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What is RADAR?

- Radar is an object detection system which uses radio waves to determine the range, altitude, direction, or speed of objects.
- It can be used to detect aircraft, ships, spacecraft, guided missiles, motor vehicles, weather formations, and terrain.

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Principles

- RADAR uses Electromagnetic waves (radio waves/microwaves).
- Travel at speed of light, 162,000 nm per second
- To get a more manageable number we can reduce the time interval to 1/1,000,000 of a second or 1 micro-second (*u*sec).
- Radar energy travels 328 yards in one *u*sec.

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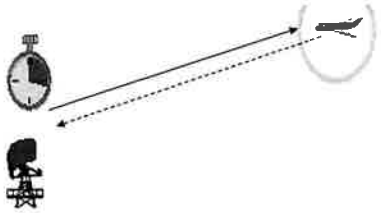
Principles

- Basic operating system relies on the echo principle



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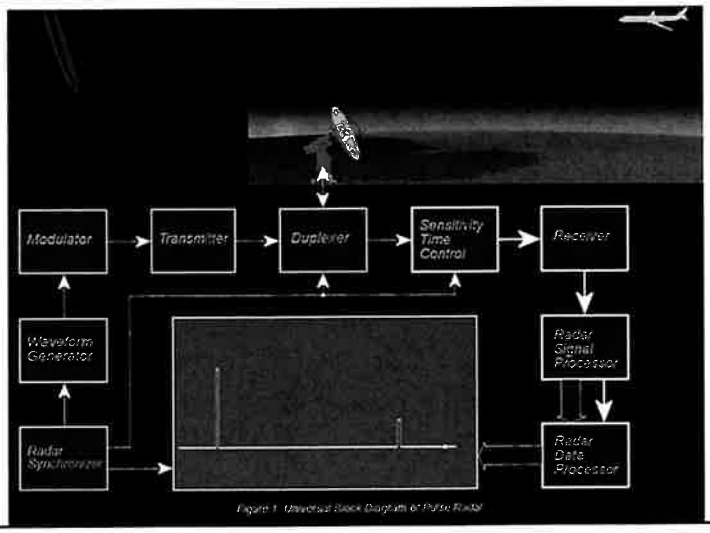
Common Components



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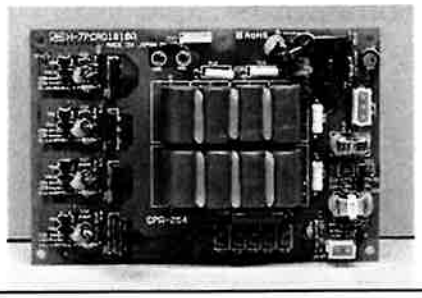
Common Components

- Modulator: converts the transmitters waveform into the carrier frequency of the transmitter.



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Common Components

- Transmitter: generates the energy of the radar pulse.
- More complex waveforms are boosted to the necessary power in a high power amplifier.

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Common Components

- Receiver
  - Amplifies the strength of weak return echoes.
  - Changes from audio to visual signals.

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Common Components

- Signal Processor
  - Amplifies and filters target echoes.
  - Suppresses unwanted noise.
  - Decides whether target is present.
  - Calculates range and velocity.

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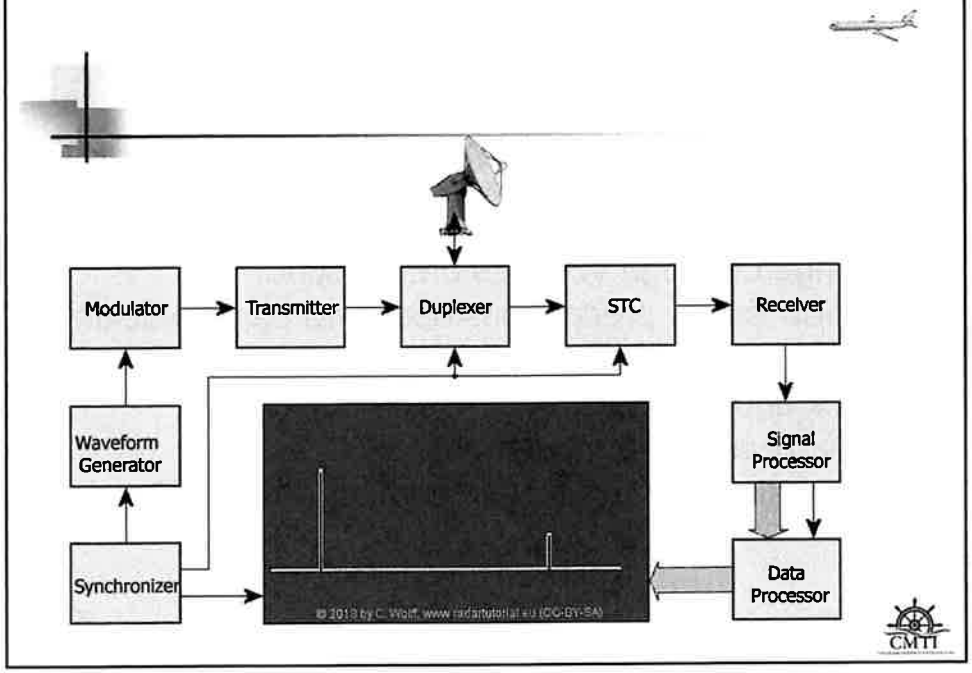

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Radiation Hazards

- Peak radar radiation is 2-30 kW but the average power is very low.
- If you are not in the center of the vertical band of radar energy, the harm to humans is very limited.
- When Pilot boats and tugs are approaching, radar should be switched to standby temporarily.

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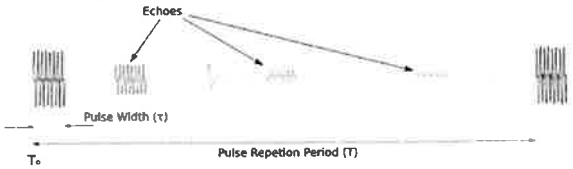
Basic Theory

- Marine RADAR is "pulse modulated."
- Rhythmic pulses with a set amount of time between (Pulse Repetition Rate).
- It is wave form radio energy.
- Resting time is the listening time to receive echoes.
- Minimum range equals ½ the length of a pulse or 164 yards (for a radar with a 1μsec pulse length).



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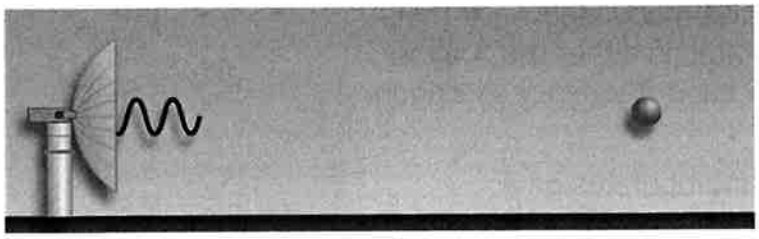

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X Band RADAR

- X band or 3 cm. Radars are suitable for inshore, close-in work.
- Best for high accuracy range and bearing.
- X band is very sensitive to clutter (atmospheric effects).
- X band is your small vessel coastwise set.

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S Band RADAR

- S band or 10 cm. Radars are the large offshore ship radar set
- S band is better for long range detection and rain penetration
- Everything about an S band set is bigger
- Larger antenna array that operates at lower RPMs (20)
- Each pulse of energy is larger so it can travel greater distances

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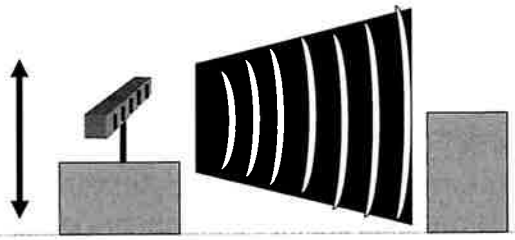
Vertical Beam Width

- To prevent loss of targets as the vessel rolls and detect nearby targets, wide vertical beam: 15 – 30 degrees



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Range Resolution

- A measure of the Radars ability to display as separate targets two contacts on the same bearing
- It is a function of pulse length
- For a one microsecond pulse rate / 328 yards; 2 microsecond / 656 yards etc....
  - Two targets on the same bearing have to be separated by ½ the pulse length, or 164 yards
  - If they are closer than 164 yards they will appear on screen as a single target

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Range Accuracy

- Main factors impacting radar range accuracy are as follows:
  - Time synchronization error
  - Pixel/spot size error
  - Pulse length error

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Bearing Accuracy

- The main factors impacting the radar bearing accuracy are as follows:
  - Bearing synchronization error
  - Beam width error:
    - echoes expansion both in right and left sides;
    - an expansion of the target if detecting the target at short range;
    - the expansion of the target when the radar is detecting the weak target at long range;

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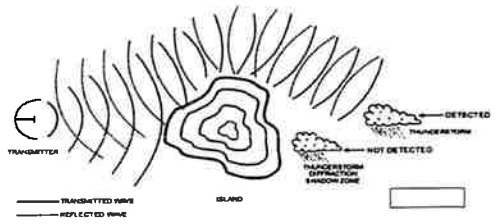
Limitations and Factors Affecting Performance

- Atmospheric conditions
  - Diffraction
    - The bending or flowing of Radar energy around an obstruction
    - The energy returns along the same path



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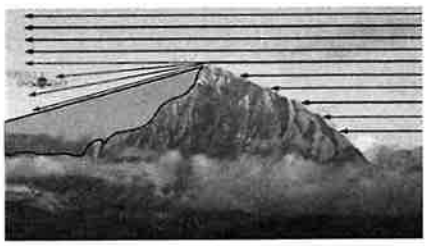
Limitations and Factors Affecting Performance

- Atmospheric conditions
  - Diffraction
    - Some illumination of the region behind the obstruction
    - Greater at lower frequencies



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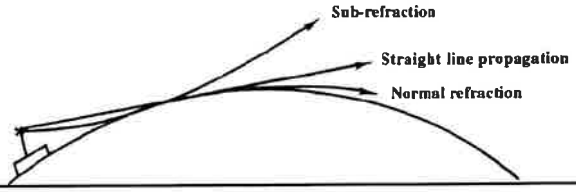
Limitations and Factors Affecting Performance

- Atmospheric conditions
  - Sub-refraction
    - A layer of cold moist air overlays a layer of warm dry air on the earths surface
    - The radar rays bend up toward the moist air
    - Decreases the maximum range that targets may be acquired at
    - Common at sunset (may need extra lookout)



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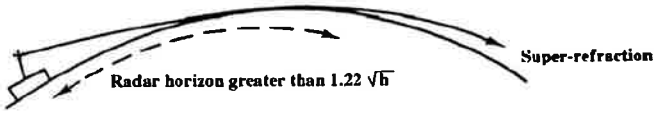
Limitations and Factors Affecting Performance

- Atmospheric conditions
  - Super-refraction
    - Occurs in calm weather, when a layer of warm, dry air is above cool moist air on the earth's surface
    - The radar energy bends down toward the moist air mass
    - This increases the range that targets may be detected
    - Common during mid-day



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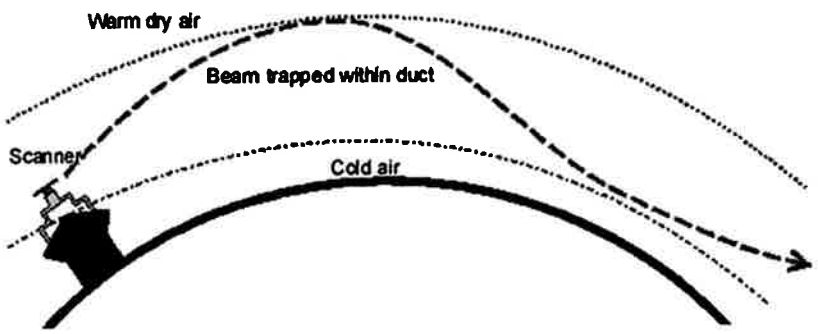
Limitations and Factors Affecting Performance

- Atmospheric conditions
  - Ducting
    - Monsoonal climate
    - Seasonal
    - Low barometric pressure
    - Atlantic coast, common in summer in North, reversed in south during Winter

CMTI

Limitations and Factors Affecting Performance



CMTI

Limitations and Factors Affecting Performance

- Sea clutters: The features of sea clutters are:
  - Clutters decrease sharply with range increase, more influencing on short range targets.
  - Sea clutters are random.
  - Clutters are strong in windward, weak in leeward.
  - Clutter range is normally 3 ~ 6 nm, 8 ~ 10 nm in rough sea.

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Limitations and Factors Affecting Performance

- Higher antenna, stronger clutters are, larger clutter range is.
- 3 cm radar is stronger than the 10 cm one.
- Clutter is strong when horizontal beam is wide.

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Target Characteristics

- Height
  - Prime importance
  - Must rise above horizon
- Size
  - Larger reflection / strong return
- Aspect
  - Nearer the angle between reflecting area and beam axis is to 90° / strong return

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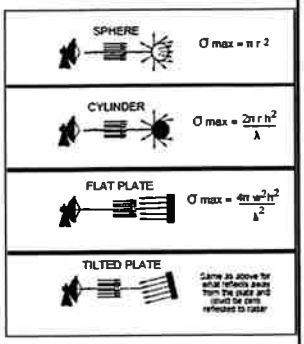
Target Characteristics

- Shape
  - Flat surface at 90° / strong echo
  - Concave surface / strong echo
  - Convex surface / scatter energy
  - Smooth conical / weak echo
  - Rough conical / may reflect echo



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Unwanted Effects

- Electronic Interference
  - Occurs near another RADAR in same frequency.
  - Greater at the longer range scales.
  - Can be distinguished from other distortions because it doesn't occur in same place on PPI.

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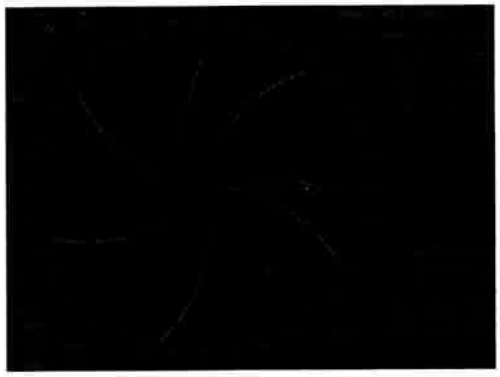
Unwanted Effects

- Electronic Interference



Vectors

- When the radar indicates a contact, the watchstander will mark them with a small pencil mark on plotting sheet at a specific time.
- 1st mark of target is labeled "R".
- Wait several minutes to mark again, typically for USCG exam, 6 minutes.
- 2nd mark of target is labeled "M".
- Your own vessel is in center of plot is labeled "E"

Vectors

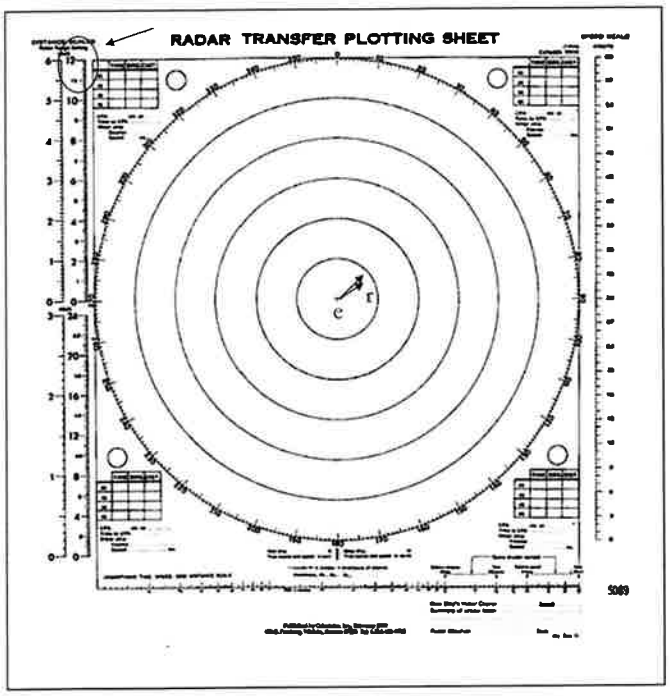
- 3 Vectors used
- "RM" Relative Motion: The RM plot is the true bearings and distances of a target from own ship.
- "ER" Is the true course and speed of own ship.
- "EM" Is the true course and speed of the target.
- You may have many target's, still same vectors but use Target #1, #2, #3.

6 Minute Rule

- 6 Minute Rule:
- Example: if travelled 2.3 NM, the speed in 6 minutes is as follows:
  - 2.3NM = 23kts
  - Move decimal one place to the right 2.3NM= 23kts
  - for 1.5NM = 15 kts

Setting Up Plotting Sheet

- Select scale
- Discuss scales on Radar Plotting Sheet.

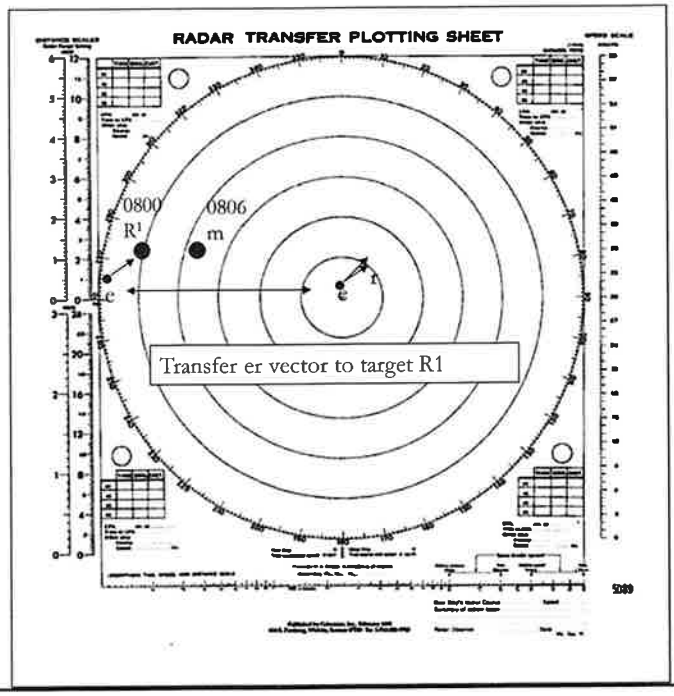


Example First Triangle

- At 0800 contact bears 280T at 10 nm
- At 0806 the same contact bears 284T at 7.5 nm.
- Find:
  - Direction of Relative Motion (DRM)
  - Speed of Relative Motion (SRM)
  - Closest Point of Approach (CPA)
  - Time to CPA
  - Bearing at CPA
  - Target's Course
  - Target's Speed
  - Rules of the Road situation

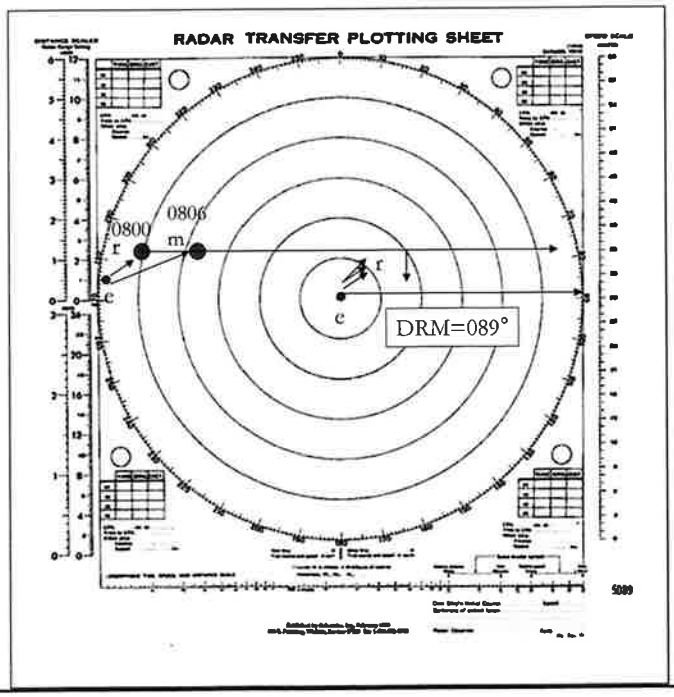
VECTORS

- Transfer ER in center to R^1
  - Line up your course and parallel it to your "R" mark.
  - Draw a line in opposite direction of "R".
  - Line will be as long as your speed in 6 minutes.
  - Be sure to check your final result.
  - E towards R should represent your course, not the reciprocal.



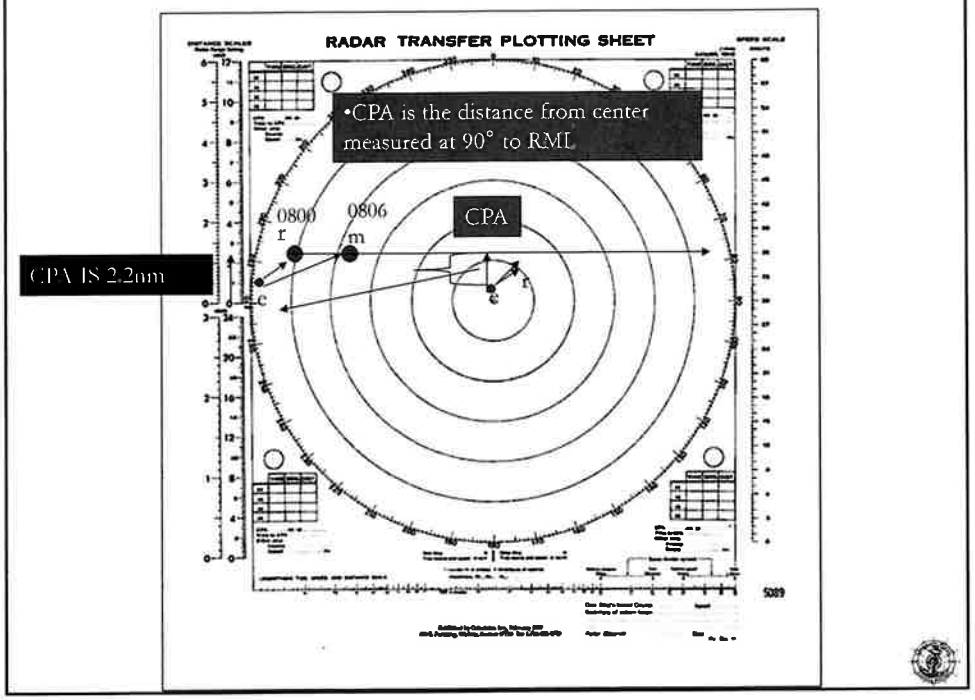
VECTORS

- RM = Relative Motion
  - Determine the DRM
  - Direction of Relative Motion (DRM) is = to the direction of the RML transferred to the center.



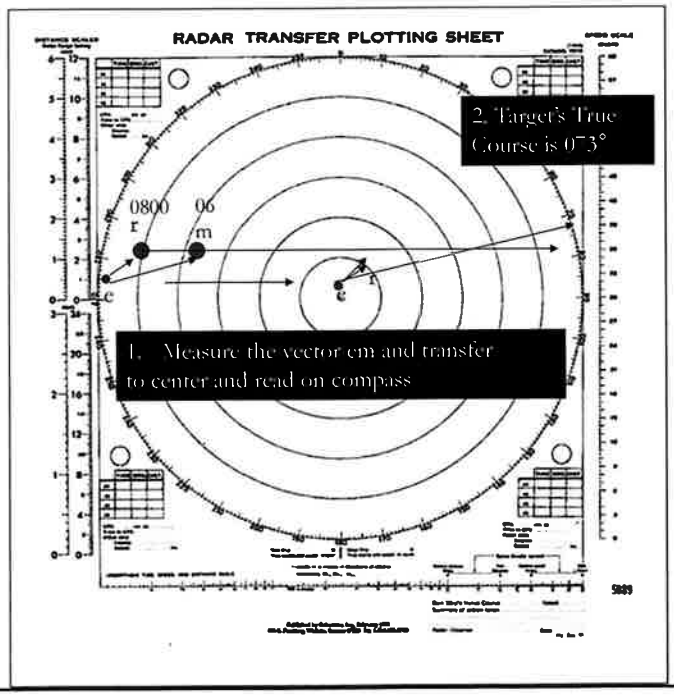
First Triangle

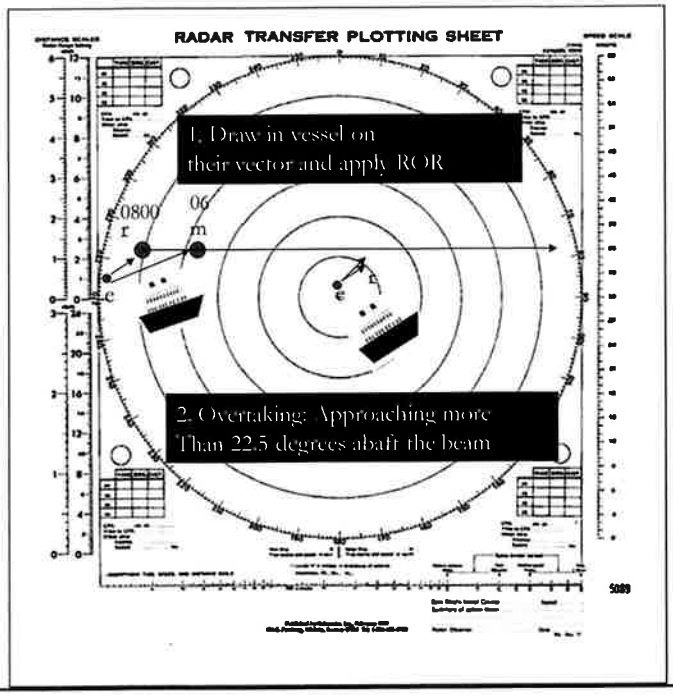
- Determine CPA, TCPA, BCPA



First Triangle

- Determine Target's True Course and Speed
  - Remember E to M is them (target)





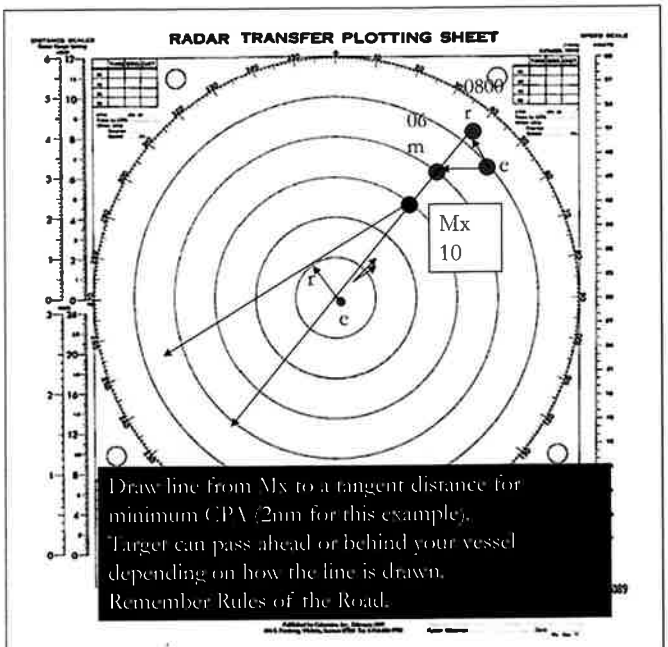
- Note to instructor: Use plotting sheet on next slide to give examples of first triangle situations.
- Complete exercises 8-11 in workbook.

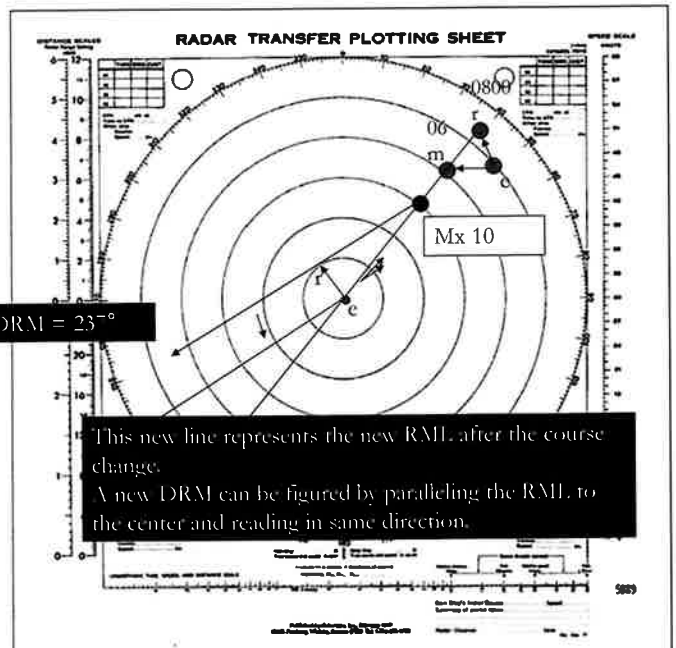
Second Triangle

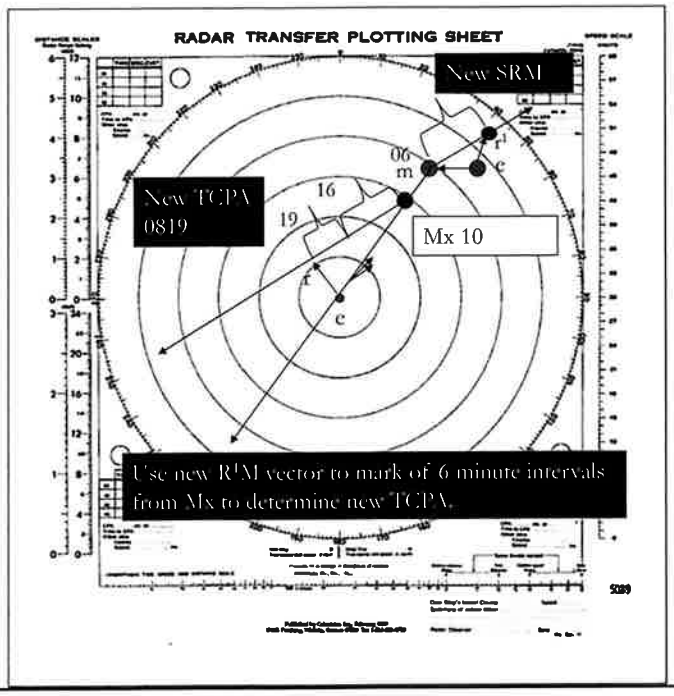
- Involves changing course or speed to avoid collision
- Need to determine:
  - Time of course change
  - New DRM
  - New Course
  - New TCPA

Second Triangle

- Example:
- Plot yourself in the center of the sheet
  - Plot your course (330°)
  - Your speed 15kts
- At 0800 contact bears 040T at 10.5 nm
- At 0806 contact bears 040T at 8 nm.


RADAR TRANSFER PLOTTING SHEET
0800
06
r
m
c
Mx
10
r
c
Draw line from Mx to a tangent distance for minimum CPA (2nm for this example).
Target can pass ahead or behind your vessel depending on how the line is drawn.
Remember Rules of the Road.


RADAR TRANSFER PLOTTING SHEET
0800
06
r
m
c
Mx 10
r
c
New DRM = 23⁻°
This new line represents the new RML after the course change.
A new DRM can be figured by paralleling the RML to the center and reading in same direction.



- Note to instructor: Use plotting sheet on next slide to give examples of second triangle situations.
- Complete exercises 7-10 in workbook.

6-55. RAPID RADAR PLOTTING SUMMARY. In the preceding pages you have been given information on how to apply Rapid Radar Plotting techniques. In the "Abbreviated Memory Sheet" below, the technique is presented using somewhat different symbols. The system, however, is unchanged. This presentation is used only for "six-minute triangles", i.e. six minutes between "r" and "m".

ABBREVIATED MEMORY SHEET
(for radar plotting a six-minute triangle)
FIRST TRIANGLE

TC ↑

1. Plot your own True Course(TC) by a dotted line with arrow.

r

2. Plot "r". "r" is a point that represents the range, bearing and time of target when it is first picked up.

TTC ↓

3. Transfer your own TC to point "r". From "r", draw a line in opposite direction of the arrow. On this line will be point "e".

e

4. Determine point "e". "e" comes from our " own ship" speed! Whatever own ship's speed is, take .1 (one-tenth) of that speed. The resulting figure is the distance, the length of "er", or how far the point "e" is from point "r" in six (6) minutes time, or as shown graphically in the six (6) minute triangle. $D = S \times .1$

m

5. Plot point "m". "m" is the point representing range, bearing and time six (6) minutes after point "r" if you are working a six (6) minute triangle of the same target.

RML

CD CPA

6. Connect points "r" and "m" and continue the line past the center. Label this line RML, which stands for "Relative Motion Line".

   The Crossing Distance (CD) point is where the RML line intersects OTC, Own True Course. The Closest Point of Approach, (CPA) is where the RML is at a right angle distance from "own ship" at center.

7. Close the triangle. Each side of the triangle is a friend that wants to give you information you need! Each side contains information such as course (direction-as related to the center), speed, time, distance (length).
   Side: "er"=OTC and OTS, Our True Course and Our True Speed
   "em"=TTC and TTS, Them's True Course and Them's True Speed
   "rm"=rC and rS, relative Course and relative Speed

8. To find "speed" on any side of triangle, measure the length of the side. This gives " distance". Multiply this distance by 10 (in a 6-minute triangle). The resulting figure is the nautical miles per hour (knots)figure .
   $S = D \times 10$

SECOND TRIANGLE

M_x

9. On RML, locate the point of execution," M_x". This point can be located in terms of time, or in terms of range. If time, measure from "r" towards center; if range, measure from the center towards the target on RML

NCPA

10. Describe (draw) an arc for the desired new CPA (Closest Point of Approach).

RML_1

11. Draw a line from M_x tangent to the CPA arc. Label it RML_1. RML_1 is drawn as crossing own true course if the Rules of the Road require the target to pass ahead of" own ship". Own ship is always at the center. Or, RML_1 is drawn astern of own ship if the Rules of the Road require the target to pass astern. Visualize the situation in a practical problem. Usually paper problems state whether the crossing is ahead or astern.

$ARML_1$

12. Advance the RML_1 line to point "m". From point "m" draw a line parallel - and away from the center. Label it $ARML_1$.

er
r_1
er_1

13. Describe an arc using "er" as its radius with point "e" as center. This arc will cross $ARML_1$ in two (2) places.
    The point of intersection farthest (usually) from "m" gives point "r_1". Draw line "er_1". "er_1" is the new course with no change of speed.

14. If a change of speed is desired with no change of course, then note that our "r_1" becomes the point of intersection of line "er" and line "$ARML_1$". Thus, the new speed will be the length of line "er_1" multiplied by 10-in a 6-minute triangle.

Chesapeake Marine Training Institute, Inc.
Radar Observer
Practice Plot

5. What is the TCPA of target #1?

A. 0730
B. 0715
C. 0720
D. 0706

6. What is the TCPA of target #2?

A. 0740
B. 0810
C. 0758
D. 0748

7. The Rules of the Road situation with target #1 is _____.

A. Meeting
B. Overtaking
C. Crossing
D. None of the above

ANSWERS

1.D 2.A 3.C 4.A
5.A 6.C 7.B

Chesapeake Marine Training Institute, Inc.
Radar Observer
Practice Plot

5. What is the BCPA?

A. 245°T
B. Collision
C. 065°T
D. 359°T

6. What is the target's course?

A. 359°T
B. 040°T
C. 180°T
D. 330°T

7. What is the true speed of the target?

A. 24 K
B. 15 K
C. 18 K
D. 10 K

8. What type of Rules of the Road situation is this?

A. Crossing
B. Meeting
C. Overtaking
D. None of the above

9. Your vessel is the _____vessel.

A. Give-way
B. Stand-on
C. Neither give-way nor stand-on

10. At night, what navigational light(s) would you see on the other vessel?

A. Both side lights and masthead light(s)
B. Port side light and masthead light(s)
C. Stern light only
D. Starboard side light and masthead light(s)

ANSWERS
1.C 2.A 3.B 4.D
5.C 6.A 7.A 8.C
9.B 10.B

Chesapeake Marine Training Institute, Inc.
Radar Observer
Practice Plot

5. What is the true course of target #1?

   A. 180°T
   B. 264°T
   C. 088°T
   D. 000°T

6. What is the true speed of target #1?

   A. 9K
   B. 27K
   C. DIW
   D. 16K

7. What is the bearing at CPA?

   A. 192°
   B. 268°
   C. 088°
   D. 324°

8. What Rules of the Road situation exists between own ship and target #1?

   A. Crossing
   B. Meeting
   C. Overtaking
   D. None of the above

ANSWERS

1.D 2.C 3.B
4.C 5.B 6.D
7.D 8.A

Chesapeake Marine Training Institute, Inc.
Radar Observer
Practice Plot

5. What is the true course of target #1?

   A. 304°
   B. 270°
   C. 088°
   D. 000°

6. What is the true speed of target #1?

   A. 9k
   B. 35k
   C. 22k
   D. 16k

7. What is the bearing at CPA?

   A. 167°
   B. 268°
   C. 088°
   D. 324°

8. What Rules of the Road situation exists between own ship and target #1?

   A. Crossing
   B. Meeting
   C. Overtaking
   D. None of the above

9. Assuming that the contact has turned on its running lights during daylight due to inclement weather, what side light(s) might be seen at CPA?

   A. Green
   B. Red
   C. Both
   D. None

10. The vector EM represents_____.

   A. Own ship course and speed
   B. Relative Motion
   C. Target's true course and speed
   D. All of the above

ANSWERS

1.B 2.D 3.A
4.C 5.A 6.C
7.A 8.A 9 .A
10. C

6. What is the true speed of target # 2?

A. 16K
B. 8K
C. 21K
D. 32K

7. What is the true course of target #3?

A. 353°
B. 170°
C. 045°
D. 090°

8. With regard to target #3, you are:

A. The give way vessel in a overtaking situation
B. The give way vessel in a crossing situation
C. The stand on vessel in a overtaking situation
D. The stand on vessel in a crossing situation

9. What lights would you expect to see on target #3 at 0020?

A. Both port and starboard side lights
B. Port side light and masthead lights
C. Starboard side light and masthead lights
D. No lights

10. What is the SRM of target #1?

A. 16K
B. 8K
C. 21K
D. 32K

ANSWERS

1.A 2.B 3.D
4.A 5.B 6.A
7.A 8.D 9 .C
10. C

6. What is the true speed of target # 3?

A. 16K
B. 8K
C. 21K
D. 30K

7. What is the true course of target #2?

A. 353°
B. 170°
C. 055°
D. 090°

8. With regard to target #1 you are:

A. The give way vessel in a overtaking situation
B. The give way vessel in a crossing situation
C. The stand on vessel in a overtaking situation
D. The stand on vessel in a crossing situation

9. What lights would you expect to see on target #3 at CPA?

A. Both port and starboard side lights
B. Port side light and masthead lights
C. Starboard side light and masthead lights
D. Stern light

10. What is the SRM of target #2

A. 11K
B. 8K
C. 21K
D. 32K

ANSWERS

1.C 2.D 3.B
4.A 5.A 6.D
7.C 8.B 9 .D
10. A

When the target is 6 NM away, change course to allow the contact to pass 3.0 NM astern.

6. What time is your course change?

   A. 2051
   B. 1946
   C. 2029
   D. 2010

7. What is your new course?

   A. 225°T
   B. 210°T
   C. 180°T
   D. 246°T

8. What is the New TCPA?

   A. 2036
   B. 2059
   C. 2044
   D. 1940

9. What is the target's true course?

   A. 160°T
   B. 202°T
   C. 180°T
   D. 252°T

10. What is the target's true speed?

    A. 12.0 K
    B. 4.0 K
    C. 8.0 K
    D. 16.0 K

ANSWERS

1. D 2. A 3. A 4. D
5. C 6. D 7. A 8. C
9. B 10. C

6. What is the true speed of target # 3?

A. 16K
B. 8K
C. 22K
D. 30K

7. What is the true course of target #3?

A. 353°
B. 170°
C. 055°
D. 247°

8. With regard to target #2 you are:

A. The give way vessel in a overtaking situation
B. The give way vessel in a crossing situation
C. The stand on vessel in a overtaking situation
D. The stand on vessel in a crossing situation

9. When the range of target #2 is 3 miles, maneuver in accordance with the rules of the road for target #2 to have a CPA of 1 NM, what would be your new course?

A. 354°
B. 190°
C. 035°
D. 249°

10. What is the NDRM of target #2?

A. 212°
B. 160°
C. 025°
D. 147°

ANSWERS

1.D 2.A 3.C
4.B 5.B 6.C
7.D 8.B 9 .A
10. A

6. What is the true speed of target # 3?

A. 16K
B. 8K
C. 20K
D. 30K

7. What is the SRM of target #1?

A. 21K
B. 8K
C. 28K
D. 30K

8. When the range of target #2 is 4NM, maneuver in accordance with the Rules of the Road for target #2 to have a 1NM CPA, your new course would be:

A. 340°
B. 256°
C. 000°
D. 060°

9. What is your new DRM?

A. 301°
B. 214°
C. 000°
D. 040°

10. What time is Mx?

A. 0018
B. 0012
C. 0026
D. 0030

ANSWERS

1.D 2.B 3.A
4.B 5.A 6.C
7.A 8.C 9 .B
10. A