Handboek voor

Starpath
Radartrainer 2.0

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Starpath Radar trainer 2.0

Korte uitleg

Dit is een uitgebreid programma om radar navigatie en radar manoeuvres te leren en daarmee te oefenen.

De bedoeling is dat je een aantal uren met dit programma oefent om de in de les behandelde stof toe te passen. Het zal even duren voordat je alle functies van het programma uitgevonden hebt en de een gaat dit makkelijker af dan de ander. Het is daarom aan te raden om met meerdere mensen tegelijk te gaan oefenen zodat je elkaar kan helpen.

In dit boekje vind je een lijst met oefeningen die je kan uitkiezen begin met een van de eerste oefeningen om het idee te begrijpen. Je kan altijd de oefening opnieuw beginnen. Doe in ieder geval de volgende oefeningen en schrijf op wat je doet. Lever deze met eventuele plot tekeningen in!

Voor de KZV: **02, 04 en 05**

Voor de GZV: **03, 05, 06 en 07**

Andere oefeningen kan je zelf altijd erbij doen.

Je start het programma op door START (links onder in de hoek van het beeld) aan te klikken en dan de optie Zeevaartschool, nu vindt je het pictogram Starpath radartrainer 2.0. *(het programma Raplot is een iets eenvoudiger programma, voor mensen die nog helemaal nooit een radar gezien hebben best een leuk programma om eens te bekijken)* Klik op het programma radartrainer 2.0 en nu zie je een radar scherm met daarop een aantal echo's. De echo's verspringen vrij snel omdat de tijdfactor als start opstelling op 30X staat. Dit kan je langzamer zetten door rechts in het vakje "time factor" het pijltje aan te klikken en de factor naar bijv. 1X te brengen. Nu heb je de echte beweging. Je kan dus altijd het proces versnellen door deze factor.
Standaard start het programma met een oefening met 3 echo's maar je kan heel veel oefeningen kiezen uit een lijst of de computer willekeurig laten kiezen of zelf een oefening samenstellen. Deze keuzes maak je in het hokje "traffic" (ook rechts in beeld).

In dit boek zitten alle oefeningen uitgeprint samen met de tutorial lessen maar je kan ook via het vakje "tutorial" meer informatie vinden.

Belangrijke Tips:

* Zet zeker in het begin de time factor langzaam

* Lees ook de introduction (vanaf blz 22) eens goed door

* Het vakje "true view" laat je een overzicht zien, zet dit ook weer uit om voor jezelf te kijken of je het overzicht juist heb ingeschat. Zet deze ook weer uit! (anders hou je jezelf voor de gek)

* Met het vakje “identify” kan je zien welke echo welke letter heeft. Met het vakje van de betreffende letter kan je de exacte gegevens van dat object (koers/snelheid enz) opvragen. (het hokje “maneuver” moet hiervoor aangevinkt zijn)
* Je kan jezelf ook verplaatsen in de positie van een van de echo’s. Vink hiervoor het hokje “jump to”aan en kies dan een van de letters.

* In het drop down menu “simulator” (links boven) vind je de optie “radar mode” hier kan je kiezen voor North up of head up probeer hier af en toe eens mee te wisselen om het effect te zien bij koersveranderingen van jezelf.

* In het vakje “plot” (rechts van je radarbeeld) kan je kiezen voor wel of geen plot en ook hoelang deze plot een object blijft weergeven. Dit is geen echte plot maar meer een doorgaande weergave (in grijs) van het verleden van het object. Hierdoor kan je de beweging van het object zien.

* Deze simulator heeft geen mogelijkheden om de radar af te stellen, (tune, gain, rain en sea clutter) lees daarom hoofdstuk 1.2 van de tutorial eens door.

* Je kan de zeegang instellen op “calm” “moderate” en “rough” in het drop down menu “seas”. Probeer als je wat geoefend heb in calm eens de rough sea. Je zult merken dat je eigen koers niet meer een rechte lijn is en dus de echo’s ook niet meer. Dit is zeker op een zeilschip waar met de hand gestuurd wordt heel vaak het geval.

Hierna volgen alle oefeningen die je kan kiezen in het drop down menu bij “traffic” rechts in beeld. De nummers staan onder de optie “demo targets”

Succes! *Bij vragen bel Bernt Folmer 0228-316364(dinsdag,woensdag en donderdag) e-mail bfolmer@tiscali.nl / bernt@ezs.nl*

00. DEFAULT TARGETS

We have 3 targets on the radar screen. Our position is always in the center of the screen.

Clearly all 3 targets are getting closer to us with time, but are these vessels actually headed towards us? That -- or something similar to that -- is the key question we must answer in all radar observations.

Open the True View and watch what is really taking place.

To identify and correlate the targets in both views, press the Identify button.

Notice that target D is not moving at all. It is either not underway or more likely a buoy.

Vessel B is likewise not headed towards us, but rather headed out to go around D.

We are all getting closer together, however, and it is this relative positioning that is always shown on the radar screen.

Target C seems to be a vessel headed in towards us.

Lesson 2 in the Tutorial suggests exercises to carry out with these targets.

01. PARALLEL COURSES

The 5 targets shown all move straight up or down the radar screen, although their true motions are individually quite different. Your vessel (the "center vessel") is called "A."

DEFINITIONS:

SRM = speed of relative motion.

DRM = direction of relative motion.

TARGETS:

B is on the same course and speed as A, so it does not move on A's radar screen. No relative motion always means target has same course and speed.

C is headed toward you (vessel A), so its SRM is the sum of your speed and his speed. Targets headed toward you move rapidly "down screen."

D is being overtaken by A. You are getting closer to him, so he appears to be moving toward you. Targets slower than you move slowly "down screen."

E is a buoy or anchored vessel. Stationary targets always move straight down the screen with a SRM exactly equal to your speed.

F is overtaking you. Faster vessels always move "up screen." His speed equals your speed plus the SRM shown on the radar.

SUGGESTIONS:

(1) Watch this demo in the True View display to see courses, speeds, and true motion.

(2) Figure the SRM of each of these targets and from that and your own speed, determine the true speed of each of these.

(3) Then repeat the demo while viewing vessel C radar and then vessel B radar for completely different radar perspectives of this same interaction.

TUTORIAL REFERENCE:

Lesson 3.2 covers parallel courses and SRM.

02. CROSSING COURSES

Whenever you are moving, vessels that appear on the radar as if crossing your course from the side, cannot be on the perpendicular courses they appear to be on. To come straight at your course line from the side, they must be partly headed in the same direction as you.

If they approach only slowly from the side (as target E), their course and speed must be similar to yours, but pointed slightly toward you.

If they come rapidly from the side (targets C and D), their speeds can be higher and their courses more toward you.

Watch this demo in True View to see that target B is the only vessel approaching on the beam. Compare the true and radar motions of targets B and F.

ANALOGY:
As the true wind is always aft of the apparent wind, the true course a vessel is approaching from is always aft of the apparent direction they come from as seen on the radar. A radar target approaching the bow, is actually comming more from the beam; a radar target approaching the beam, is actually coming more from the quarter.

Put another way, the actual course of a target approaching from the right is always to the right of its DRM; the actual course of a target approaching from the left is always to the left of its DRM.

Suggestions:

(1) Open True view and watch both views to see how the direction of relative motion (DRM) is related to the true direction of motion in light of the above discussion.

(2) In the Glossary look up "aspect," and read the related discussion in the Tutorial.

03. COLLISION COURSES

DEFINITION:

CPA = CLOSEST POINT OF APPROACH. This is the minimum range to the target as it passes.

A "collision course" is one that has a dangerously small CPA. Key related terms are "close quarters." Read about these in the Tutorial.

Targets are on collision courses if their radar bearings do not change. You can check this with the electronic bearing line (EBL).

Put the EBL on the targets to see if they are moving straight down the line for a collision, forward of the line to pass forward of you, or aft of the line to pass aft of you.

In this example:

D is on a collision course;
C will pass astern;
B will pass ahead.

E is stationary and will pass close abeam on the port side.

SUGGESTED EXERCISES:
Slow down the action as the targets pass and read the CPA using the VRM (variable range marker).

Then repeat the action and see how well you can estimate what these CPAs will be while the target is still some distance off.

CAUTION:
When the seas are calm, the plotted trails of targets are relatively straight lines which are relatively easy to project ahead to estimate the CPA. But when the seas are rough, your heading swings around which smears out the plotted trails and makes estimating CPAs difficult when the targets are far off.

The effect of sea state on observed target trails can be simulated using the sea state option in the menu bar. It is discussed in some detail in the Tutorial.

When viewed from a distance, all targets headed anywhere near you appear to be on collision courses. It is important to recognize this and to establish the correct DRM as soon as possible. When a close encounter is anticipated from a large distance off, there is a risk of altering course erroneously and actually reducing the CPA.

Compare these targets and practice course and speed alterations to clear them. Use "CPA info" to check the interaction with specific targets.

How long does it take to estimate the CPA?

04. SPEED CHANGES

The relative motion of radar targets is similar to the relative motion of the wind: the true wind always comes from aft of the apparent wind, regardless of wind direction or boat heading.

Likewise, moving target vessels are always approaching from a direction that is aft of what they appear to be on the radar. How much the true track is aft of the apprarent track depends on the target's SRM and DRM.

SUGGESTED EXERCISE:
Start with Time Factor = 30, Plot on Continuous, and Range 24.

Step (1) Run this demo till all tracks are clear (Radar clock about 12:21) and then stop vessel A.

Notice the target tracks all turn "up screen." When stopped, you see their true motion, which is from a direction aft of the relative direction seen when moving. This exercise is a good way to get a picture of what we mean by "aft of their apparent direction." View the motion in True view and radar view together to get more insight into this.

Step (2) Repeat the demo, but now increase your speed to 12 knots. By increasing speed, you increase the effect of the relative motion, so the target tracks are pushed even farther off their true tracks.

Tutorial Lesson 4 covers the relative motion diagram which illustrates this point with a vector drawing.

GENERAL RULE:

When you slow down, targets turn up screen; when you speed up, targets turn down screen -- the effects are small, however, when the target's SRM is large or its DRM is near parallel to your heading.

05. COURSE CHANGES

It is valuable to know how to anticipate the effect of your course changes on the relative positioning and subsequent tracks of radar targets. When you turn right by some angle, all targets will shift to the left by the same angle -- and vice versa.

This is a simple result of their change in relative bearing. If you are headed 000, and see a target bearing 340 R, and then you turn 40° right, this target will shift 30° left to then appear at 300 R. You can check this effect with target B, or similarily with any of the others.

It is easy to picture what is going on so far. The next step to anticipating what the radar will look like after our turn is not so simple to guess ahead of time.

Repeat the demo and watch B. The target B is coming in from 340 R at a DRM of 168 R (check this with CPA info B). We know when we turn 40° right, that it will shift left to 300 R, but now what will its new DRM be? The answer is 145 R. In other words, when we turned away from the target, its DRM turned towards us. Or put another way, when we turned right, the target appeared to shift left and then turn left on the radar.

To see this, repeat demo and run at time factor 30 till about 12:20 -- long enough to see its DRM established. Then change trime factor to 1 and execute a 40° right turn. We have set vessel A in this demo to be a large vessel so on time factor 1 you will see this slow turn evolve on the radar screen.

After Target B reaches the 300 R position, you can switch time factor back to 30 to more quickly see the new DRM. Notice that it has turned left.

In more general terms, to account for targets on either side of us, we can put it this way: when we turn clockwise, targets will shift counterclockwise and then appear to turn counterclockwise. Look at the trails from this last exercise to verify this description.

Turning the other direction, the reverse occurs.

Exercise:

Use the Set Targets option to change the speeds of several of these targets or your own to see how this effect depends on relative speeds.

06. FINDING CPAS

The closest point of approach (CPA) is how close the target will pass you if neither of you alter course or speed. The CPA is the perpendicular distance from you to the target track line. Note, it is not the distance off when the target crosses your course line; typically the target will reach CPA before or after actually crossing your course line. If a target shows a well defined track on the radar screen, the CPA can be determined using the EBL and VRM.

To measure a CPA, set EBL parallel to the track line and then measure the perpendicular spacing between the EBL and DRM track using dividers or ruler. This distance is the CPA; you can convert it to miles by reducing the VRM to this spacing, measured from your central position. A "portable range scale" (see Glossary) is useful for this measurement as well.

Run this demo and determine the CPAs of the targets. After the tracks are established with a higher time factor, you can pause the action or reduce time factor to make the measurements. Check your answers for each target (X) by with the CPA Info X. Note that close CPAs (targets C & D) can only be determined on the lower range scales.

CPA measurement is discussed in Tutorial Lesson 3.3.

07. MANUEVERING GAME

Practice with chosing course for desired CPA.

In this demo target F contains dangerous cargo with a fire on the aft deck. She is maintaining course and speed of 5 knots toward 260 T. All approaching vessels are instructed to pass at 2.0 miles off and report her conditions as they are observed. At the moment she is headed toward you, vessel A.

Start with vessel A and practice turning to achieve this CPA as F approaches.

Then jump to vessel B and do the same. After safely passing with B, jump to C, then D, then E to get all vessels by her as instructed. Do not alter speed and do not cross her bow. You will find that each of the subsequent vessels are all converging with F to begin with.

Tutorial Lesson 4.5 covers maneuvering to achieve a specific CPA. The right course to choose can be computed with a calculator or solved graphically.

Note that we can't list specific answers to this, because the proper course to choose depends on the distance to F at the time of the maneuver.

Or, practice this approach: set VRM to 2.0 miles and then alter course until target's DRM runs tangent to this circle. Determine the right course from the screen alone in this manner. You can always check your results with the CPA Info option.

Then repeat the demo and choose to cross her bow in each case to observe the other side. Then repeat and choose to pass at 1.0 miles, etc.

08. BUOY CHANNEL

B and C are buoys marking the port side of an entrance channel.

D and E mark the starboard side.

F is a vessel heading out the channel. You are approaching at 7 knots.

EXERCISES:

(1) Just watch this for a while to see how you might identify the target headed out the channel. What is diferent about their plotted trails.

(2) Jump to vessel F and watch its radar as it leaves the channel. Ddo you see A approaching from the left? Slow down the time factor if needed.

(3) What is the course that would take you into the channel? Use the EBL to align with the channel. This is a valuable exercise for identifying similar channels underway.

(4) Practice driving up to and into the channel? You can get rid of F by just selecting Set Targets and then 4 targets. This process always takes off the last (highest letter).

(5) Do it again with F coming out (select demo 8 again to reinstall F), and just stay clear of him. Note you will have to set the time factor to a low value or you won't have time to think through the maneuvers.

08A. BUOYS IN CURRENT

This is the same as demo 8, but now current has been added.

C and D are buoys marking the port side of an entrance channel.

E and F mark the starboard side.

There is a strong current flowing northward. You are approaching from the South in vessel A.

B is a vessel heading out the channel. You are approaching at 7 knots; you can slow down, but your maximum speed is 9 knots.

EXERCISES:

(1) Just watch this for a while to see how you might identify the target headed out the channel. Note that if there is current present, if you stop, the buoys keep moving, because when you take way off, you are still moving in the current.

(2) What is different about the trials of the buoys and those of the target headed out?

(1) Head North till you can identify the channel (and traffic), then set your course and speed to clear the traffic and correct for the current, so you will track straight into the channel, between the buoys.

(2) What is the true course of the entrance range marked by the buoys?

(3) What is the set and drift of the current?

09. SAILBOAT RACE

This is only a sample of what you can set up on your own for practice using the Set targets option. Use of radar in sailboat racing and related terms and jargon are discussed in Tutorial Lesson 7.

Vessels A-E are sailboats on the weather leg of a race. The true wind direction is 315. Target F is the windward mark. There are no currents or wind shifts on the course.

D is on Starboard tack; the rest on port. Each can only maneuver by tacking (turn right 90° on a starboard tack or left 90° on a port tack), or falling off to leeward from either course. All vessels have radar.

It will be necessary to lower the time factor to near 1 or there will not be time to figure out the maneuvers or answers. Start with radar range 6 miles, but you may have to lower the range to answer the questions.

Watch this demo run on True view long enough to see the general picture of what is taking place...also jump onto the other vessels and take a look at the radar from their perspectives. Repeat as often as needed.

Then, using only the radar view and your own screen marks or plot trails, answer these questions:

(1) Who is ahead at time 12:00 -- or shortly after?

(2) Who has the fastest boat speed?

(3) Who is pointing higher and who is pointing lower than vessel A? (Hint, this is easy to read from the radar trails when competitors are on the same tack. But what about D?)
(4) Who will have to tack or duck as D crosses?

(5) If B tacks, will A clear him?

(6) Figure the times that each boat should tack to lay the mark.

(7) Who will get to the mark first...tacking as needed?

(8) As a game, use True View to drive all the boats around the mark by just tacking. Do not change their speeds.

Answers are in the Tutorial.

10. SQUALL TACTICS

The following is a *very rough* schematic presentation of a squall. The idea is to illustrate how important radar is in evaluating squall motions and related navigation.

Targets C,D,E,F are intended to mark the boundary of a developing black squall approaching vessels A and B.

Wind and seas are from 315 T, which are big enough to limit the courses of all vessels involved, power and sail.

Vessel A is a port-tack sailboat; it can tack (A C L 90) or fall off up to 20°, or tack and then fall off to the left.

Vessel B is a power-driven vessel headed downwind. It can steer any course between 105 and 085, or cross the wind and steer between 165 and 185.

First run this demo in True View to see what is taking place, then refer to the Radar screen. Study the squall's motion, and then drive both vessels past the squall with these goals in mind:

Vessel A wants to clear B and get as far from the squall as possible.

Vessel B intends to cross the squall, but wants to spend the minimum time possible in doing so. He must also keep clear of A, who has right of way.

11. HOSTILE PATROL

A sample of radar maneuvering game. You can make up games like the following using the Set Targets option. Games can also be stored in a demo for later use. The following example "Hostile patrol" is an exercise on storm avoidance. Your job is to maximize the CPA between you and an approaching vessel. The procedures for doing this are discussed in Tutorial Lesson xx.

You know you are within a fleet of hostile patrol boats and if any one of them sees you, they will confiscate your vessel and throw you in jail forever.

You have two of them on the radar screen at 12:00. You know there are others, but so far you don't know where they are.

The patrol vessels are large radar targets -- you can see them whenever they get within 24 miles of you, but you can't see them farther off.

You are a small wood vessel which they can only detect by radar if they get within 8 miles of you.

Set VRM to 8 miles to mark your danger zone. If any of them gets within this 8 miles you lose!
Your maximum speed is 7 knots. You can take any course.
You know that they maintain constant course and speed thoroughout the patrol. They patrol until 1600 and then all go off radar watch.
Your job is to start the radar, use this knowlege and drive without being detected until 1600 on the Radar clock.

RULES:
To complete this exercise without cheating...
-- Leave your radar range set to 24 miles throughout the exercise.
-- Do not use the CPA info option, since this is not a real option underway and will warn you if the maneuver won't work, etc.
-- the only controls to use are Maneuver A.

NOTES:
You will need to run this on low time factor, at least until you figure out your optimum course at each maneuver. You will also have to compute the proper courses to take or they will get you.

HINT:
You must respond rather quickly to what you know to begin with. One approach is to set course to make target DRM tangent to VRM ring, then don't alter course till you reach that CPA. Proper headings can be determined using storm avoidance maneuvering.

Set the plot freq to 6 minutes so you can quickly estimate the course and speed of the patrol boats.

If you can't make it through, you can e-mail us from jail and we will send you the maneuvers you should have made.

Other maneuvering games using the random target generator are presented in the Tutorial.

12. CROSSING VS. OVERTAKING

This demo presents a classic radar problem.
PART 1.

Read just this first part and do it then come back to the second part.

It is a clear night and you see the two targets approaching the port bow on the radar. If you could see the running lights from these vessels, what lights would you expect to see?

HINT: solve the relative motion diagram (Tutorial Lesson 4.2) to figure the true course and speed of the targets and from this figure their aspects.

These matters are discussed in the Tutorial. Check User's Guide Glossary for "relative motion diagram" and "aspect" to get directions to the right place to look.

Stop here, study their motion on the radar screen and figure that out.

Answers are in Tutorial.

PART 2.

New approach. Press Repeat and start again.

It is dense fog. We have two targets approaching on the port side, not yet in sight.

We estimate the visibility in the direction of these targets to be about 1 mile.

Question 1.
What Nav Rules apply and what are we supposed to do?

Question 2.
What role does our knowledge of the visibility play in the action we take?

Question 3.
If this were clear weather, what are we supposed to do?

Answers are in the Tutorial.

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13. RENDEZVOUS PRACTICE

This is an exercise is setting a course to intercept (rendezvous) with another moving vessel. Procedures for doing this are covered in Tutorial Lesson 4.3.

In short, you know the range and bearing to the target, its true course and speed, and your own maximum speed. Your job is to figure out what course will take you straight to the target. If the target is headed away from you, you must be able to go faster than it is to catch it, but this is not necessarily the case if you are intercepting one headed near you.

Example 1.
Target is 100 miles off in direction 015. Its course is 050 and its speed is 12 knots. Your max speed is 18 knots. What is the minimum time to get to him and what course should you take?

Example 2.
Target is 175 miles off in direction 143. Its course is 280 and its speed is 15 knots. Your max speed is 20 knots. What is the minimum time to get to him and what course should you take?

Example 3.
Target is 16.0 miles off in direction 115. Its course is 210 and its speed is 6 knots. Your max speed is 14 knots. You are to take up position 1.0 miles off her starboard quarter (135 R off the target's heading). What is the minimum time to arrive on station and what course should you take?

NOTES:
These problems are explained in Lesson 4.3. They are from the excellent book called Navigation for Masters by David House, although we use a differnt method of solution.

Clearly the Time factor will be extremely valuable in these exercises, but you can also "cheat" by checking the CPA Info option as soon as you make a maneuver to see if you are right...

14. PUB 1310, EX 4.

This is practice on maneuvering to achieve a specific CPA.

You will have to set time factor low to work this.

Your speed = 18 knots at course 188. Target is approaching on true course 258 at true speed of 12 knots. You wish to manuever when target is 6.5 miles off when target bears 153 to make good a CPA of 3.0 miles.

The topic is covered in Tutorial Lesson 4.5.

The printed answer is: turn to course 218.

15. STORM AVOIDANCE

For practice with storm avoidance (and to prepare for the Hostile patrol boat exercise in Demo 11), we set up here a single target headed toward you. He is 35 miles out at bearing 315, headed straight toward you (his course 135). His speed is 9 knots. Your max speed underway in present conditions is 5 knots.

Question 1: What course do you steer to put the maximum distance between you and he as he passes (maximize the CPA)?

Question 2: What is the max CPA you can achieve?

Question 3: What will be the time of this max distance?

Question 4: Compare what happens if you took an evasive action of just heading off perpendicular to his course?

Note you need to run this on time factor 1, or low, so you can maneuver when he is still near 35 miles out to compare answers, given in Answers section of the Tutorial.

Storm avoidance is covered in Tutorial Lesson 4.4

16. SAIL RACING

Radar can be extremely valuable when racing. The subject is discussed in Tutorial Lesson 4.6.

Here we have 5 boats sailing to weather, all on port tack, with the wind at about 315. Noitce how quickly you can tell what the performace of each is relative to your own. You will have to switch to the 3 mile range and then Repeat. Most radar applications to racing will be limited to ranges of less than 5 miles or so, because you just can't see the targets much farther off.

B is sailing at the same speed, but is pointed 5° lower.

C is making the same speed as well, but is pointed 5° higher.

D has the same point, but is 0.2 knots slower.

E has same point, but is 0.2 knots faster.

F is sailing some 3° higher and about 0.1 knots faster.

Remember you can always check to see the initial course, speed, and location of targets with the Set Targets option. Just run a demo, and then run Set Targets. This is also the best way to make variations in the targets and have them repeat the way you want.

See tutorial for more discussion, in particular for how to determine these things, who is ahead, etc.

Practice using EBL and VRM to mark a target to check how it is doing relative to you and so forth.

1.0 Introduction

The process of "learning to use radar" involves several steps.
(1) Understand (in basic terms) how radar works and what you are looking at on the radar screen.
(2) How to tune the instrument in various conditions.
(3) How to use the instrument for simple piloting or chart navigation.
(4) How to incorporate radar in to your routine navigation
(5) How to interpret moving targets on the radar screen to evaluate risk of collision and maneuver safely and efficiently according to the Navigation Rules.

Ultimately number (5) is the most important and the biggest challenge to learn properly. Consequently that is the main focus of this course. We also cover the basics of each of the other topics, but you will find that the main virtue of a computerized radar simulator is to learn collision avoidance.
Identification of land masses, for example, (discussed in Lesson 6) can be done well with picture books or videos, which show what various land shapes really look like in various conditions. Even top-end, multi-thousand-dollar computer simulators do a very schematic job of this at best. And the tuning of radars (discussed briefly below) is covered very thoroughly in most radar manuals with pictures and sketches appropriate to the individual models.

1.1 What is Radar

Radar is an electronic nav aid that tells the range and bearing of landmarks and vessels in your vicinity. It works by sending out microwave pulses and then detecting the signals reflected back from the "targets" around you. It is not, however, like a scanning TV camera; we only see on the radar screen the blips or echoes of the targets, not realistic representations. Consequently it takes some practice to read the radar screen and from that to interpret what is really out there.

Isolated targets like other vessels, buoys, islets, or drilling platforms are easier to interpret than large irregular land masses. At larger distances, isolated targets all appear as simple dots or small line segments. As they get closer, the target size increases, but unless the object is big and fairly close, the "size" of the echo on the screen is not a measure of the actual size of the target. More on that later.
In simplest terms, the basic elements of the system are an antenna and the radar unit itself, which has on it accessible to the user a CRT screen and a set of controls (knobs, buttons, and maybe a track ball). There are sophisticated electronics inside, and generally it takes a professional electronics person to install and calibrate the unit before use. After that it runs very dependably and requires little attention as a rule.

On the other hand, many installation manuals are quite good, and an industrious mariner could do the installation himself. A key part of this process, once done with the mechanical and electrical parts, is the calibration of the unit using a set of special adjustment buttons or knobs. These are typically accessible from outside the unit, but they are not intended for day to day adjustment. Often they are behind a hidden panel on the instrument. These adjustments are for calibration and alignment of the various functions. You must read the manual before adjusting these and generally they require your being in radar sight of a good isolated target, so you can tune up on it.

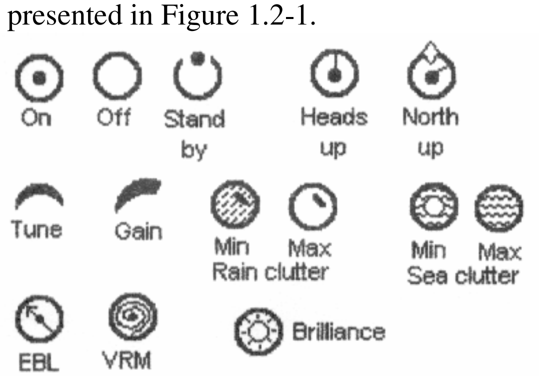
What you see on the radar screen is the region of space around you out to a maximum distance equal to the Range setting selected. The location of your vessel is always in the center of the screen, unless you have some special "offset option" that lets you shift your position back on the display. Some radars have this, so you can see farther ahead on that particular range setting. The Radar Trainer does not include that type display option. Measuring the ranges and bearings of targets is discussed in Lesson 2. For now we just stress that when you are moving, the motion of the targets that you see on the screen is relative motion, not true motion. If you are moving toward a stationary buoy at 5 knots, it will appear on your radar screen as if that buoy is moving toward you at 5 knots. The only stationary target on a radar screen is one that happens to be moving exactly in the same direction and exactly at the same speed you are. In which case these is no relative motion between the two of you, and it appears stationary.

1.2 Radar Tuning

This is a brief overview of user adjustments in typical radar operation underway. We do not simulate these features in Radar Trainer, but just discuss them. The rest of the Tutorial is not dependent on this section, so you can skip over this section for now if you like and go on with the topics involving use of the simulator.
Most people refer to the adjustments of these knobs or buttons as "tuning the radar," but only one is actually called "tuning." They all have to do with optimizing the image display on the screen to best show what you want to see.

Your manual is the best reference for these adjustments -- better than most text books. You may also find it very instructive to read the manual from another radar brand. When visiting another vessel with a different brand or model of radar, ask to see their manuals. Each emphasizes different parts and have different ways of explaining things. The more approaches you see the better you will understand it. It is a good philosophy for GPS, depth sounders, SSB radios, and all forms of marine electronics as well.

Most of these adjustment have international symbols to represent the controls. These are presented in Figure 1.2-1.



There is a note at the end of these definitions, called General tuning tips.
These are presented here in no particular order. You can later come back to specific terms by looking it up in the Glossary which will direct you back to the right place.

Warm-up

All radar units require some period of time to warm up the electronics. When you first turn a radar on, it is not ready to operate immediately. It will first go into a warm up mode, often with a count down timer showing on the screen, perhaps with a note about the warm up delay. The warm up time is 1 to 2 minutes. This time is primarily required (I believe) to thermally warm up the magnetron so it functions properly -- there is at least a part of the circuit called "magnetron heater." For safe operation it is important to remember this delay. You cannot at the last minute flip on the radar to see what is out there. Consequently, most radars have a stand-by mode which keeps the instrument warmed up and ready to transmit, without the full power consumption or actual transmission.

Stand-by mode

This is a radar operation mode in which the instrument is warmed up and ready to transmit, but is not actually transmitting microwaves. Sometimes this mode also stops the antenna from rotating, but in other models antenna rotation is a separate control. This mode is sometimes called "economy," "power saver," or such, and is often toggled on and off with a control panel button marked "Transmit." The power savings is typically about 45%, going from, say, 33 W to 18 W in stand-by mode, in some models the savings might be less. In the stand-by mode, the radar screen will usually be blank with the words "Stand by" or "ST-BY" showing on the screen. Press Transmit to get the picture back. Note that on power driven vessels, power consumption is not so much an issue, but judicial use of the stand-by mode can also extend the lifetime of radar components.

Brilliance

This knob or button controls the brightness of the display. It is not a true radar function like Gain which has a roughly similar apparent effect, but just a CRT control that brightens or dims the display. Generally this must be changed whenever the ambient light in the nav station changes, such as night versus day or bright sunlight versus overcast. Generally it is best to increase this to just bright enough to be clearly seen. If turned up too high, it can mask proper adjustments needed with the gain that truly does influence the functioning (resolution) of the radar.

If you simply can't see the picture because it is too faint, then try this first before increasing the Gain. Likewise, if the picture ever appears too bright, turn this down first before reducing the Gain. Usually this adjustment is in steps which cycle through a series of brightness levels, so to go back you may have to go forward.
Tuning (tuning bar)

Tuning in radar is (I believe) the adjustment of the synchronization of the transmitted and received pulses. It is related to the frequency and phase of the sweep and display, since the powerful output of the magnetron is probably not adjustable. "In tune" means the images of the targets are sharp and well defined. Most modern radars have automatic tuning through a circuit called automatic frequency control (AFC) and thus do not have a separate control knob for this on the front panel. All older radars do, however, have this control and some new models that have AFC still provide a tuning bar to indicate the quality of the tuning even when there is not a separate knob for manual tuning. And some units with AFC provide manual tuning as well. The tuning bar is like a tuning bar on a FM radio used for entertainment. Adjust the tuning knob until you get the largest number of segments filled in.

If you do not have a tuning knob, and the display shows either a completely full tuning bar or one with just a small segment activated, then this is sign that the internal adjustment needs set, which is usually best done by a professional.
To use manual tuning, the best procedure is to tune on an isolated clean target a mile or two off and adjust until the image is sharp, with Gain set about 50% full range and Sea clutter and Rain clutter turned off. Your manual will be the best guide to this. Watch the tuning bar as well if one is there. If the sharpest image does not correlate with the fullest tuning bar, then again see a technician.

Without tuning bar or isolated target, manual tuning can be done on the sea state reflections or on your own wake after a turn. Set sea clutter and rain clutter off, and then adjust tuning for maximum sea clutter.
Tuning may drift some when the unit is first turned on (first 30 minutes or so of transmitting), but should remain stable and not require adjustment after that. If you do indeed have a manual tuning knob, it should not be considered one of the knobs one has to frequently adjust when it is properly set up internally. Again, modern units do not even include this control. See International symbols in Figure 1.2-1.

Focus

This too is another control that does not appear on modern radars. It is purely a focus control for the CRT display. This is done automatically in modern units. In older units, set the range scale to one of the higher ranges, set the VRM to about half that scale and then adjust the focus knob until that VRM line is sharp.

Gain

Gain is how much the reflected signals are amplified when received. This is the major control used in radar tuning and must usually be adjusted when making large changes in the range. Normal settings of this are done with the rain clutter full off and on a high or maximum range scale. Then increase the Gain until you see a faint coverage of white specks on the background over the full radar screen. Note that full gain can turn the screen white and zero gain turn it black. Most operators prefer just a faint coverage of white specs in the background.

If the Gain is too high, you will lose resolution and if too low you will miss targets. You must also experiment with the Brilliance control in this regard. Depending on the ambient lighting, this can take some balancing, but usually you will easily find a combination that works and then repeat it always. The key is to be sure the sea clutter is off, and then turn up the gain till you see white specs. It is easy to set the gain when a target is in view, but always less certain when none are there, hence the specs.

Gain must usually be reduced when large close targets are present and may have to be increased when looking for small targets or when using rain clutter. Sometimes better range and bearing resolution can be achieved by reducing the gain and sometimes reducing the gain will help reduce clutter from rain or snow.

Remember to always replace the gain to its normal settings if it has been changed for special purposes.

Sea clutter (AC sea or STC)

Radar echoes from waves are called sea clutter. In bigger seas this background can dominate the screen and block out the detection of smaller targets. Consequently all radars include an electronic filter to remove or greatly reduce this problem. The control is called by various names: sea clutter, AC sea (for anti clutter), or STC (for sensitivity time control). Since it has many names, there is special value to knowing its international symbol, shown in Figure 1.2-1.

This is a control that should be kept at minimum or off unless needed. If set too high, it can block out close targets. Generally it does nothing, regardless of setting, for ranges farther than about 4 miles or so. In calm sea conditions, this should be kept off. In rough seas, the entire close in region of the screen on the lower ranges will be nearly solid white from wave reflections. In these cases, this control should be increased until this smear is broken up into a pattern of small dots. This is easy to optimize if you have close small targets present. Just increase the sea clutter till they stand out prominently. Without such targets, you have to just estimate this. The above guide line generally works.

It is important to not run this filter too high or you will lose small even medium sized close targets. Always leave some clutter showing. If you are heeled over, or for any reason there is more clutter to windward compared to leeward, you can get a reasonable confidence that the sea clutter is right by turning it up till you see this distinction clearly on the radar screen, but still leaving some clutter on the weaker side.

Rain clutter (FTC)

When in or near a rain or snow squall, the radar screen becomes cluttered with reflections from the precipitation itself. This can be so severe that it can mask the presence of any target in a nearby squall, or if you are in the squall, mask the presence of traffic approaching even though they are not in the squall. Reflections from precipitation are usually easy to identify from their "wool like" appearance. A rain squall on the radar screen looks rather like the Magellenic Clouds seen against a background of stars or a very clear night (in southern latitudes).Often the exact boundaries of a squall, or at least the part with rain content, can be clearly seen on the radar and even maneuvered around if it might serve some purpose.

This filter breaks up the continuous display of precipitation echoes into a speckled pattern. Often the filter is presented with two modes. A toggle to Fast time constant display, which is an on/off switch used for heavy interference, or a variable control, often called rain clutter, for weaker interference.
These filters generally work quite well in rain and snow and will reveal targets which might not otherwise be seen. In heavy snow, hail, or a sand storm, on the other hand, the radar may be effectively blocked out by this interference and these controls may not adequately solve the problem. Needless to say, in cases like this if there is any probability of traffic occurring during this block out, one must assume a safe speed consistent with the conditions.

If the FTC mode has been selected and then the precipitation goes away, then the filter should be shut off since it does tend to reduce the sensitivity of the receiver.

Note that these FTC controls might also be used in fair weather in crowded or confined harbors that present much radar clutter or regions with bright land areas to sharpen the picture since it does reduce the sensitivity in a manner that is qualitatively different from reducing the gain.
Note that unlike sea clutter that works in close and progressively less at larger ranges, the FTC control works uniformly over the full range of the display. The FTC is not a good way to reduce sea clutter.

Echo stretch

This is a radar option that enhances the sizes of targets. It can be useful when looking for or following a small target. Turn it on, and all targets get larger. It lengthens then along the arc about the center of the screen. This option should normally be run in the off mode.

Interference rejection

The interference referred to here is that coming from other radars. Your radar unit will pick up noise from other vessel radars which will appear as either a background of dots or dotted arcs that shoot across the screen. This can present problems in crowded harbors and in other circumstances as well. Turning on this function will eliminate this background. This feature is only used for this purpose. The shooting dotted arcs are easily identified. They are transient and usually do not appear in the same place twice. This option can be left in the on mode with no deterioration of performance. It should be tried periodically in congested waters to see if it helps.

As an aside, if you detect these while at sea, it is a sign of the presence somewhere of another vessel with radar on, even though you do not see it on the screen or visually. The source of this interference can be well over your visible horizon and may not appear at all. On the few cases that I have tested with this, it seemed that one might be able to locate the direction of the traffic by noting the location of the sweep when the arc appears. The arc can appear anywhere, but it seemed to me that the sweep would always appear in the same location when the arc appeared. In these cases, the arc only showed a few times, over many minutes of watching and in all of the cases the traffic did not appear visually to confirm this observation.

Zoom and offset (shift)

These functions appear on some modern radars, although their function and operation may differ with the models. Offset or shift relocates the center of the display away from your own position so you can concentrate on a specific region. Generally you set a cursor to the new center and press a button to shift to it. Zoom allows users to expand the range about the new center, also sometimes using the cursor position to determine the extent of the zoom.

These can be very useful options for watching specific circumstances, but they do leave the radar set in an unusual display. This could lead to confusion in some cases, so it is important to convey to all in use of the radar about how it is set and to return it to normal when done with that observation.
guard sectors, alarms, and watch mode

Many modern radars allow users to define a safety range ring using the VRM, and then set an alarm that will sound whenever a target is detected within that ring. Others allow for two rings to define more complex alarms, or even allow for using the EBL to convert the rings into sectors. Naturally you should test such arrangements extensively before relying on them for assistance in any specific service. Read the manual carefully on their use, as the gain and other options must be set properly.

Some radars also offer a power saving option that allows you to program the radar to remain in stand-by mode but still automatically come on every 5 or 10 minutes to make a few radar sweeps to look for traffic. This option combined with guard rings and alarms might offer some level of warning for short handed operations. Needless to say, however, a proper watch is not kept by such arrangements. There is no electronic device that can be relied upon completely to detect and warn you of approaching traffic with risk of collision. Serious collisions have occurred involving vessels depending on such a system. The "all appropriate means" of keeping watch referred to in Rule 7 should include human eyes, attached to a body that can both think and speak, and does indeed understand the significance of the task of watch keeping.

heel angle

This is not a customary radar adjustment, especially for power driven vessels, but it can be very important for sailing vessels. It is not part of the radar, but rather an option of the mounting method used for the antenna. If you will indeed be sailing to weather any significant amount of time in areas where you expect to see traffic, then one should consider some rig that will gimbal or tilt the antenna so it can be kept parallel to the horizon. When you are heeled over, the windward side is not covered well by the radar sweep and the leeward side points so much more into the waves that the sea clutter is greatly enhanced. Hence the value of some rig which compensates for the heel angle.

There are several commercial products available. A pioneer in this field is a company called Questus which produces high quality gimbaled units for mounting on the backstay or on the mast. I have also sailed on several vessels with jury rig devices for this made from hydraulic trim tab adjusters. These are not gimbaled, but must be manually adjusted at each tack.
A related issue is that of smaller planing power boats. Some of these do not ride on an even keel, but with some significant trim by the stern even when on a full plane. In these cases, your most important view forward is not being covered as well as it might be, and building in some permanent "rake" to the radar antenna may be the most efficient rig. Check with your radar and vessel dealer on this concern.

General tips on tuning

It is always easier to tune with targets on the screen than with none in range. If you can, practice with this where there is traffic to prepare for when there isn't. Try to watch for a case with traffic safely passing in a rain or snow squall to practice with and see the effects of rain clutter. Remember, in a squall that limits your visibility you are operating on Rule 19, so it is crucial to have the radar tuned as well as possible.

Do not "over tune." Some controls work against each other. As a general rule, keep all optional controls in the off or minimum settings. Set Gain to have a light background of speckles when set to the high ranges. Then use the others only as needed.

With no targets and significant waves present, to look for close targets, first zero the rain and sea clutter, set range to high value, increase gain till a light speckled background, reduce to lower range, and then increase sea clutter to break it up into speckled pattern of dots.

For optimum resolution (i.e. to distinguish two close vessels, or identify a landmark) , use the lowest range scale that shows the target, and lower gain.
When a big target gets close, reduce the gain or it will smear across the entire screen and block out all other targets.
When looking for targets at your maximum range, turn up the gain temporarily to a more continuous pattern of speckles... and watch the screen intently. When new targets first come into view, they may show only on every other sweep or maybe every tenth sweep.

1.3 Radar Piloting

Radar has two basic uses underway, position fixing (or confirmation) and collision avoidance. You can with radar, for example, take the range and bearing to charted landmarks if they can be identified on the radar screen, and a range and bearing is a fix. The VRM and EBL make this very convenient.
There are definite advantages to such radar fixes as compared with other means of piloting -- speed, versatility, and use in restricted visibility are the main ones -- but there are also distinct uncertainties that must be addressed. And there are numerous variations on the piloting techniques that can be applied using radar. These matters are discussed in some detail in Lesson 6.

Lesson 6 concentrates on how to apply specific techniques and what their limitations are. Often equally important, however, is the more general question of how radar is best incorporated into navigation and watch keeping procedures. This subject of when to use radar, as opposed to how to use it, is the subject addressed in the next section, Lesson 1.4.

1.4 Use of radar underway

It is fairly easy to argue that of all electronic navigation aids, radar is the most important. The value of radar can be illustrated by pursuing that thought a bit.
In comparison, for example, GPS, and especially differential GPS, can certainly provide a more accurate position than radar can, at least with regard to absolute coordinates, but it is not often that we need this high degree of position accuracy when navigating in coastal or inland waters. If my radar can convince me, for example, that I am indeed in the middle of a narrow channel, I do not need to know my precise coordinates.

I am gratified, naturally, to see the plot of the GPS positions trailed out across some electronic chart display follow right through the middle of the channel, but many mariners are more assured by the actual vision of the channel boundaries showing clearly on the radar screen.
At sea, on the other hand, radar does not help at all with position fixing, whereas the GPS does, but at sea I also do not need to know my precise position in most cases -- not to imply low standards in navigation, I simply mean we rarely need 10-meter accuracy in the middle of the ocean.

What I want to stress is that the real value of GPS is not its position accuracy per se in most cases, but rather its ability to tell us accurate course over ground and speed over ground. With good radar targets in view we could also get this course information from the radar (see Lesson 6), but it is quicker and easier and always there with the GPS.
What the radar can do that the GPS cannot -- at least for now! -- is warn of collision risk with moving targets. If I pay attention, GPS can tell me if I am going to collide with land, but it does not tell me what other vessels in the neighborhood might be doing.

In short, with GPS alone, try as hard as I like, I am still vulnerable to the actions of other vessels. With radar as a tool to watch around me, I can spot any traffic in the neighborhood, and with some observations figure out what they are doing. If I can't figure it out, I know they are there and I can call them on the radio.
Hence the argument goes like this: with good land mass targets, often available in the dangerous situations, I can find from the radar everything that GPS tells me (only more slowly and less accurately) but the radar in addition can tell me what traffic is around and what risks they might present, whereas the GPS (for now) cannot. Hence radar is the more important aid! Furthermore, the radar is fully controlled from your own vessel -- no outside dependence. Radar produces its own navigation broadcasts, whereas we are all vulnerable to the availability of the much more complex GPS broadcasts. A minor point, but definitely favoring radar as an important nav aid for world voyagers.

Putting aside the "who's best" discussion, the truth is they are both important and every vessel should have and use both of these nav aids. These two, together with a depth sounder, are your main arsenal for safe navigation. GPS, especially interfaced to an electronic chart plotter, is the boss of the group when it comes to position navigation, because it is quickest, easiest, and most accurate.
Note that if you still have a LORAN on board and functioning, then this is a valid and useful confirmation of the GPS position. They are both black boxes, but their position assessments are completely independent, even operated by different branches of the government. If they both say you are at the same place (meaning the LORAN has been properly calibrated), then chances are that is where you are.

The key point is we need some means to confirm the GPS position, and in coastal or inland waters, radar is most often the best way.

Now (finally) the method

A normal position assessment might proceed by plotting the GPS position on the chart and then, from that position on the chart, note the range and bearing to some charted landmark that is likely to be a prominent radar target. Then go to the radar to check if that is true. At the same time, when in soundings, one should check that the depth is what it should be as well. On most electronic chart displays, the range and bearing to a landmark can be make with the mouse cursor in a matter of seconds. Without such things, we must plot the position on a chart and use parallel rulers and dividers.

This is a valuable way to use radar for position navigation whenever possible. It not only confirms your position, but also helps you identify radar targets (land masses) on the screen. Without this ongoing practice, it may be difficult to identify a headland or bay or islet or some such thing when you do need it. It also builds simple confidence in your work. If you rely solely on the GPS you will be anxious about your work and you have a right to be.

Once you detect traffic approaching, the GPS has limited value. Well offshore you might call the "vessel at 48 degrees 35 minutes north, 132 degrees 20 minutes west" or some variation, which you got from the GPS, but a broadcast on low power VHF usually provides an adequate location specification without coordinates -- not to imply this is not a good procedure, it can be. The point is, in traffic encounters, you must rely on the radar. You will even need to make careful "systematic observations" on the radar before you know which way it is headed. In other words, you can't even call "north bound vessel...." etc., when you first see it's radar image (in the fog) without making some quick computations from the radar observations.

These types of observations and the use of them for evaluating risk of collision is discussed briefly in the next section (Lesson 1.5) and in detail in Lesson 3.
In coastal navigation, the process of going back and forth from radar to chart has another advantage of keeping you informed of the name of the headland or bay you are nearest. It can be very helpful to have this in mind. You may hear a vessel calling for assistance in some region or another making a general call such as "This is the tanker Darth Vader, north bound at 20 knots calling the small radar target dead ahead, 2 miles off Cape Trouble" in which case it would be nice to know if it is Cape Trouble you are off of -- without having to get out a chart, plot your position and then look around for the nearest landmark, etc.

An aside...

For completeness, let me follow up on the implications left above that GPS (itself) might someday assist in collision avoidance. It is standard, often used technology these days to acquire a live GPS position on board and broadcast it back to some land based station. There are many applications of this technology. It was used in the America's Cup yacht race, for example, to show second-by-second on national TV exactly where the two yachts were relative to each other during the race -- right down to a boat length.

If these yachts each had a TV on board tuned to ESPN (I assume they did not!) they would not only have a live view of where the nearest boat was, they would also have a trail of it's past route drawn out in purple across a beautiful schematic of San Diego Bay, complete with simulated whitecaps. Someday we will all have some variation of this technology on board with a computer graphic not just of the chart but of all vessels in the neighborhood moving across it.
With all vessels broadcasting (via short-range FM) there present positions, plus COG and SOG, and with all vessels having receivers to acquire this data for nearby traffic, we have a live video type of radar that can easily be programmed to monitor risk of collision. This is not only possible, it is inevitable.

1.5 Collision avoidance and maneuvering

This is the premiere function of radar, telling us what traffic is out there and what it is doing. But we must do some homework to figure this out, it is not a simple matter of just looking at the radar screen -- unless we happen to have on board the most modern and very expensive types of radar used on large ships. And ironically enough, even though these top-end radars do this analysis more or less automatically, they are so complex to use that they take a great deal of special training to operate. In fact, it may take more training to operate a radar that does all the analysis automatically than it does to learn to analyze observations from a radar that doesn't do it automatically! So there is no way to win. We have got to do some homework to use radar.

The virtue, by the way, of the larger (ARPA) radars is they do it faster, presumably better, and can do several vessels at once.
The analysis involves first and foremost to determine whether or not the target poses a risk of collision. Next is determining what the circumstance is that leads to this risk. I could, for example, determine fairly easily that a target is moving straight down the ship's heading line toward me from dead ahead on a collision course. My next job is to decide if this is someone I am going to run over from astern or if it is a target headed full steam right at me. And so on.

For targets closing in on a diagonal track, as opposed to coming from dead ahead, the analysis is a bit more involved. Our job is to develop standard simple procedures that will let us know as quickly as possible what is taking place. And the next step is to review those pertinent Navigation Rules that tell us what to do in various conditions.
Radar Trainer is intended to make this an engaging and enjoyable exercise and we hope to share with you the satisfaction that can be obtained from a study of the Nav Rules. See Editor's Preface. If you are new to radar use, your time on the water in traffic, especially radar traffic that you cannot see visually, will be much more relaxed and your maneuvers made with more confidence after working through these exercises.

That concludes Lesson 1.
If you like, you can go from here straight to Lesson 2.

1.6 Radar etiquette

Here we include a couple side issues that might be classified by this unusual title.
(1) When you first enter the wheel house (nav station) when someone else has been on duty till now, or still is, check with them before adjusting the radar in any manner. It could be that they have it tuned in a special manner to watch something important, or they could be accumulating the plot trails on an approaching target to evaluate risk of collision. If you wander up and do something so simple as just change the scale, it will erase these trails which could create a totally avoidable risk... and will in any event likely make someone unhappy.

Consequently, whenever you want to make adjustments to the radar, first check with the person on watch. This is not only good manners, it is good procedure -- rather like not erasing people's waypoints from the GPS without asking first.
On some vessels there are strict rules about who can make adjustments to the radar for the reasons given above. In these cases, having a program like the Radar Trainer is the best way to get practice with radar!
(2) The microwave emissions from radar are a potential risk to health according to some publications. Specific exposures that pose a risk are not known, however, nor has it been established with certainly that there is any risk at all from typical exposures to typical radar units. Nevertheless, it is a rightful concern to not take risks unnecessarily. Radar manuals generally provide guidelines in this regard.

It might also be of interest to note in this regard, that even through specific data for marine radar may not be available, in all other cases of radiation exposure (i.e. gamma ray, x-ray, and

UV) where data does exist and specific tolerances have been established long ago, the recommended tolerances have continued to lower over the years as more data is accumulated. One consequence of this is that you would definitely not want to install your antenna so that it would be continually exposing crew or helmsmen to the radar beam. Another is to check when you have people working in the vicinity of the antenna before turning on the transmission mode.

Another point on the fringe of this of this topic is when entering a marina or locks or any other close quarters with personnel about, it is good manners and practice to shut off the radar transmission.

Lesson 2. Radar and simulator controls

This lesson will familiarize you with the operation of the simulator and at the same time introduce general procedures and terms of radar operation.

2.1 Setting simulator options
2.2 Use of the True View
2.3 Practice with radar controls

The last of these is the one that actually begins using the simulator with specific targets. In all of the above, however, new terms are presented and linked to the User's Guide. Please check them as they appear and test out the functions on the simulator as you proceed. Remember that the Glossary (menu bar) will take you to quick and then specific info on any topic.

2.1 Setting simulator options

Overview of Lesson 2.1

The function and operation of these controls are covered individually in the Radar Trainer Help file. If you are not familiar with the basic terms, click the indicated jumps as they appear below which will take you to the appropriate sections of the Help book. Selecting Back, will then bring you back to the part of the Tutorial you left.

This Lesson adds a few notes about recommended simulator usage in this Tutorial. Please read through these notes and then carry out the practice exercises that follow them. The jumps below just scroll down to the topic listed. You can alternatively just read through them in sequence.

Heads-up versus North-up mode

If you operate small craft (less than 60 or 70 feet), recreational or professional, then chances are very good that your radar or ones you will use have only the heads-up display. Hence it is best to just make that selection in the simulator and leave it set there. All of the tutorial functions can be worked in that mode and most of the discussion makes the assumption that you are running in that mode.
We include the North-up for navigation schools and ship operators who might use this function, but specific training unique to that display is not covered here.

Relative vs. Course bearings

You can use either one of these for the operation of the Tutorial. However, since it is an add-on feature to real radars be able to display course bearings, it is likely best for the most basic practice, to select and use Relative bearings for all of the exercises. Note that when we use "course" bearings here, it is simply implying that we have a compass interfaced to the radar so we can read out actual bearings (compass or gyro) as opposed to just relative bearings. In particular, the use of course bearings here does not imply the radar is stabilized. See notes below.

Stabilized vs. unstabilized radar

Radar Trainer does not offer specific settings to distinguish between these two types of radar, however, the sea state option effectively simulates this difference. If you run with the sea state set to calm, you are effectively seeing what stabilized radar tracks would look like. Most radars that do offer stabilized operation run in the North-up mode with headings set to gyro course. These are ship radars, not small craft radars. Small craft radars are typically unstabilized.

A main challenge to learning real small craft radar underway is the problem of dealing with the tracks of targets on unstabilized radar. In any seaway, the plot trails are broad and difficult to interpret. Radar Trainer, however, is specifically designed to help with this training, as discussed below and later in this Tutorial.

Sea state: calm, moderate, heavy

In typical small craft radar (meaning unstabilized), the plot trails of radar targets are smeared out due to the yaw of the vessel in a seaway. In stabilized radar the trails are much more true to their actual paths. We simulate this difference here with the sea state option. This option simply inserts a typical yaw pattern into the course of the center vessel.
As the heading of this (your) vessel swings around in this seaway, the apparent location of a radar target moves with it. If you were on a heading of 200, for example, and you observed a target at 7.0 miles off bearing 40° on the starboard bow (its true bearing being 240), when the radar beam hit that target and plotted it on the radar screen it would show it on the radar screen at 7.0 miles off at 040 relative.

But if a wave sent you onto a heading of 204 for a moment, and the radar beam happened to hit that target at that moment, it would see and mark the target at 7.0 miles off at 034° relative -- even though the actual true bearing to the target is still 240. The wave caused the a rotation in the radar's reference line.
Furthermore, if your heading slowly swung back and forth between these two limits as the radar marked the target positions, it would plot the single target as a smear between 034 and 040. At 7.0 miles off, this angular spread corresponds to a arc length or target width of about 0.7 miles -- the arc length is about 0.1 x time range per each 6° of angular width.

As the target got closer in this same average seaway, then at 2 miles off, the effect of an average 6° heading swing would only lead to a 0.2 mile spread in target width.

A stabilized radar can compensate for this effect once it has identified and locked onto a particular target. We can simulate this effect by simply shutting off the waves. In the real world, when we are running typical small craft radar, we won't have this luxury and we must deal with this problem in radar observations. And later in the Tutorial it will be extremely valuable to turn on the sea state and start working with this. But to begin with, it is best to run in calm mode. We start with the simpler case, and work up to the more complex.

Plot option

This is a valuable option in modern radars and should be used almost continuously in these exercises. If your radar does not have this option, then use it here anyway, to simplify the training, and then later on do the exercises again using your own screen marks with the plot off. You will have to mark the targets (automatically or by hand) to do any sort of analysis.

Use of the Time Factor

The ability of the program to vary the rate of the action is a key factor to convenient and versatile training. It should be practiced with and used often. In some cases, you might want to start it on one setting and then change it underway. Or change it back and forth to suit your needs. You can for example, run through an exercise rapidly with a factor of 60 or 120 to see what is taking place, then change time factor to 10 or so, press repeat and work on the problem.
Especially when working with the random targets generator. You can scan what it offered quickly, and if you don't like it, run it again till you do. In any event, you will ultimately learn to make decisions more efficiently this way, and real time will end up seeming quite slow. In other words, if we learn to make good decisions fast, we will do even better when we have more time, but if we learn slow, we don't get this free boost in performance.

Summary of recommended settings

For the majority of the exercises included here we recommend these settings (as explained above);

mode = heads-up	headings = relative
sea state = calm	plot = on
time factor = 30.	

These are the default settings that the program will always start with. In some exercises you will have to change these, but these are the typical ones that will prove most convenient.

That completes Lesson 2.1. Next is Lesson 2.2.

2.2 Use of the True View

Basic operation of the True View is covered in the User's Guide. Here we just give a few pointers on specific applications.

First to note is that this option is a key feature of the simulator. With it you can gain insight into the all important difference between the relative motion we see on the radar and what is really taking place on the water. We recommend that you refer to this view frequently.
In many cases when you are running on the 12-mile radar range, you can simply pop open the true view and see what you want. In other cases, you may want to adjust the view. You can make it larger (but keep it square), and you can move it off to the side, so it does not block the radar. If you open and close it, you will lose the radar tracks it has drawn, so in some applications you will want to just move it to the side.

Check out the grid function. The number of miles per grid line is shown in the caption bar when the grid is active. Once you get the grid set where you want it, press repeat to erase the grid and start again. Generally it is easier to see the targets and their trails with the grid off. Notice how the grid scale works. The default setting (that is, when you first show it after starting the program) will have 12 grid lines at 2 mile separation. In other words, the full screen covers 24 miles, which is just like the radar when set at range 12 miles, except this one is square. The "+" and "-" keys on the toolbar are effectively changing the range of the true view. The difference between this view and the radar, however, is you can physically change the size of the display by dragging the corners of the window.

For some exercises you may want to enlarge this to nearly full screen and drive the traffic around as on a game board. Pressing the "Center" button will take the center vessel back to the center of the true view, but it will also reset the plot trails.
Remember too that you can increase the time factor to 120 to get a quick perspective of how the target motion is going to evolve across the screen and then set the true display accordingly, and then slow down the time factor and repeat the action to study or do you practice exercise.

Relative motion -- Practice with the true view

Look, for example, at Demo 00, Default targets, with the true view running. Start it from the beginning. If you have not run anything else it will already be loaded, so just open the true view and then click Repeat. If you have run other targets, get to the defaults from the Demonstration targets. It is the top one. You can always restart the on-going run from the button in the true view toolbar. This button is there since the window will often be covering the one below it.

With these default targets on the radar we see what is apparently 3 targets coming toward us. By watching the true view of this same interaction, you can see what is really taking place. The buoy, target D, is coming towards us simply because we are moving towards it. The fact that it is coming towards us at exactly our speed is a results that we later use to identify such targets that are dead in the water (Lesson 3.2). The target B is indeed getting closer to us as indicated on the radar, but from the true view we see that its actual course is out and around buoy D.

Now repeat again and when the buoy gets about half way to you, maneuver A with a turn of 50° to the right and watch the true view. Then after watching that for awhile, maneuver C with a turn of say 50° to the right and watch that. There you can see what shows on the true view.

Then run Demo 1, Parallel courses. Here is another example of the power of the true view in helping us understand what is taking place. If you read the description of these targets, it suggests what to look for.

Remember, that we won't have a "true view" at sea, so our job -- and what we cover in the rest of this tutorial -- is how to figure out what is in the true view by making specific measurements of what we see in the radar view.
More specifically, what we want to learn from the radar is the true course and true speed of the targets along with the true aspect of the targets. We will determine it from the direction of relative motion and the speed of relative motion that we see on the radar screen.

The use of the true view and other examples will be presented throughout the Tutorial.

2.3 Practice with radar controls

Practice with range settings

For background, check these pop-up definitions from the User's Guide and read the "more info" links they provide: range, range rings, range limits.
Run any of the Demos, and watch how the display changes when you change the range. You can change range with the buttons or from the menu bar. Pracitce to see which you like best. Note that if you are running the plot option on, the trails will be erased when you change range. This is the way real radar works, so it is important to remember this effect. See radar etiquette.

Note how the targets move on the screen when changing ranges, but are still at the same distance off. A target that is 3 miles off will be seen half way out from the center on the 6-mile range, but right on the circumference on the 3-mile range. On the 1.5-mile range this target would not show up at all.
To determine the exact range of a target use the VRM as discussed in the next section.

Practice with EBL and VRM

It is pretty straight forward what these do. They give numerical values for where you draw the lines. Please read the "more info" links from EBL and VRM. Remember that the numerical value of the EBL output will be in the same units you have chosen for bearings.
The main thing to practice here is the different modes, cursor vs keys. It may be that your own unit has only one of these (most have just one option) so you might concentrate on using it. On the other hand, for doing the practice exercises, it will be convenient to switch back and forth -- each has its virtues.

The cursor mode has the advantage that you can read the range and bearing of a location with a mouse click and not have to draw the line. This can be useful for determining the length of the plot trails for trials that go straight up and down the screen, and it a bit faster than using the VRM circle.
The cursor mode is also fastest for chosing where you want to put a target for the Set Targets option. Just click the place on the screen you want a target and read the range and bearing.

Note that the VRM will not tell you the length of a plot trail unless than trail is dead ahead or astern. You have to use what we call the VRM method for this, or use a portable range scale. The Law of Cosines is what mathematically relates the actual length of the line to the two ranges and angle between them. So if you care to play with such things, you can see how much you would be wrong by just subtracting ranges instead of figuring the length properly.

Practice with bearings

For background, check these pop-up definitions from the User's Guide and read the "more info" links they provide: ship's heading line, bearings, course-up, heads-up.
We can make this simple, we include the course-up mode since most radars offer this option, but for the sake of practice, it is likely best to stick with the relative bearings. Even though you may run with the course-up mode in effect on your own radar (the usual best choice when avaiable), it does distract in some cases from learning the basics.

The course-up mode does indeed complicate the interpretation of the relative motion diagram and other analytical computations you may wish to make. In relative bearings mode, for example, you know a vessel approaching from 135 is on your starboard quarter. In course-up mode, this guy could be anywhere depending on your couse.
On the other hand, sometimes if does indeed clarify a problem to switch back and forth between these two display modes.
When you wish, for example, to plot the position of another vessel on the chart, or check the bearing to a landmark, then the course-up display is most convenient since it saves you one step of arithmetic. But the general analysis of how targets move in response to your moves and so forth, the relative display is best.

Brief exercise with Demo 00
Here we start use of the demonstration targets included with Radar Trainer. The first set we will use is just the default targets, Demo 00. If you have not run any other target scenario, then these will be the targets running on the simulator now or when you first start it. If you have changed targets, then to get back to these, from the target selection box, select Demonstration targets, and then Default targets.

Then do this:
(1) Read the description of the Default Targets. You get the opportunity to do this just after selecting them from the list of demos.
(2) With time factor at 30 watch targets move past you. Then open the True view window and watch them again (press Repeat). Compare the radar view with the True view to understand how a target sailing away from you can appear to be coming toward you.
(3) Think of this -- not related to these default targets, just hypothetically. There is a vessel dead ahead 6 miles off, making 5 knots to the north. You are also headed north, making good 11 knots. What's happening? You are overtaking him. How fast? Answer, at 11- 5 = 6 knots. On the radar, this will look like a target headed toward you at 6 knots -- which is a speed of 1 mile every 10 minutes. If he was first sighted at 3 miles off, you will be on him in 30 minutes.

(3) Using the default targets, set time factor = 1, range = 12 and press repeat. Press identify to learn the target letters or look at the True View. Now use the EBL and VRM to answer this question. What is the range and bearing of target B and C when first sighted? Answer. B = 11.5 miles off in direction 066, C = 8.0 miles off at direction 333.

(4) Close true view, set time factor to 1 to watch the action slow down to real time. Press repeat again, and then change the range to 6 miles. What happened to target C? Answer. Its out of range, off the scale. The target is 6 miles away, there is no target within 3 miles of you so you see a blank screen. Change back to 12, then go to 24 miles range. See how the target moves on the screen in proportion to the range setting.

Now select Set Targets and read off the answers from here. This shows how the Set Targets table works. Every time you start a target run, it stores the initial locations in this table.

Lesson 3. Evaluating risk of collision

3.1 Introduction to "systematic observations"

How to mark a target
Portable range scale
Six-minute rule

3.2 Target identification (SRM and DRM)
3.3 Estimating CPAs
3.4 Estimating Time to CPA

3.1 Introduction to "systematic observations"

We put "systematic observations" in quotes as it is a phrase directly from Rule 7 of the Navigation Rules. In other words, it is not an option that we do some sort of systematic analysis of radar targets to evaluate risk of collision. The Rules don't say what this means, but we go over in this Tutorial what is usually considered to be prudent systematic observations. When a target first appears on the radar screen, we know only one thing: before there was no target there and now there is one. If we go on about our business and make no other observations than that, when we next look at the radar screen we will know less than we did the first time. We will see a target, but we won't even be certain if it is the same one -- and we will have already wasted valuable time. Since we did not record nor mark where it was before (it's range and bearing), we do not know if it is closer or farther than it was, nor if it is headed towards us.

One might argue that this procedure did not break any navigation rules because there was clearly no risk of collision -- let's say the target was 12 miles off. But that argument is, if not outright wrong, at least not prudent. Rule 7 specifically calls for long range scanning to obtain early warning whenever we have radar. And even if one continues to argue about "what is long range?" whenever we are in restricted visibility, the argument fails unambiguously. Rule 19 calls for us to avoid not just the risk of collision, but the development of the risk and specifically says that we must evaluate the motion of that target when it first appears on the radar screen. Radar and the Nav Rules is covered in Lesson 5, and we will put off further discussion of the important distinctions between clear weather and fog till then.

The conclusion is that prudent operation calls for us to mark the target when first detected. The simplest approach is just to tag it with the EBL and VRM. If the range gets smaller then as time goes by, it is getting closer, and if the trail of its plotted positions tracks down or

nearly down the EBL line, then it is headed in towards us. That is the first thing we need to know.
We might add here, by the way, that for distant targets (say just visible by sight or binoculars, usually some 8 to 10 miles off) a change in a the bearing to a distant ship can usually be determined from a hand-held fluxgate compass more quickly than it can with the radar's EBL. This is especially true in a sea way that is causing the plot trail on the radar screen to be significantly smeared out.

For those targets that are headed in according to these first early observations, we must make further, more specific determinations. First we want to know, how close it will pass (CPA) if neither of us alters course or speed. Then we want to know when this will occur, and finally we need to rely on the Nav rules and whatever special circumstances are at hand to decide how to maneuver appropriately if we must.
It is the subject of the rest of this Lesson to go over these procedures in detail with examples and practice with the simulator.

For those new to such encounters underway, we add that if it should turn out that we are the stand on vessel and as such should hold course or speed, then we will once again be confronted with the realization that this is indeed the more burdened of the two positions to be in, and we must, if anything, watch the development of the passing even more closely.

How to mark a target

In nearly every example of systematic observations of what is taking place on the radar screen, we need to somehow mark the target's position right on the screen itself and label it with the time of observation.
The often mentioned method is to use a grease pencil or china marker for this job. These markers come in different colors and have traditionally been used for this job, at least according to text books. These markers have the advantage of being durable, yet they can still be erased with a rag and a little "elbow grease," or store a small bottle of alcohol in the nav table. Simple rubbing alcohol works well for cleaning up china markers. China markers work reasonably well on some radar displays. However on many displays the lighting is such that these do not show up well, no matter what color is tried.

An alternative is called an "overhead projector pen." One company that makes them is called Vis-a'-Vis. These come in various colors and also in a fine-point version. They make sharp clear marks and lines on the radar screen. They dry quickly and once dry are very durable so long as they do not get wet. These marks come off (very easily) with a damp cloth. This is the type of marker I have found most useful for radar marks.
One might be tempted to use the "dry-erase" markers for this job, since they too come in many colors and do leave sharp clear marks on a radar screen or computer screen. They clean up very easily -- in fact, too easily for this job, especially underway. If you just touch them, they smear or erase. These markers are convenient for practice at home on the simulator, but they are not a good choice for underway. Generally when you mark a target it is important to watch the marks and we do not want to risk losing them.

When you mark a target it is important to also write the time beside it. Be sure you are using the same clock for each mark. Often there is some nav output such as position and time from the GPS next to the radar which makes a convenient reference. Generally these times are only recorded to the nearest minute (i.e. 1247), but it is useful to round off the seconds to the nearest minute when doing so, or wait till an exact minute for the mark. Another good reason to have a time output in prominent display next to the radar.

If you don't have such an output in ready view next to the radar, then I would consider getting some digital clock to put there. They cost under $20 these days for some very slick models, with optional displays. I prefer those with big digits showing hours, minutes, and seconds and one that is easy to set from the front. Some come with self adhering backing that you can mount anywhere. Some oven timers are good for this. A built in stopwatch is also valuable for various jobs in navigation.

Portable range scale

In many practical applications we need to read the distance between two marks on the radar screen according to the current setting of the range scale. These can be two marks of a target's position that we made while evaluating collision risk, or they could be two landmarks (width of a bay, for example) that we need to check to determine what we see.
One way to do this is to turn on the range rings and just interpolate the distance by inspection, i.e. just looking and guessing. Another method is to mark the separation on a sheet of paper or set dividers to the distance and then use the VRM, as shown in Figure 3.1-2

A very convenient method, however, which is more accurate than the former and much quicker than the latter is to construct a special "portable range scale" that matches your radar unit. You may also want to make one for your computer to use with Radar Trainer.
The device is just a range scale hand drawn onto a piece of cardboard or any flat surface. We have found the tongue depressors used by nurses and doctors are very convenient for this purpose -- a trick we learned from a river boat captain in Biloxi. They can be purchased by the box from a pharmacy. Just mark the scale along the edge to match the spacing of the range rings on your radar. An example of the use of this is shown in Figure 3.1-1.

In Figure 3.1-3 we present a simple scale that can be printed and used for this purpose. Just find where the scale matches your ring spacing on radar or computer and cut it off there and paste or tape it onto a piece of cardboard or a tongue depressor. This one can be printed several times and used for different scales. Note that the graphic we have in here now has pretty crude lines, and may not serve the purpose intended because of that. But you can see from this what the principle is and make one of your own if this won't work. Loran interpolators on charts are set up in a similar way and may be useful for this.

Remember the meaning of a range ring changes with the scale -- at a range of 6 miles, they are usually 1.0 mile apart and at a range of 12 they are 2.0 miles apart, and so on -- but this does not affect the use of the portable scale. The actual distance between rings on the screen usually stays the same, at least until you get to much lower ranges.

In some modern radars, this problem of distance measurement is solved in a very elegant manner in that they provide two cursor positions on the screen. In these models, you can set one cursor at one of your points of interest and the other at your second point or mark of interest, and then just click a button to have the radar compute the distance between the two cursors. This is fairly straight-forward to simulate in the computer, but since so few radars have this feature to date, we have not provided this convenience here. Measuring these distances accurately with available equipment is, after all, one of the principle skills we must learn in practical radar work.

Six-minute rule

This is a common trick used in radar observations to simplify computations. It is a special solution to the standard speed, time, and distance problems that we must solve over and over again in navigation. In radar they take these forms: during the time interval of 1214 to 1226 how far did I move when my boat speed was 8.5 knots. Or, a target position on the radar screen moved 2.5 miles during that time interval, how fast is it moving.
The normal solution to these problems is:

distance (nmiles) = speed (knots) x time (minutes) / 60
or
speed (knots) = 60 x distance (nmiles) / time (minutes)
These are the solutions that will work for any time interval. But notice if we restrict our timing intervals to exactly 6 minutes, the equations become very simple.

Distance = Speed / 10
Speed = 10 x Distance.

In other words, the distance you move in 6 minutes is equal to your speed divided by ten. This special cases is sometimes called the "six-minute rule." Hence in radar observations and analysis, whenever possible we use time intervals of 6 minutes or some easy multiple of that, such as 3 minutes or 12 minutes, and then we can do this part of the computation in our heads and won't need to break out the calculator.
When using 12 minutes, for example, the length of the line representing distance covered at 9 knots, would not be 0.9 miles, but 1.8 miles, and so on. Just remember, in 6 minutes you would go 0.9 and in twice the time you go twice the distance.

3.2 Target identification (SRM and DRM)

Speed of relative motion

When a radar target first appears on the radar screen, as a rule the first thing we want to know is: What is the speed of relative motion of this target? This is especially true for those important cases of targets moving down screen towards us from near dead ahead. Targets moving down screen towards us from ahead could be a slow moving fishing vessel that we are overtaking or it could be a fast moving deep sea vessel headed straight towards us. It is the speed of relative motion of this target that is crucial to answering this question.

Speed of relative motion (SRM) is how fast the target moves across the radar screen. It can be thought of as a "closing speed" if the target happens to be headed toward you. It is measured in knots. It is the distance the target moves across the screen divided by the time it took it to move that distance. Or from a more "operational" point of view:
(1) When a target first appears on the radar screen mark it with the time of observation.
(2) Some time later, after the target has moved a noticeable distance away from the first mark on the screen, mark it again and record the time. Note the radar range must not change during the time we are watching and marking this target. We cannot compare a mark made on one range with a mark made on another.

(3) Next figure the distance on the radar screen between these two marks using the current setting on the radar range. This can be done by just estimating the distance from the spacing

of the range rings, or the distance can be set onto dividers or marked on a piece of paper and then aligned with the center of the radar to measure the distance with the VRM (see Figure 3.1-2). A portable range scale is especially valuable for this operation. This distance should be expressed in nautical miles.

(4) Figure the time interval between the two marks and convert this time to decimal hours or to minutes, as needed to compute the speed.
(5) Figure the SRM by dividing the distance between marks by the time between marks.
There are several approaches to figuring SRM:
SRM = distance / time (hours)
SRM = (distance x 60) / time (minutes)
SRM = (distance covered in 6 minutes) / 10
We look at a few examples of figuring the SRM and then return to discussing how we use this information. Here are a few examples worked out from the demos, then you can practice with the simulator.

Ex. 3.2-1 Put on the range rings and run Demo 1 till 12:15, then Pause the action. Use Identify to put labels on the targets. There are 3 targets headed toward you: C, D, and E. One not moving, B, and one coming up from behind, F.
We have run for 15 minutes, so the SRM is the distance covered times 60 / 15, which is the same as 4 times the distance moved in 15 minutes. Use a portable range scale or other method to show that C moved about 6.0 miles so its SRM = 24 knots down screen. We are moving 8 "up screen," so this target is approaching us at 24 - 8 = 12 knots.

D moved about 0.8 miles for a SRM of 3.2 knots down screen. Since we are moving up at 8 knots, he must be moving away from us at 8 - 3.2 or 4.8 knots
Note that B did not move at all, and since we are moving at 8 toward 000, he must also me moving at 8 toward 000. Any target that does not move on the radar screen has the exact same course and speed as we do. This is something we can even extend: any target that does not move very fast on the radar screen, must have a course and speed that is very near our own. See related discussion in Radar and sailboat racing.

Target F moved up screen by 2.0 miles in 15 minutes for a SRM of 8 knots. But we are also moving up screen at 8 knots, so for him to catch us at this rate he must be moving 8 + 8 or 16 knots.
Target E moved 2 miles in 15 minutes for a SRM of 8 knots. Since we are moving at 8 knots, and this target only moved at 8 knots, it must be dead in the water. Its entire motion was due to us.
Rule: any target that moves straight down the screen at your own boat speed must be dead in the water or a buoy. Note that as we see from this example, we can have many targets moving straight down the screen that are not dead in the water, but they will have other SRMs. If the SRM is greater than ours, it is headed towards us at a speed equal to SRM minus our speed. If SRM is less than ours, then we are overtaking it, and its speed is our speed minus SRM.

Ex. 3.2-2 Run Demo 00, the default targets. Set the Plot on to a frequency of 6 minutes then run for some time and then pause. Now measure the distance between marks for each target.

C covered 1.8 miles in 6 minutes, so its SRM = 18 knots. D covered 0.9 miles, so it has a SRM of 9 knots. And E covered 1.5 miles, so its SRM = 15 knots. You can check these with the CPA Info option.

In this example, only D is moving straight down the screen, so it is the only one we can analyse in a simple manner. We are moving 9 knots in this Demo, so D is a buoy. To determine what is going on with the other targets (B and C) we must use the Relative Motion Diagram, covered in Lesson 4.

Finding DRM

In Ex. 3.2-1, the targets were moving straight up or down the screen. Their DRMs were either 000 or 180. In the default targets of Ex. 3.2-2, targets B and C were on diagonal courses. To figure their DRMs, set the EBL parallel to their courses and then read off the bearing from the digital output. Remember the EBL is the direction from center toward the way the line points, so you must orient it in the same direction the target is moving.
That concludes Lesson 3.2. You can practice this with any of the Demos, and then just use the CPA Info option to check your work. It shows SRM and DRM for any target on the screen. You will find very shortly that it pays to make a portable range scale for these exercises, and it will be even more important to make one for your own radar.

You can use Annotate to mark this Lesson done. Go to Lesson 3.3 ?

3.3 Estimating CPAs

The CPA is how close a target will pass assuming that no one changes course or speed. Generally we can estimate this once a plot trial of the target's motion across the radar screen has been established. See Figure 1 for an example of a plot trail and the forward projection of this to make an estimate of the CPA.
In Figure 1, the range rings are set to 1.0 miles, so we can see that the CPA is about 1.6 miles in this case.

In Figure 2 the range rings are also set at 1.0 miles, and we have one up-screen target that has already passed the CPA point, which was at a distance of about 2.3 miles. The down screen target in that figure will have an estimated CPA of about 2.0 miles.
Note that in some cases this estimate is facilitated by placing a ruler along the line of the plotted trail to project it forward. This projected line can even be marked on the radar or computer screen using an overhead projector marker.

In Figure 3 the estimated CPA was about 1.6 miles, but when this was plotted on a larger scale (see Figure 4) we see that the CPA was more like 1.2 miles. Obviously, the accuracy that we get for the estimated CPA depends on how good our data is on the trail line. In a seaway, the trails are often smeared out which makes a precise estimate more difficult. See discussion under sea state.

How to compute the CPA
The CPA can also be computed analytically once a numerical value of the DRM has been established. To do this, use the latest range and bearing of the target (R2 and B2) and follow the procedure below. First find the acute angle (< 90°) between the DRM and the reciprocal of the latest bearing. That is, take B2 plus or minus 180, and then take the difference between this angle and the DRM. Subtract the smaller from the larger. We abbreviate this process below with the absolute value signs (| |).

beta = |DRM ± (B2 ± 180)| and then

CPA = R1 x sin (beta)

In Lesson 4.2 we solve the relative motion diagram of Figure 4 to show that the DRM in that example is about 227. The latest bearing (at 1412) is about 027 and the latest range is about 3.3. Hence in this case, beta = | 227 - (027 + 180) | = | 227 - 207 | = 20. And the CPA = 3.3 x sin(20) = 1.1 mile.

Remember, though, that even an accurate computation provides an approximate answer if the input is approximate. And in these cases we do not often know any of the input values with much precision. It is in fact not very often that we are called upon to make a numerical calculation of the CPA. The biggest value of the procedure is to check plotting exercises for precision in plotting.

Practice estimating CPAs

This is very easy to do with the Radar Trainer simulator. You can run just about any demo there and let the trails build up some, and then slow it down with the time factor and practice estimating what the CPA should be. Then simply check your answers with the CPA info button on the simulator panel.

Then for more advanced practice, keep the time factor set to a low value and turn on the sea state (menu bar) to moderate or rough and you will begin to see what the real problem is. Note especially that it is difficult to determine an accurate CPA in rough conditions or even moderate conditions when the target is far off, more than 8 miles or so.
The key lesson to learn from this is that it is dangerous to maneuver on the basis of a perceived CPA before you know for certain what it is. The worst case is a target headed nearly straight toward you from near dead ahead. In these cases, in a seaway, the trail is so ill defined at a distance that every target anywhere in this region will appear to be on a collision course. It can be crucial in these cases to stand by with careful observations until you know for certain what is taking place. To maneuver too early with say a turn to the right may only reduce the CPA for a vessel that would have passed safely on your starboard side had you waited to discover his true course. This is an important exercise to practice with. It is also discussed in more detail in the Rules section, Lesson 5.

3.4 Estimating Time to CPA

After we establish the DRM of a target from several marked observations, the next thing we do is estimate the CPA for the interaction as described in Lesson 3.3. Next we want to know when this is going to happen. In other words, how much time do we have.
We can do this mathematically once we know the SRM, but generally it is adequate to just measure off known intervals on the radar screen to make a reasonable estimate. This process is shown schematically in Figure 3.4-1.

You will have two timed marks on the screen, so you know how long it took the target to move that distance, so all you need do is walk off that interval as shown in the figure.
You can also use this method to decide how long it will be till your maneuver. Suppose the target is 8 miles out and you decide that if he continues on his course you will maneuver when it is at a range of 5 miles. Set the VRM to 5 miles, then walk off the timed interval to see how long that will be and you can then alert the crew to the upcoming maneuver.

Note there are two terms in common use for these time estimates. TCPA (time to CPA) is an actual time based on the recorded time of the latest observation. MCPA (minutes to CPA) is a time interval from the latest observation. In this program, the CPA Info uses MCPA as an output, whereas the CPA computer uses the TCPA. There is no logic behind this.
Practice finding TCPA

This is easy to practice with since the CPA Info button tells this value for any target. You can run any Demo, estimate the MCPA and then click CPA Info for that target and check your results. There are further practice exercises discussed in the Practice Exercises.

Lesson 4. Radar plotting and maneuvering

4.1 Introduction to radar computations

There are two ways to solve radar problems. One is by direct numerical computation which we call here the analytical approach and the other is the traditional method of graphic plotting. The plotting method is the most reliable because it does not require a functioning calculator or computer and it shows much more explicitly the vector triangles involved in the solutions. For most of us, it is the drawings that show what is taking place; the equations are much less intuitive.

Later, for example, we can see very clearly from the diagrams that if we slow down, the radar track of the target will curve up screen, and so on. The drawings are also a way to judge whether or not the answer makes sense. Going strictly by numerical computations, we must rely more on faith than insight -- which is not good procedure when interacting with traffic at sea. And this is in part why all USCG exams on radar use require candidates to be familiar with the plotting procedures. In fact they do not test at all on the equations behind the plots.

We present both methods here simply because it is valuable for training. You can work out a plot, and then check yourself with the computation to see if you plotted carefully enough.
We also cover more material here than many readers might care about. Hence it is important to keep this in perspective. The most important is the relative motion diagram (RMD) discussed below. The minimum that all readers should cover is the graphic solution to that problem. This is fundamental and all should know it. Beyond that, it is up to the individual.

Radar plotting problems can be solved either directly on the radar screen using an overhead projector marker or china marker or on a separate sheet of paper. There are special plotting sheets designed for this application called radar maneuvering sheets or "boards." When the plotting is done on the screen (of the radar or the computer) it is often called "rapid radar plotting." When this same type of plotting is done on plotting sheets, it is called "transfer plotting."

For many practical applications, a quick plot on the radar screen will provide adequate information for safe efficient operation -- at least as far as the basic operation is concerned, which is a solution of the RMD to find the course, speed, and aspect of the radar traffic. The more complex operations, such as choosing the course to change to a specific CPA or related problems, are usually better done as transfer plotting (see Lesson 4).

4.2 Relative motion diagram

This diagram is the fundamental basis of most radar observations. It is the what we use to learn the true course and speed of a target vessel from observations of how its position changes with time on the radar screen.

In special cases of a target moving straight up screen or down screen, we know its course by just looking. It is either headed in our direction or opposite to that -- or it is not moving at all. Which of these is correct, depends on the target's SRM, and in these "parallel" courses cases this can be found from simple subtractions. These cases are covered in Lesson 3.

So whenever the targets are moving straight up or down the radar screen, we do not need this diagram, but in all other cases we must use this relative motion diagram (RMD) to figure out what a target is really doing. Everyone who wishes to understand radar observations should practice this section and understand this diagram. There is no way around it. Several practice problems are presented here and elsewhere in the Tutorial.

The User's Guide presents one example of the relative motion diagram in Figure 3, which includes an expanded view of the diagram in Figure 4, which includes the plotting sequence. The plotting procedure is the same for all cases, regardless of where the target approaches from.

Discussion of the procedure.

The example shown in Figure 4 uses the 6-minute rule for plotting and analysis. This is often the simplest and most useful approach, but it is not required that we use 6 minutes all the time. Any time period can be used. Before going on, we will take a closer look at the example in Figure 4. Use the Back button in the menu to go back and forth from this discussion to the illustration.

With the scale showing in the diagram as 6.0 and range rings at 1.0, we can figure out all we need to know in order to solve the problem, but we might just add here that the first sighting at 1406 was at R1 = 5.6 and B1 = 035 and the second mark was made at 1412 when R2 = 3.3 and B2 = 027.

The relative motion plot is always initiated from the first sighting of the target -- or, more precisely, from the first sighting that we marked. We then wait for some time (say 6 minutes, but it could be 4 minutes or 10 minutes) and then mark the target position once again. We now have two marks for the target at some time interval apart. In this course we call the first point "R" and the second point "M," which stands for Relative Motion. Our next job is to mark a point on the screen directly below R. How far below depends on the time interval and our knotmeter speed. We want the distance below R to be equal to the number of miles we moved during the time it took the target to move from R to M. This is just a standard speed, time, and distance problem: our knotmeter speed multiplied by the time interval between marks equals the distance run between marks.

The 6-minute rule is used because it simplifies figuring this distance run:

distance run in 6 minutes = knotmeter speed / 10.

Likewise, if we know how far a target moved in 6 minutes, we can multiply that by 10 to get the Speed of Relative Motion.
In Figure 4 we can see that the length of the RT line is 1.3 miles (to check this make a hand-held scale as described in Lesson 3). In other words, the speed of the center vessel is 13 knots. Or put another way, the driver of the vessel in Figure 4 marked a target at 1406 (point R) and again at 1412 (point M). Since their own speed was 13 knots and the marks were 6 minutes apart, the position of mark T was 13 /10 = 1.3 miles just below R.

Once point T is marked, all that is left is to draw the line T to M. The length T to M measured on the same radar scale times ten is the true speed of the approaching vessel and the direction T to M is the true course of the approaching target vessel. T to M stands for True Motion. Using your hand-held scale, check Figure 4 to see that the true speed is about 17 to 18 knots. As in real radar, it is difficult to determine this precisely as the target marks are always smeared out a bit.

On a real radar or the simulator, you can measure bearings with the EBL, but on this graphic picture you will need a protractor (the C-Thru brand 376 E for about 1$ is very convenient for this.)
We will also have to make some assumptions on bearings here since Figure 4 does not show how the radar is set in this regard. There are no numbers identifying the ship's heading line. We will assume then that this radar is running in heads-up mode with bearings set to Relative. With this assumption, confirm that the course of the target is about 258 R. Use the scale to further confirm that the SRM is about 23 knots -- that is R to M is 2.3 miles long -- and that the DRM (direction of R to M) is about 227.

If we were actually sailing on course 200 T, for example, then we have learned that this vessel is on course 200 T + 258 R = 458 T (-360) = 098 T. If this is not clear, it will pay to stop at this point and draw out several examples to be sure that you understand how these relative bearings correlate with true bearings. You can also set up this target situation in the simulator and then bounce back and forth between radar bearing displays while watching the true view to get a feeling for this.

We will pursue these numbers more in a moment using the CPA computer, but for now let's go back over what we have learned from the exercise. At 1406 we noted a target at R1 = 5.6 mile and B1 = 035. Then 6 minutes later at 1412, we noted this target had moved in to R2 = 3.3 and B2 = 027. From this, we could immediately determine without any other plotting that we have a target moving diagonally down the screen at a relative speed of 23 knots in a relative direction of 227. (See CPA comptuer example for precise answers.)

We then completed the RMD as described to learn that we have approaching us a vessel of speed 17 knots on a course of 258 R. And now we are ready to ask an important question: what is the "aspect" of this vessel. It is the aspect of the vessel and how it changes with time that determines risk of collision and the right of way status of the vessel during daylight when the vessel can be seen. It is also the aspect that determines what lights we should see from it at night.

Aspect
Aspect is the angular perspective at which we see a vessel approaching or leaving -- more specifically it is defined as the relative bearing of our vessel as seen from the other vessel. It is measured from 0° to 180° and labeled red when we are on the port side of the vessel or green when we are on the starboard side. To say we see a vessel with an aspect of 90° red, means he sees us on his port beam and we are looking square at his port side. We see his red running light and his mast head range lights are as open (separated) as possible. An aspect of 45° green, means he sees us broad on his starboard bow. He is headed at the moment 45° to the right of our line of sight to him. We would see his green starboard running light. A vessel with aspect 0° is headed straight toward us.

The big difference between visual observations and radar observations is the perception of a vessel's aspect. When a vessel turns we can usually detect a rotation of the hull or lights much more quickly by eye than we can on the radar. A radar observation in itself tells nothing of the aspect. We can only figure this from the bearing we observe and the computed target course we get from the RMD. But this diagram takes some minutes to collect. This is partly why it is always important when a target is first detected on the radar to immediately go on deck with binoculars and start looking to see if you can discern its aspect. Is it pointed to the right or left of us?

In the Figure 4 example at 1412, we see a vessel at a bearing of about 027 R (you have to check this, we have not used that information yet in this section), which we have learned from the RMD is on course 258 R. Since we see him at 027, he would look back to us at 027 + 180 = 207 and since he is steering 258, the aspect is 51° red. If that aspect increases, as it will in this case, he will pass ahead of us. If it were to decrease, we would cross in front of him.

The solution to the RMD reminds us of this important fact, the true aspect of a target headed towards us is always higher than it appears from the DRM. If we think we should be looking broad onto their bow from what we see in the radar, we are actually looking more toward their beam. The amount higher depends on how fast we are moving and on their relative bearing. Note that this is true for targets headed toward us or away from us. Sometimes a glance at the radar might lead us to think we should be looking for a red light on the horizon, when in fact a proper analysis would show we should be looking for a single white stern light. True aspect is always aft of apparent.

That concludes Lesson 4.2, but there is much more in the Tutorial about this most important part of radar observing:

4.3 Rendezvous

Rendezvous means choosing the course that will intercept another moving target. Put another way, it is figuring the "collision course." For a target headed away from you, you must be able

to go faster than it is, but this is not necessarily the case if you are intercepting one headed toward you.
There are graphic ways to solve this problem, illustrated in Rendezvous plot. They are usually done on plotting sheets as the targets are often well outside of radar range when the computation is made.

This problem, however, is much easier to solve analytically, which is also the superior method since a fraction of a degree error can mean a long miss for a distant target. To work these you only need a calculator with trig functions. Or use the Windows calculator in the scientific mode.

Definitions:

R1 = initial range to target
B1 = initial bearing to target
v = target speed
u = your speed
w = your closing speed with the target
beta = target's course relative to B1
gamma = your course relative to B1

Solution:

gamma = arcsin [(v / u) x sin (beta)]
w = v x [sin (beta - gamma)] / [sin (gamma)]
course to steer = B1 + gamma
time to intercept = R1 / w

We have 3 examples here adopted from the excellent book by David House called Navigation for Masters He works the problems graphically, we will do them analytically using the above formulation. These three are set up as Demo 13 in the simulator. Then a few practice problems are given which can be tested with the simulator.

Example 4.3-1.

Target is 100 miles off in direction 015. Its course is 050 and its speed is 12 knots. Your max speed is 18 knots. What is the minimum time to get to him and what course should you take?
In Demo 13, this is target B. Remember you must set your speed in the simulator.
beta = 50 - 15 = 35°, v = 12, u = 18, sin (gamma) = [12/18] x sin (35) = 0.382, or gamma = 22.5° and course = 015 + 22.5 = 037.5 true.
w = 12 x [sin (35 - 22.5)] / [sin (22.5)] = 6.80 knots = closing speed, and time = 100 / 6.80 = 14.70 hr = 14h 42m.

Example 4.3-2.

Target is 175 miles off in direction 143. Its course is 280 and its speed is 15 knots. Your max speed is 20 knots. What is the minimum time to get to him and what course should you take?
In Demo 13, this is target C. Remember you must set your speed in the simulator.
beta = 50 - 15 = 35°, v = 12, u = 18, sin (gamma) = [12 / 18] x sin (35) = 0.382, or gamma = 22.5° and course = 015 + 22.5 = 037.5 true.

w = 15 x [sin (137 - 30.8)] / [sin (30.8)] = 28.15 knots = closing speed, and time = 175/ 28.15 = 6.21 hr = 6h 13m.

Example 4.3-3.

Target is 16.0 miles off in direction 115. Its course is 210 and its speed is 6 knots. Your max speed is 14 knots. You are to take up position 1.0 miles off her starboard quarter (135 R off the target's heading). What is the minimum time to arrive on station and what course should you take?
The first step in this one is to figure R1 and B1 to the real target (starboard station) from what is given about the vessel. This can be done several ways.
(1) When the target is in view on the radar as this one would be, just set the EBL and VRM at the right location (1.0 mile away at 135 R for a vessel headed 210) and read off the answer. Go to Demo 13 to confirm this.

(2) Graphically on a plotting sheet, by drawing the location of the vessel and the desired station and then measuring range and bearing to the station. This is simpler than the computation provided the target it fairly close.
(3) Compute the new range and bearing using a navigation computer, which is the simplest and likely best of the approaches. This type of computation can be done with most GPS units or any software program running electronic charts. There are also numerous hand held calculators such as the Merlin II which do these computations. Procedure: from your present position and the given range and bearing to the target vessel, compute the lat-lon of the target vessel. (In practical cases this is likely to be a given). From that position, compute the lat-lon of a point 1.0 miles in direction 135 to the right of 210). Then from your present position, compute R1 and B1 to the point you just found. Done. Takes seconds, once the procedure is mastered.

(4) To do this analytically from scratch, the navigator must be familiar with the law of sines and law of cosines for solving trig problems. First find the subtended angle: initial location of station is 135 aft of 210, which is 50 back of 115, so new range = sqrt[1x1 +16x16 - 16xcos(50)] = 15.707, and the angle offset = arcsin [(1 / 15.707) x sin (50)] = 2.8°, hence R1 = 15.707 and B1 = 112.2.
Once we know the proper R1 and B1 (15.71 and 112.2), we proceed as before. In Demo 13, this is target C. Remember you must set your speed in the simulator.

beta = 210 - 112.2 = 97.8°, v = 6, u = 14, sin (gamma) = [6 / 14] x sin (97.8) = 0.511, or gamma = 25.1° and course = 112.2 + 25.1 = 137.3 true.
w = 6 x [sin (97.8 - 25.1)] / [sin (25.1)] = 13.50 knots = closing speed, and time = 15.707 / 13.5 = 1.16 hr = 1h 10m.

More practice problems

Example 4.3-4. In Demo 13, this is target E. There is a life raft adrift in the Gulf Stream, making 4.0 knots in direction 340 due to the set and drift. The life raft is 50 miles SW of you (bearing 225). Your max knotmeter speed is 6 knots and you are in the same current. What is the quickest you can get to them and what course do you steer? See Answers.

Example 4.3-5. In Demo 13, this is target F. Same problem as above, but the raft is located 120 miles from you in direction 005. See Answers.

4.5 Course to steer for desired CPA

his is one of the primary exercises of advanced radar maneuvering. You detect a target and determine its CPA and decide you need to maneuver to increase this CPA. The practical situation is generally that you already know the SRM and DRM from two observations of range and bearing, because if you did not know these you would not know that you needed to maneuver to increase the CPA.
You can maneuver to achieve the new CPA by either (1) changing course while maintaining the same speed -- the most common choice -- or (2) by changing speed while maintaining the same course. Or there is (3), do some combination of both.

In clear weather, the Nav Rules recommend (1). In fog that recommendation is not given, but the obligation to maneuver applies more often -- since there is no stand on vessel in the fog -- so we are called on to use some form of this analysis more frequently. Rule 8b discourages option (3), unless the combination ends up with a clear indication to the other vessel of what we are doing.
There are two ways to solve these problems: graphic solution using plotting or analytic solution using a calculator. We cover the analytical solution first as a means of introducing some of the terminology used in the graphic solution which follows it.

Case (1). The solution is based on first determining the DRM that will achieve the desired CPA from the latest or a future location (R2 and B2) of the target. A DRM equal to B2 + 180 would point the target right at us for a collision course. We want to shift this direction to the right or left by an amount beta, where beta is determined by the desired CPA and how far away it is to begin with:

beta = arcsin (CPA / R2).

The DRM we want is then:

DRM = (B2 ± 180) ± beta.

The first ± just says that it does not matter how we figure the reciprocal, the second one is determined by whether we cross ahead or duck behind of the approaching target.
To figure the actual course we should turn to, we need to first know the true course (TC) and speed (v) of the target. This we have to figure from solving the RMD from our first observations -- those that told us the uncorrected CPA would be too small (see Lesson 4.2). Once you know TC and v, figure the angle alpha which is the difference between the target's true course, TC, and the DRM we want it to have after our turn:

alpha = TC - DRM.

Next figure the angle gamma, similar to used in rendezvous and storm avoidance:

gamma = arcsin [(v / u) x sin (alpha)],

and from this the final course to steer

C = (DRM ± 180) ± gamma.

The process appears a bit involved, but with a hand calculator going step by step, it is not so bad. Again, the first ± is just to figure the reciprocal, and the second is based on crossing or ducking the traffic. A quick sketch of the problem helps in selecting the latter ± option, since this depends also on the quadrant the target approaches from.

Example 4.5-1. Target D in Demo 3 is on course TC of 268 with a speed v = 12.0 knots. Your vessel A has speed u = 7.0 knots. If nothing changes, this target will pass with a CPA of 0.28 miles on our starboard quarter. He is coming in from the right, nearly on a perpendicular course, he has right of way and will indeed miss us, but just by 0.28 miles. The Rules would require us to maneuver to stay more clear than that. They would also suggest that we do not cross his bow, as we are now on a course to do. Hence we want to turn right, by an amount that will open the passing to a CPA of 2.0 miles. We will do this when he gets within 6 miles of us, so we can be certain of his course.

At 12:33 R2 = 5.7 miles and B2 = 060, which is the data we use to compute the maneuver.
beta = arcsin (CPA / R2) = arcsin (2.0 / 5.7) = 20.5°.
DRM = (B2 ± 180) ± beta = (060 + 180) ± 20.5 = 240 ± 20.5 = 260.5.
Note we want him to cross in front of us, so we want his DRM to rotate clockwise, which means a + sign here.
alpha = TC - DRM = 268 - 260.5 = 7.5°.
gamma = arcsin [(v / u) x sin (alpha)] = arcsin [(12 / 7) x sin (7.5)] = arcsin [0.2238],

or gamma = 12.9°.
Note that if the quantity in the square brackets turns out to be greater than 1.0, then we cannot do it. We cannot achieve the CPA we want with the conditions we have. The sine of an angle must always be less than 1.0.
C = (DRM ± 180) ± gamma = (260.5 - 180) ± gamma = 80.5 ± gamma = 80.5 + 12.9 = 093.4.
Note that DRM ± 180 is just the reciprocal of the DRM, and since we want the target to cross in front of us (we duck behind it), we adjust our course to the right of that, which is + in this case.

Now do this in Demo 3, with target D to see that it all works.

4.6 Sailboat racing with radar

Radar can be extremely valuable for yacht racing, especially when competitors are in vessels with very similar performance. In these cases you can tell from the radar whether their conditions of wind, seas, and current are giving them an advantage or disadvantage in their location compared to yours. You can do this very readily for separation distances of up to 3 or 4 miles, and in some cases as far off as 5 miles.
Even when vessels are not of the same performance, you can watch them in the fog, or tell if they have tacked or gibed when barely visible by eye in any conditions. This is, of course, beyond all the advantages of radar with respect to collision avoidance and navigation. And you naturally have a big advantage if your navigation is better in a race.

The main tactical advantage, however, is the quick way you can tell what another vessel is doing relative to you. It is easiest to analyze when both are on the same tack or gibe, but it can be done in any situation with the RMD, it just takes longer. On the same board, you can spot the relative performance of another similar vessel in about 10 minutes.

The similar performance is stressed because if another vessel is much faster or slower to begin with it is more difficult to evaluate changes in this. But it is still possible after you gather some data. You can also use radar to tell in a glance who is ahead relative to the wind.

The first step is to decide what is the difference in performance (faster, slower, higher, lower) and then to figure out if this is due to wind or current... or poor sail selection or trim, but let's assume everyone is doing their best in this regard.
Start with the basics of radar interpretation.
(1) If a target does not move at all on the radar screen, it is doing precisely what you are -- in speed and angle.
(2) If a target moves only to the left or right, and not up or down on the screen, then its speed is identical, but it is pointing higher or lower.

(3) If it moves straight up or down the screen, then it is pointing exactly the same as you but is faster or slower respectively.
(4) If it moves diagonally, then both course and speed are slightly different.
We now give some numerical examples of these using targets from Demo 16, but it will be easy to make up your own examples with the Set Targets option to make further studies. You can make remarkably precise evaluations of relative performance using radar -- more accurate and much faster than can be made by even seasoned experts who must rely on visual evaluations or ones made using a hand bearing compass.

Demo 16 pictures 6 vessels (you, A, are one of them) sailing to weather, all on port tack with wind at about 315.
Start Demo 16, change range to 3 miles, turn on range rings, and start again. You can use time factor of 30 for part of this, and later slow down for other tests. Watch the targets for 12 minutes or so on radar clock time, then pause it. Plot must be on continuous.
Already you can see that boats B and C are moving at very nearly the same speed as you but have different courses made good relative to you. B is knocked (course more downwind) and C is lifted (course more upwind) relative to your course.

D, E, and F, are not as clear so far, but there is already an indication of what is going on. Can you see it? We will come back to them.
Now how much is C lifted over us? Use a portable range scale to measure the length of the trail. This is how much it has come to weather on us. It is roughly 0.15 miles (measure carefully, use VRM method if needed -- from far end of the gray to closest end of the green). Our speed is 7.0 knots, so in 12 minutes we moved 1.4 miles. You can plot a right triangle with sides of 0.15 and 1.4 and measure the angle, or use trig. Angle = arctan (0.15/1.4) = 6°. See Trig Definitions. Since B has slipped the same amount to leeward, we have to make our first guess that C is sailing some 6° higher than us, and B is some 6° lower. This we found in 12 minutes. If we run longer we can be more precise. (The correct answer is 5°.) The best trained eye will not spot that angle in 12 minutes for vessels several miles apart. Also note with the EBL, that the bearing to B and C only changed about about 3° during this period, and that would be very difficult to detect with even the best digital bearing compass (a KVH Datascope), and then you would have to make assumptions about thier speeds to make any further evaluations.

Now let's run longer to see what is going on with the others. Run till 21 minutes, or better still, just start over and run till 12:21 on the clock. Then we can clearly see that D is slightly falling behind and E is slightly gaining on us. It is still difficult to estimate how much --

which shows already that they are not much different -- but my best estimate is 0.05 miles for the length of the trails, and again both are about the same. This means that in 21 minutes, one moved 0.05 miles farther, so speed difference = (0.05 / 21) x 60 = 0.14 knots. E is faster by about 0.14 knots and D is slower by about that much.

Making a rough guess about F at this point we would have to conclude that it is pointed higher than us, but not as much as C is (the left component of its trail is shorter than that of C), and it appears that is it moving ahead, but not quite as fast as E is, so we conclude a few degrees higher and about a tenth or so faster, which is indeed the case. See Set Targets. Normal procedure when racing is to plot, figure what is going on, write it down, then start plot again. If you don't keep restarting the plot you will not detect changes in performance. Also since it is easier to analyze as shown above when on the same tack, generally you want to start a plot as soon as either one of you tacks to put you on the same tack.

I can recall numerous examples of how this type of analysis was a tremendous advantage over near identical vessels without radar. In one case, for example, our competitor took a route in close to a beach (some 3 miles from us) in order to avoid adverse current where we were. But as it turned out, the wind was less there and they ended up loosing ground not gaining it. We watched this for several hours and when they did start to gain on us, we just carried our tack into the beach ourselves having nicely gained by staying offshore. Here was a case where all local knowledge called for going in right away, but the radar proved we were better off staying out for awhile.