of the point will be fraught with danger. A safe course is one which, among other things, results in passing at a safe distance, which implies a knowledge of clearing distance. Safe and effective use of PPCs depends upon a thorough understanding of the factors which affect their location and movement. As is evident from the following treatment this is, in many cases, not a simple matter. Some systems make it possible to display these points as small circles when, but only when, true vectors are selected.

The concept of collision points

When two ships are in the same area of sea, it is always possible for them to collide. The point(s) at which collision can occur may be defined and depends upon:

(a) the speed ratio of the two ships,

(b) the position of the two ships.

Considering any two ships, usually one is moving faster than the other; the possibility that one is at exactly the same speed as the other and will maintain that ratio for any period of time is remote enough to be disregarded for the moment.

The ship which is the faster of the two will always see displayed one and only one collision point, since it can pursue the target if necessary. This collision point is always on the track of the target as shown in Figure 5.3.

The ship which is the slower of the two may see displayed two collision points, both of which must be on the target track. One exists where the slow ship heads toward the target and intercepts it, while another exists where the slow ship heads away from the target but is struck by it. The two cases appear in Figure 5.4. Alternatively there may be no way for the slower ship to collide with the faster (even though the faster may collide with the slower) because it is just not fast enough to reach the target (see Figure 5.5).

- Predicted Area of Danger (PAD)

The PPC gives no indication of the course which needs to be steered to clear the PPC by some specific distance: to this end, the PAD was devised (Figure 7.18(a)). A further improvement is that the

target is connected to its PAD on the display, which was not the case with the PPC.

Example 7.8: With own ship steering 000_(T) at a speed of 12 knots, an echo is observed as follows:

1000 echo bears 045_ (T) at 10.0 n mile

1006 echo bears 045_(T) at 8.5 n mile

1012 echo bears 045_(T) at 7.0 n mile

Plot the target and draw in the PAD for a 2.0 n mile clearing. Answer See Figure 7.18(b).

The construction of the PAD

(a) Plot the target and produce the basic triangle.

(b) Draw lines AT1 and AT2 from the target's position A, tangential to a circle of radius equal to the required CPA. Extend beyond A.

(c) With compasses at W and radius WO, scribe an arc to cut T1A and T2A at O1 and O2 respectively.

(d) JoinWO1 andWO2. These represent the limiting courses to steer to clear the target by the required CPA.

(e) Draw CE1 and CE2 parallel to WO1 and WO2 respectively, to cut WA produced at E1 and E2 respectively.

(f) At the mid-point of E1E2, draw the perpendicular to E1E2 and extend it in both directions. In each direction, mark off the 'required CPA' and label the points E3 and E4.
(g) Draw in the ellipse passing through the points E1_ E2_ E3, and E4 (or the hexagon as indicated in Figure 7.18(b)). In the interest of simplicity, the ellipse was replaced by the hexagonal PAD in later equipment.
For a clearer appreciation of the PAD, Example 7.8 should be drawn out full size and to scale on a plotting sheet.

.2- Describer different ways in which Targets may be acquired

Radar targets are provided by the radar sensor (transceiver). The signals may be filtered (reduced) with the aid of the associated clutter controls. Radar targets may be manually or automatically acquired and tracked using an automatic Target Tracking (TT) facility.

- The automatic target tracking calculations should be based on the measurement of radar target relative position and own ship motion
- Any other sources of information, when available, may be used to support the optimum tracking performance.
- TT facilities should be available on at least the 3, 6, and 12NM range scales. Tracking range should extend to a minimum of 12 NM.
- The radar system should be capable of tracking targets having the maximum relative speed relevant to its classification for normal or high own ship speeds.