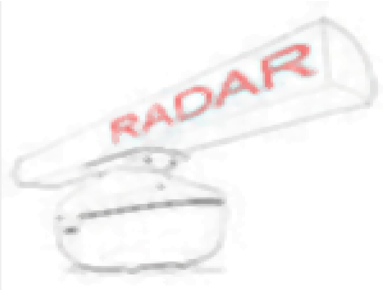
Radiolocation 5

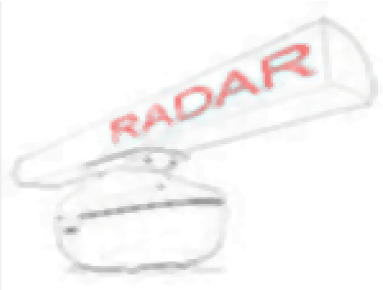
Distortion and clutter of the radar picture

Radar measurements, measurement accuracy



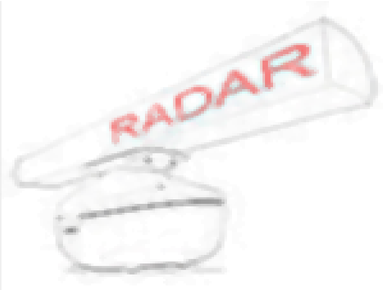
Echoes identification

- A number of factors affect the correctness of the identifying echoes process (radar image interpretation), the most important of which are:
  - technical parameters of the radar and reflective properties of the objects,
  - hydrometeorological conditions,
  - conditions of propagation of radio waves.
- These factors make the radar image looks different then the situation shown on the navigation map. Differences between the radiolocation map and the classic map result from:
  - distortion of the radar picture,
  - the occurrence of unwanted echoes (clutter),
  - false echoes



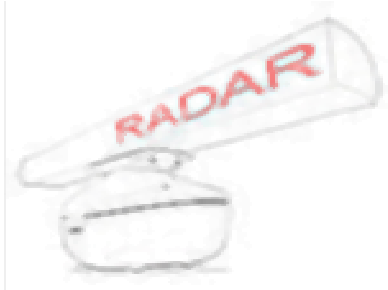
Target enhancement

- Some targets like aids of navigation, boats (built of wood, glass fiber etc.) have poor radar responses, but to provide a safety of navigation, it is necessary
  - to detect them in sufficient distance, and
  - to identify them in a proper way.
- There are two methods of target enhancement:
  - Passive
  - Active



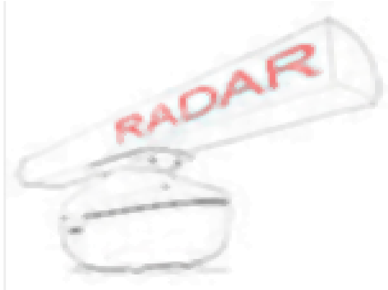
Passive target enhancement

- They consist in minimizing the dispersion of energy in undesirable directions, which means to reflect of as much of the radiation as possible back towards the radar antenna.
- Radar reflector

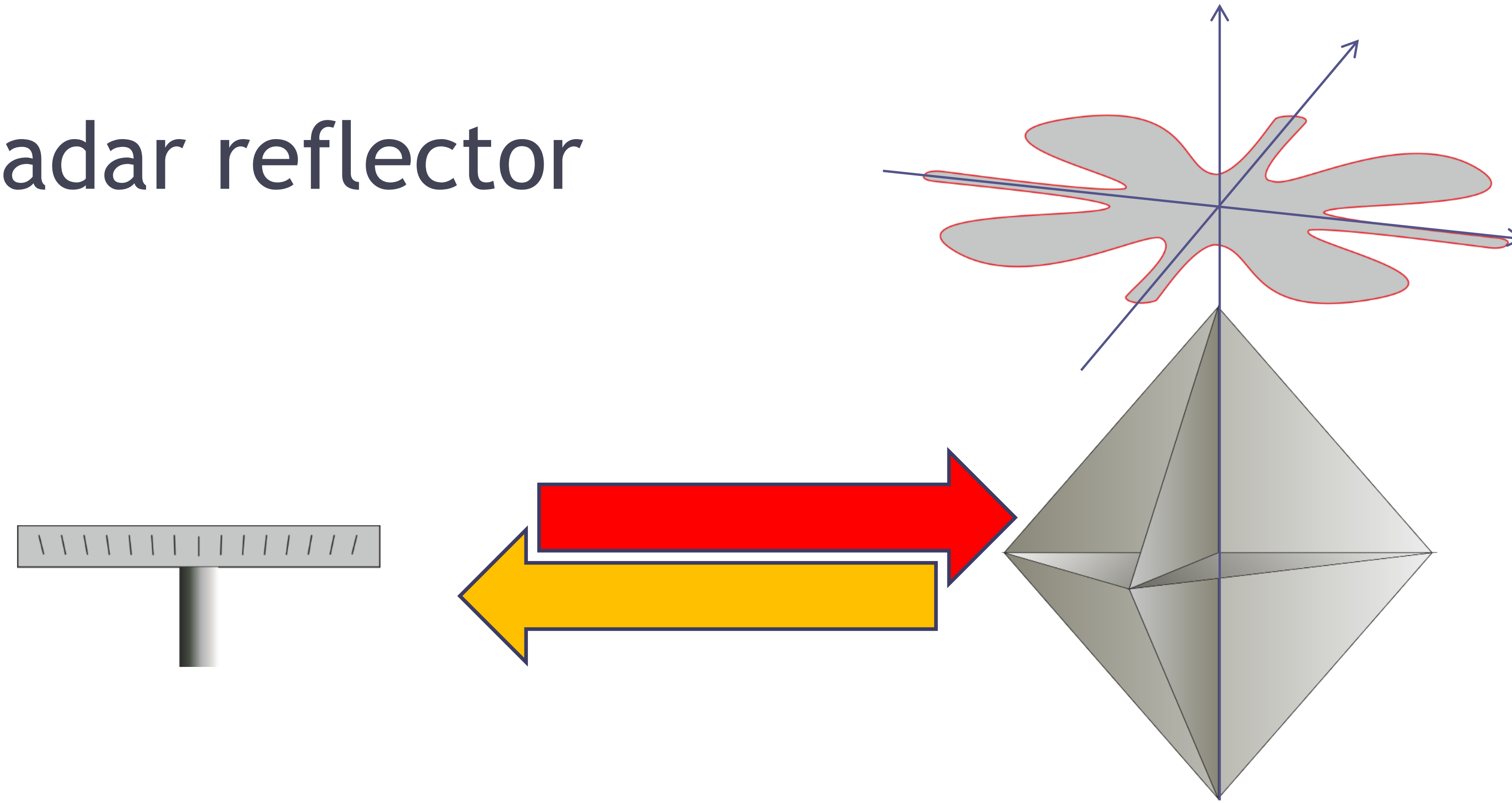


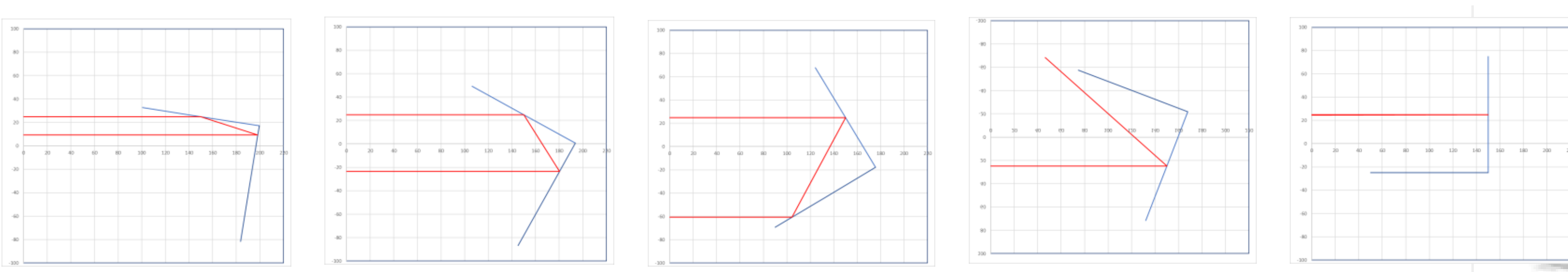
Radar reflector

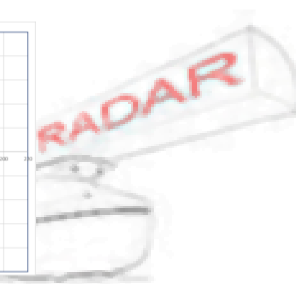
- RESOLUTION MSC.164(78) (adopted on 17 May 2004).
- The radar reflector should be mounted at a minimum height of 4 m above water level and provide a performance measured in square meters of RCS (radar cross section) of at least:
  - 7.5 m^2 in X-band, and
  - 0.5 m^2 in S-band



Radar reflector





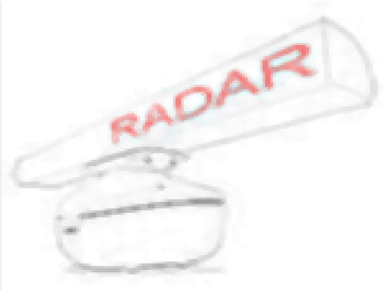


Active target enhancement

- Racon
- Ramark
- Flara
- SART

Racon

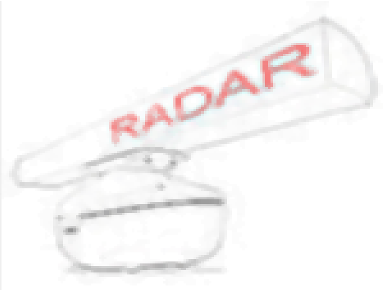
- radar transponder beacon - radar response station.
- It is a radio station transmitting radiowaves, with frequencies in the range corresponding to frequencies of marine navigational radars, after activation by the pulse of the radar. The signal sent in response is longer and has more energy than the radar pulse.
- As a result, on the screen, in the direction and distance of a possible echo from a buoy or a beacon equipped with a racon, the observer will notice, behind the real echo, an artificial echo with an angular dimension of 1° - 2° and a radial dimension 1.5 - 3 Mm.
- The racon signal transmission can be interrupted to obtain the desired object-specific appearance. For example, Morse coding is used, this is of particular importance when identifying many racons on a given water area.
- Currently applied racons usually work in the X band.



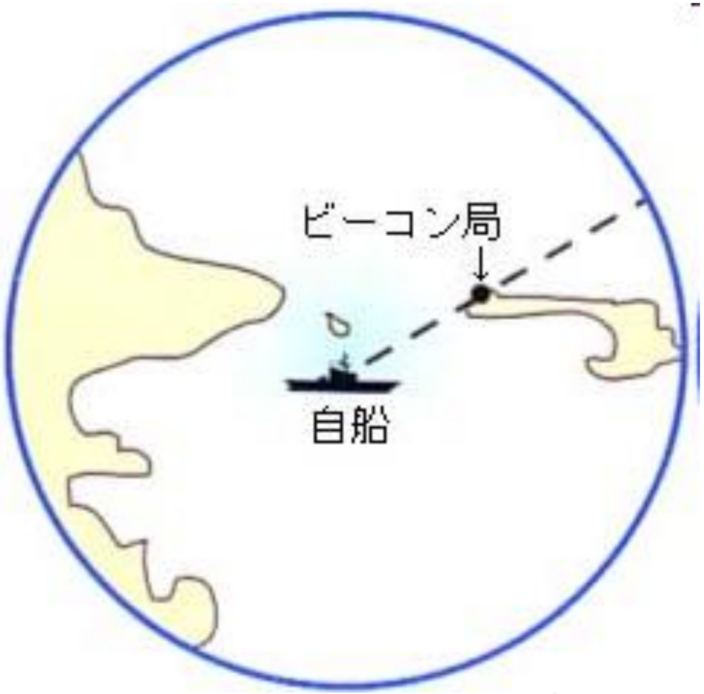
Racon

Ramark

- Radar station with continuous transmission.
- In contrast to the racon, the ramark continuously sends a series of pulses with frequencies corresponding to the radio waves of marine navigational radars without prior activation by a radar pulse.
- The pulse frequencies in the 9200-9500MHz range are changed so fast that, as a result, a continuous echo will be created on the screen of any radar.
- The appearance of the ramark signal is similarly coded as the racon echo but does not contain distance information.
- Detailed information on racons and *ramarkas* are provided in the second volume of ALRS.

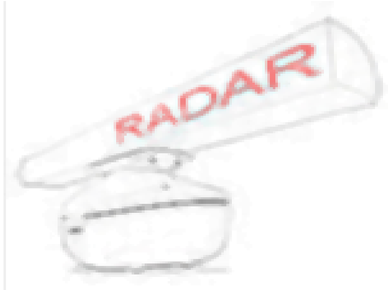


Ramark



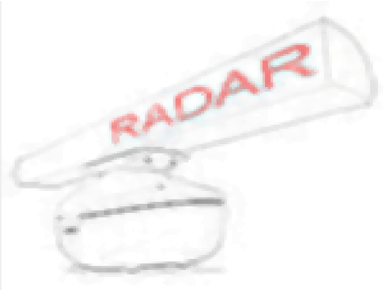
Radar flare

- In marine rescue, radar flares can be used, just like light signaling rockets.
- The flare is fired from a pistol at a height of approx. 400 m, they emit a strong light signal and ejects a large number of electric dipoles reflecting well the 3 cm length radio wave.
- The maximum detection range of such a cloud of dipoles is about 12 Nm and lasts about 15 minutes.

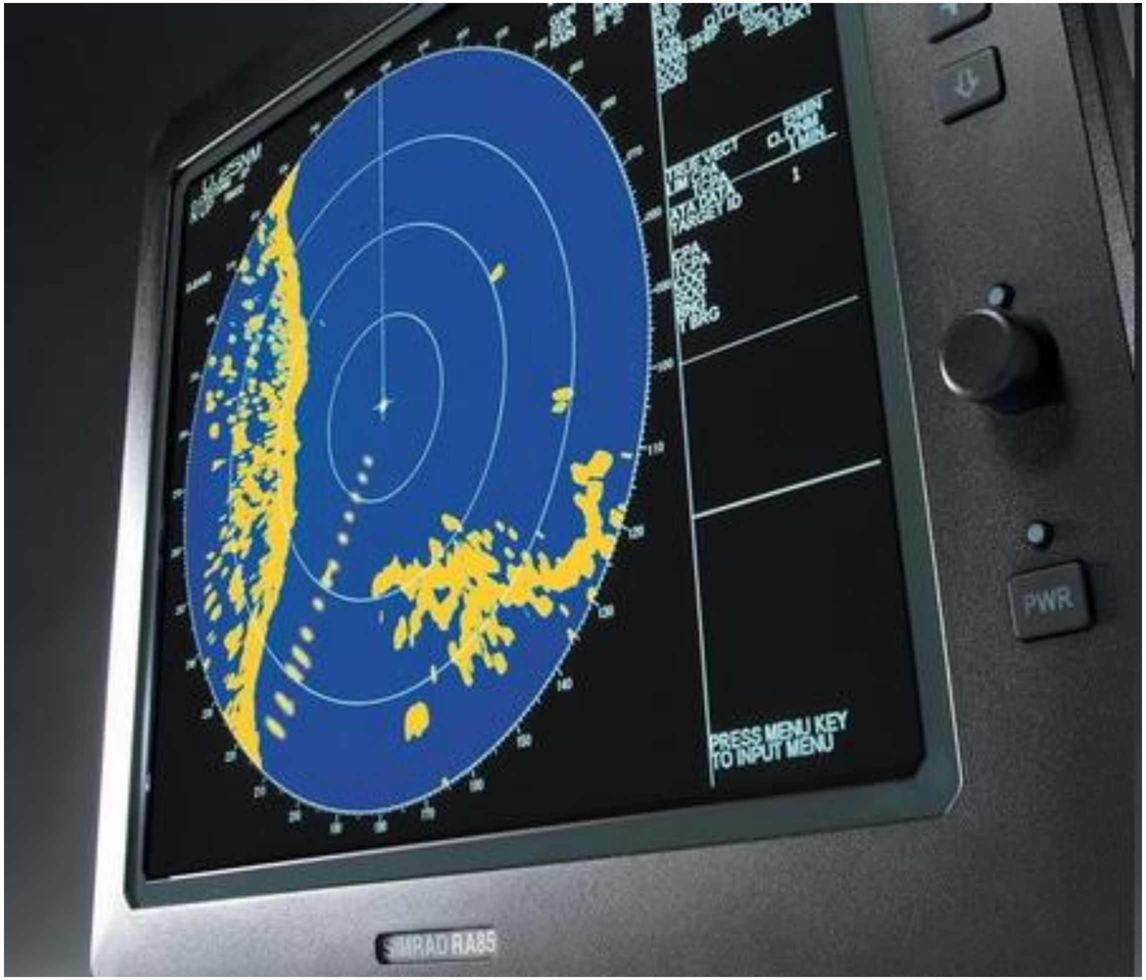


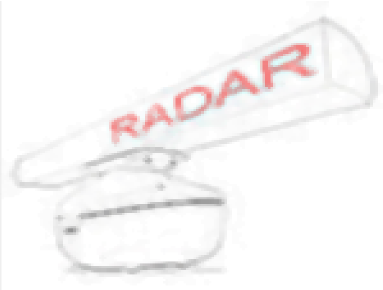
SART

- Search and Rescue Transponder – racon on lifeboats and liferafts
- These stations operate in the standard X band (9.2-9.5 GHz) of marine navigational radars. When activated by radar pulse they send a signal visible on the screen in the form of 12 "dots".
- The racon signal always appears behind the object in its distance and angle, therefore it points to the object requiring help.
- SARTs are additionally equipped with a visual or audible signaling indicator, which at the moment of receiving a radar signal informs the survivors about the presence of a radar-using vessel, which raising their morale.



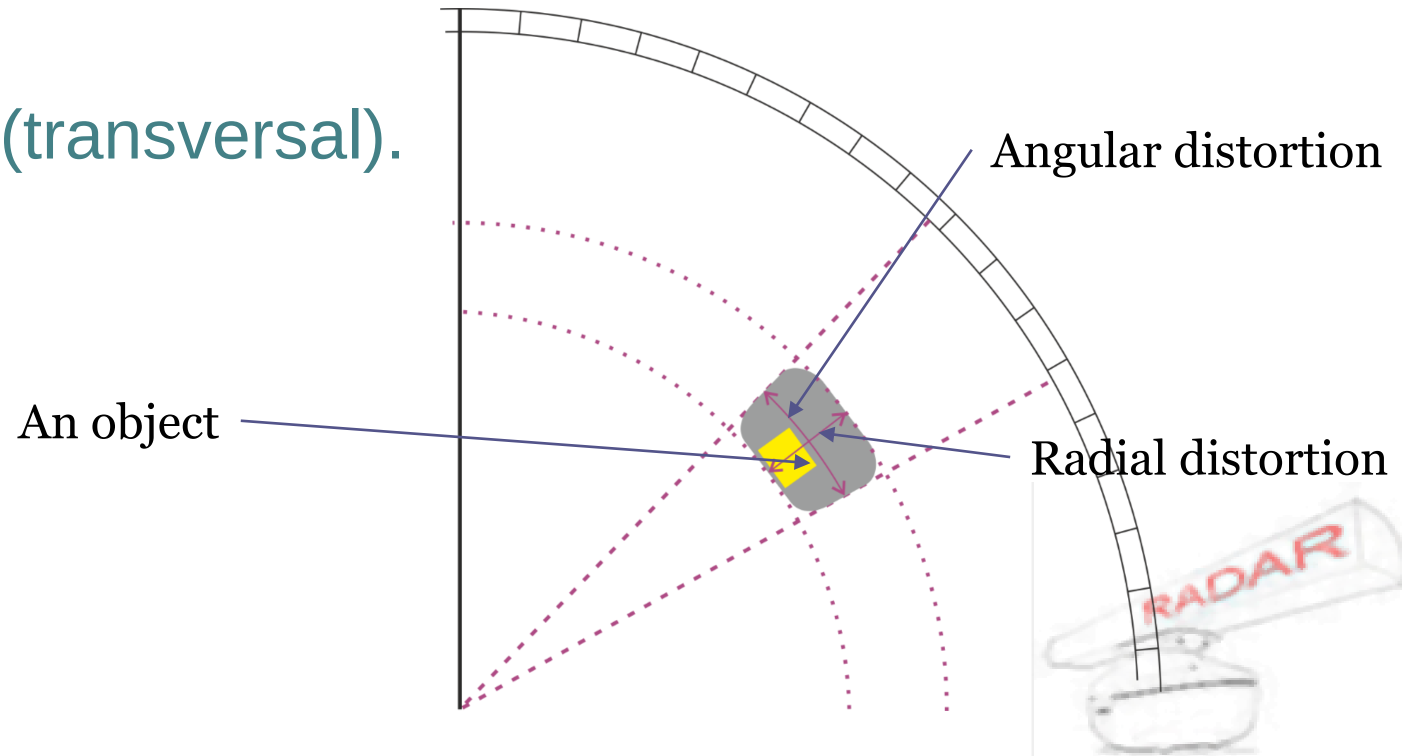
SART





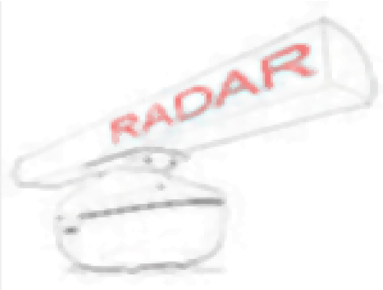
Distortions of the radar image

- The basic distortions of the radar image are the distortion of the echo dimensions:
  - radial,
  - angular (transversal).



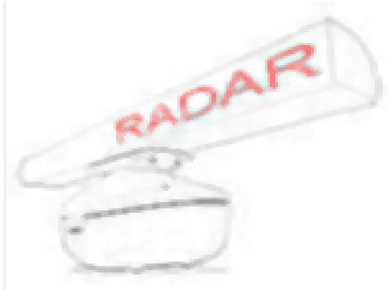
Radial distortions of an echo

- The length of the echo of the point size object, measured along the radius of the screen, depends on
  - the duration of the pulse (half the length of the pulse,) and
  - diameter of light spot (screen resolution, number of memory cells).
- Therefore the radial distortion of the echo depends on the radar range and screen diameter (number of memory cells) and increases as
  - the range scale increases, or
  - the screen diameter decreases.

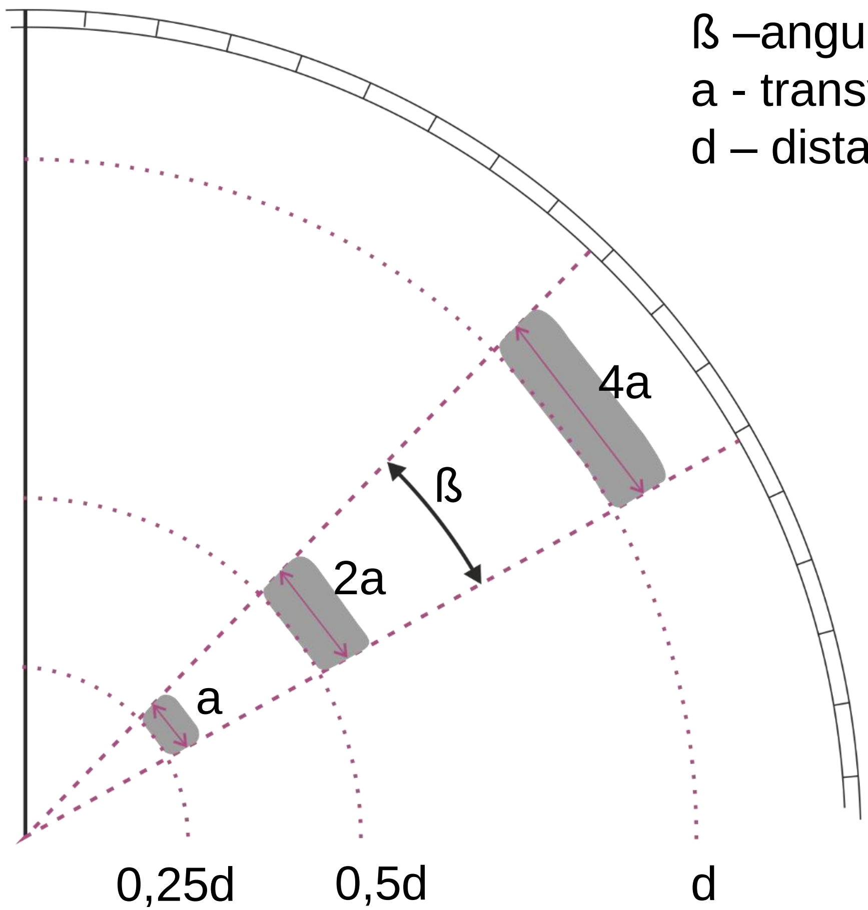


Angular distortion of an echo

- Factors affecting the angular width of the echo on the radar screen are:
  - the width of the radiation horizontal characteristic (beam width) of the antenna,
  - the signal amplification in the receiver,
  - radar cross section
  - distance to the object being detected



Angular distortion of an echo



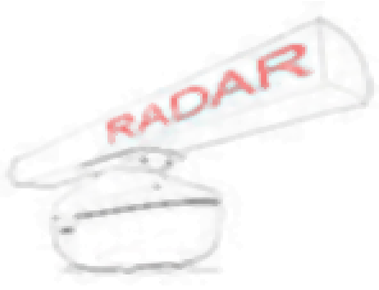
ß –angular dimension of the echo
a - transverse dimension [m]
d – distance to the center of the display

General conclusions regarding distortion of an echo

- the echo shape on the screen is similar to the object shape only when the angular dimension of the observed object is many times greater than the width of the horizontal characteristic of the antenna, and the radial length of the object is many times greater than the length of the pulse,
- On small ranges of observation, the shape of the echo depends primarily on the pulse length, on the width of the beam and on the signal gain value.
- As the echo moves towards the edge of the screen, the shape of the echo changes as a result of the echo extension.
- By changing the general gain, you can change the width of the echo.
- The width of the echo depends on the equivalent area of reflection and distance to the object.
- Object identification is easier on smaller ranges of observation.

Clutter of the radar picture

- Clutter - all unwanted echoes which are generated by existing matter (rain, waves, electrons movement.
- The basic clutter of the radar picture are:
  - thermal noise,
  - echoes from sea waves,
  - echoes from atmospheric precipitation.



Thermal noise of a receiver

- The thermal noise is caused by thermal movements of electrons in the elements of the receiver (mainly the IF amplifier)
- When the high gain level is set the thermal noise in the input circuits of the receiver appears on the screen as a background in form of randomly speckled spots.
- If amplified too much, they blur the image and make it impossible to detect weak echoes.

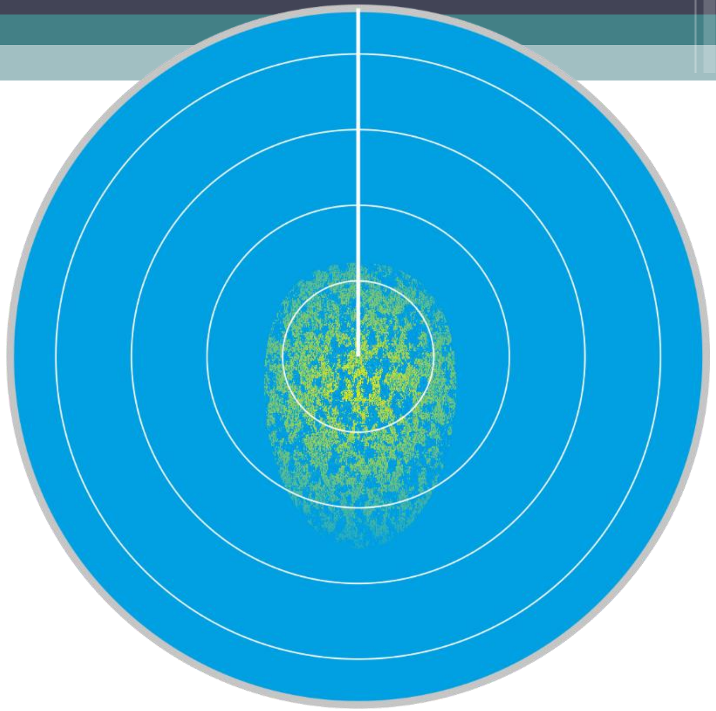
Thermal noise of a receiver

- Easy to identify - spots which are much smaller than real echoes; they appear randomly on the entire screen.
- The occurrence of own noise requires correct selection of the gain level.
- Criterion for correctly set of gain - a level slightly lower than that at which thermal noise appears (the beginning of appearing of thermal noise).

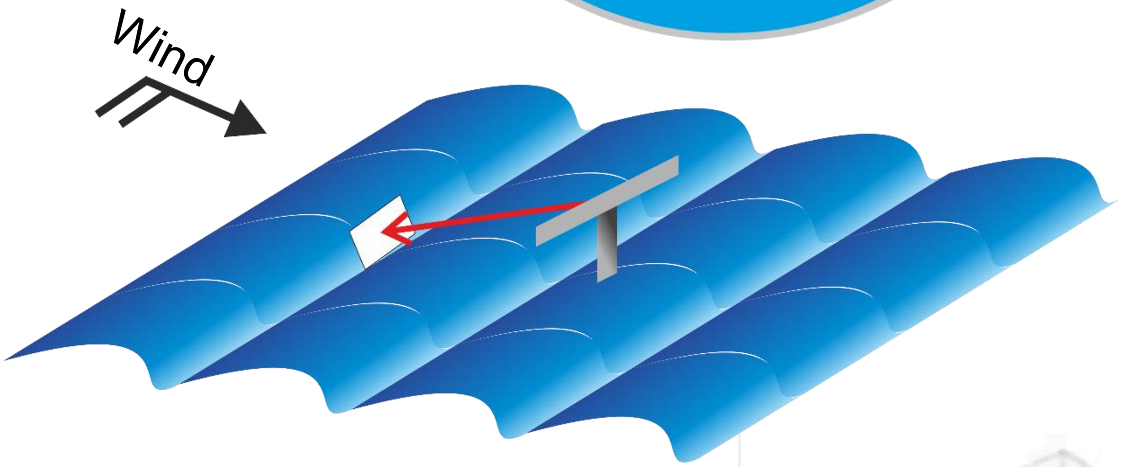
Sea clutter echoes

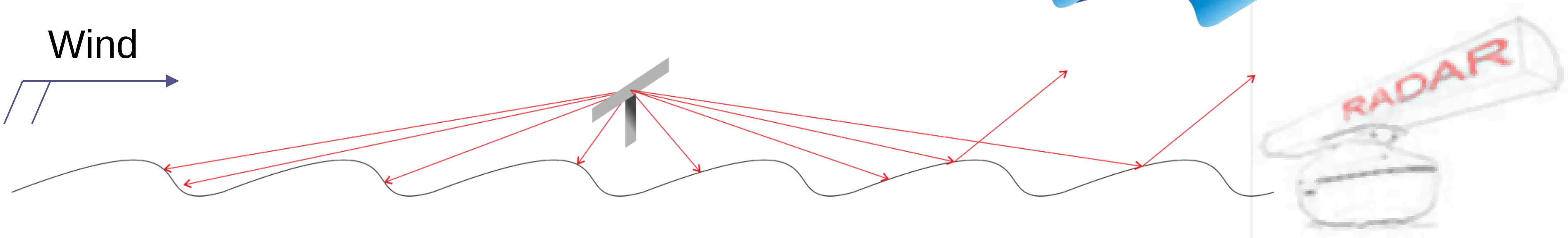
- They are generated by the reflection of the pulses from those parts of the waves that are perpendicular to the direction of microwave propagation.
- Signals reflected from the waves resemble the thermal noise because appear in random places with a random amplitude, but have a duration depending on the length of the pulse and occur only in a certain area - close to radar antenna (own position)
- The size and range of sea clutter echoes depend on the following factors:
  - the size, type, shape and direction of the wave movement,
  - vertical characteristic of antenna,
  - height of radar antenna placement.

Sea clutter echoes



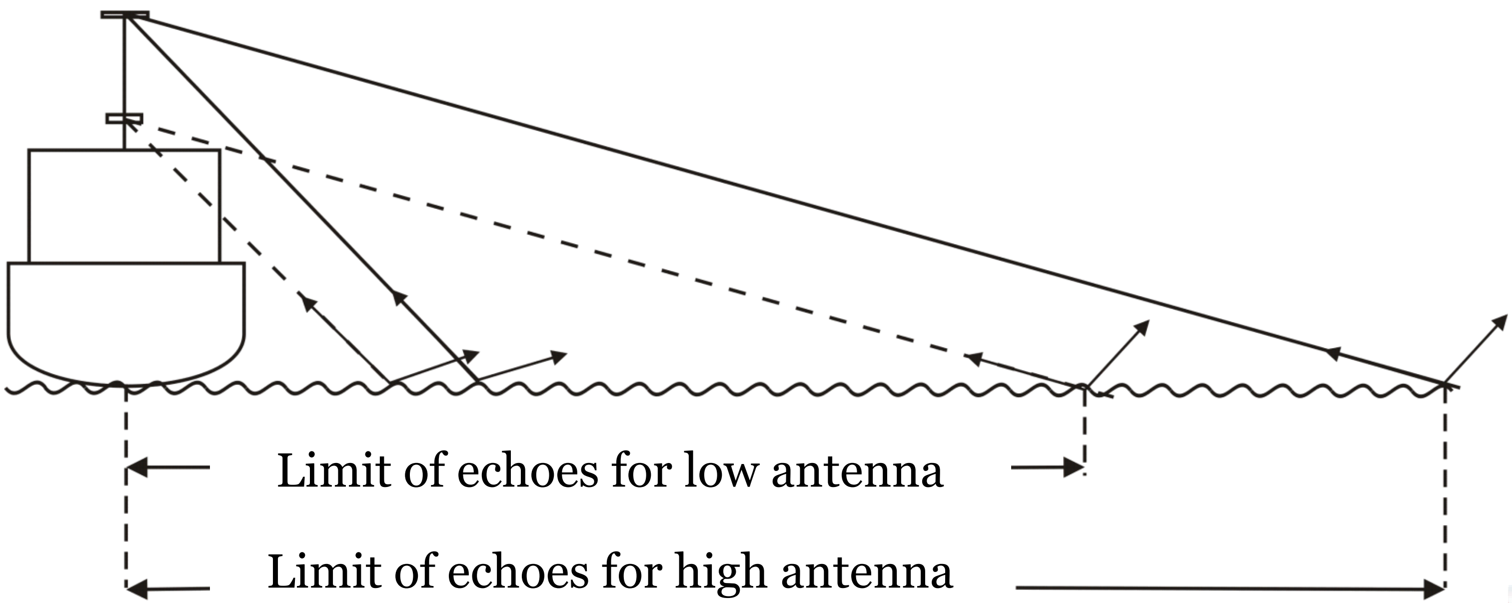
The advantage of the occurrence of sea clutter echoes is the opportunity to determine the wind direction on their basis, a feature that is particularly useful at nighttime.



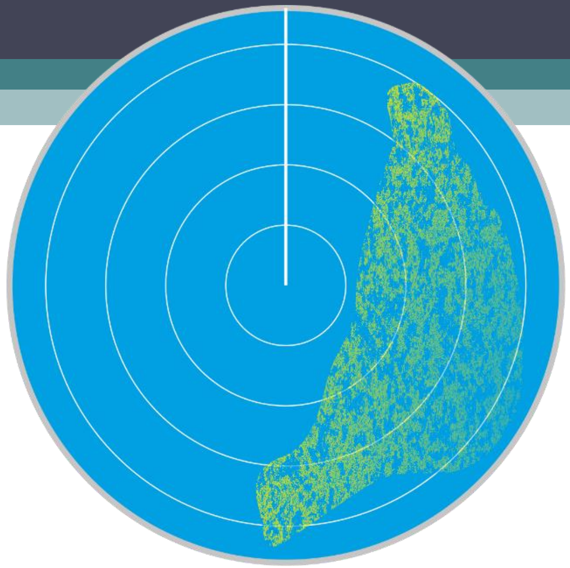


Sea clutter echoes

- Influence of the antenna height on the range of occurrence of echoes



Rain clutter echoes

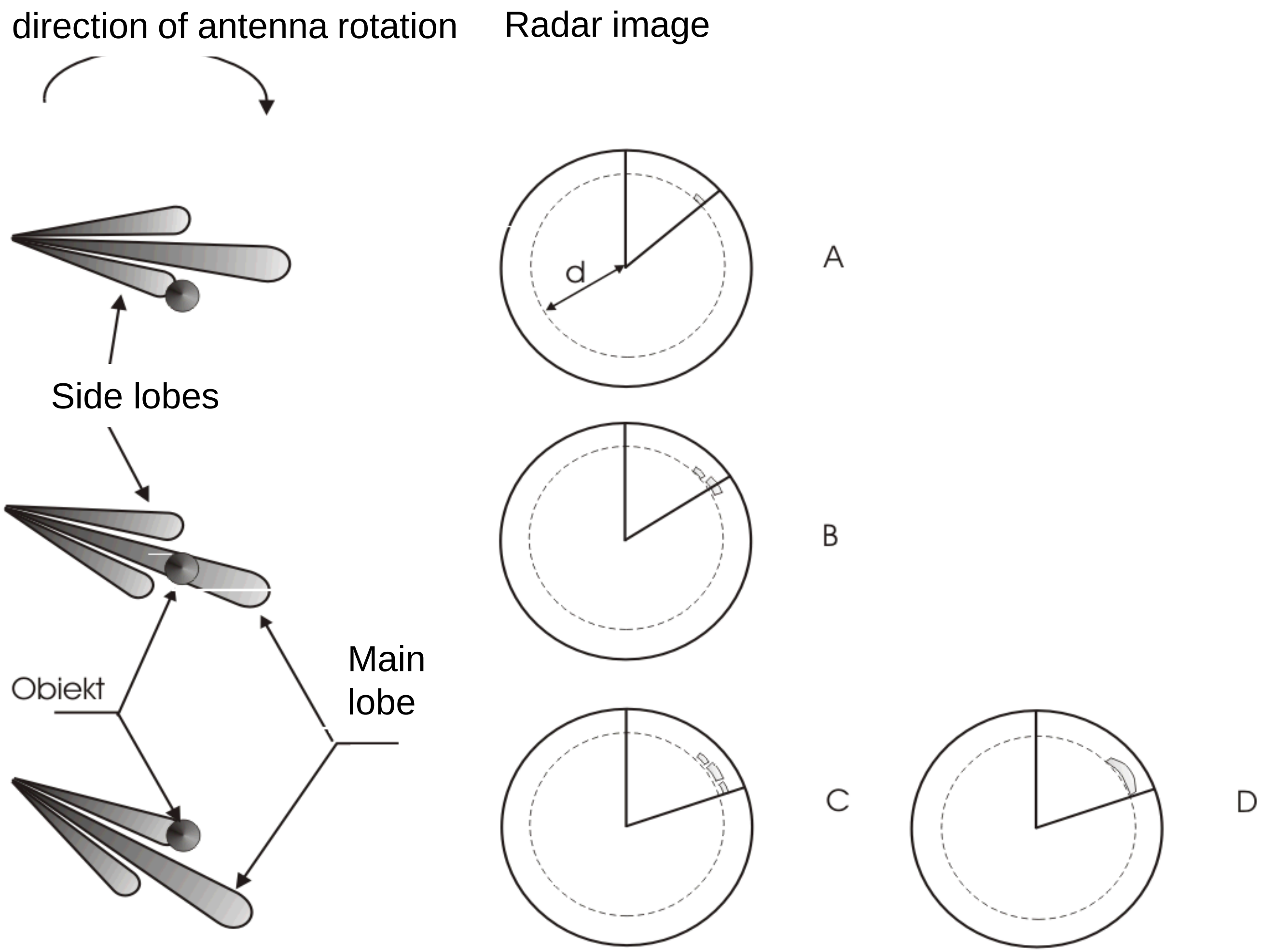


- They clutter the radar image, causing difficulties in detection and identificaton of the desired echoes, and reduce radar coverage as well.
- They are similar to the thermal noise due to randomly appearing on the radar, but the size of individual echoes depends on the length of the radar pulse, similar to the case of echoes from sea waves.
- They can occur anywhere within the operational area, and their strength depends on the type, intensity and shape of the particles of rainfall and the wavelength on which the radar operates.

False echoes

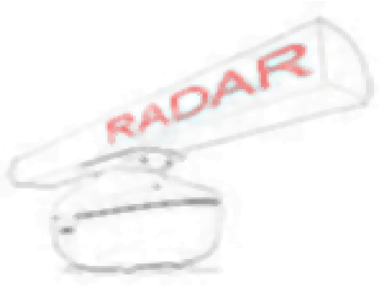
- On the radar screen except useful echoes and clutter echoes can be observed false echoes so called "ghost echoes".
- Depending on the type, these echoes can arise randomly or occur in strictly defined positions.
- Some of them can be eliminated, while some should be properly identified and be aware of their occurrence and the conditions in which they may occur.
- The false echoes can be divided as follows:
  - side lobes' effect,
  - indirect echoes,
    - internal,
    - from external object,
  - multiple echoes,
  - Second-trace echoes,
  - interference echoes

Side lobes' effect



Indirect echoes

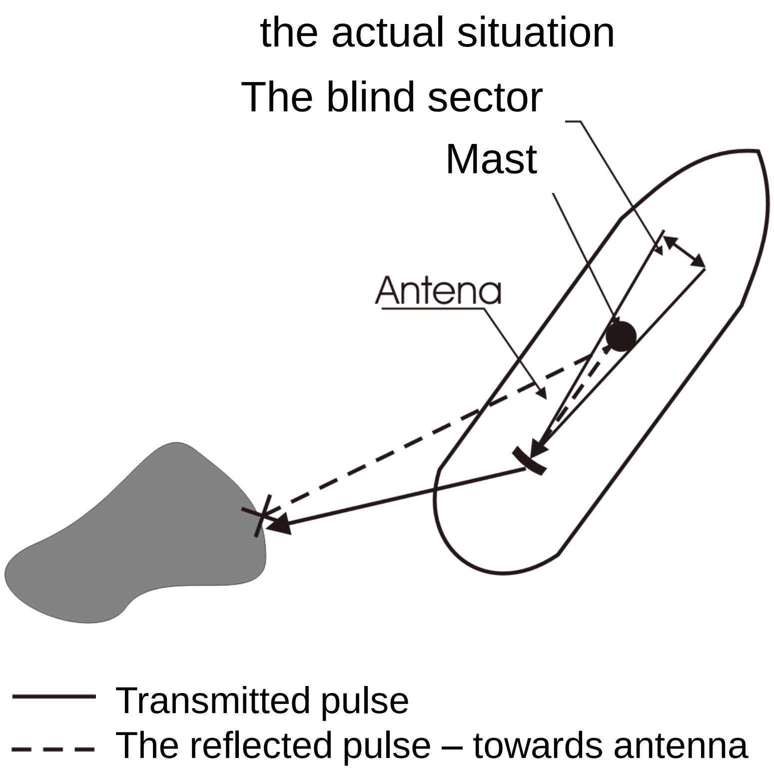
- They arise as a result of the mirror reflection of the pulse and the echo impulse from the element (object), with good reflective properties, which is located in the propagation path.
- Depending on the position of the reflecting element, we distinguish two types of indirect echoes:
  - internal – element of the own ship,
  - from external object.

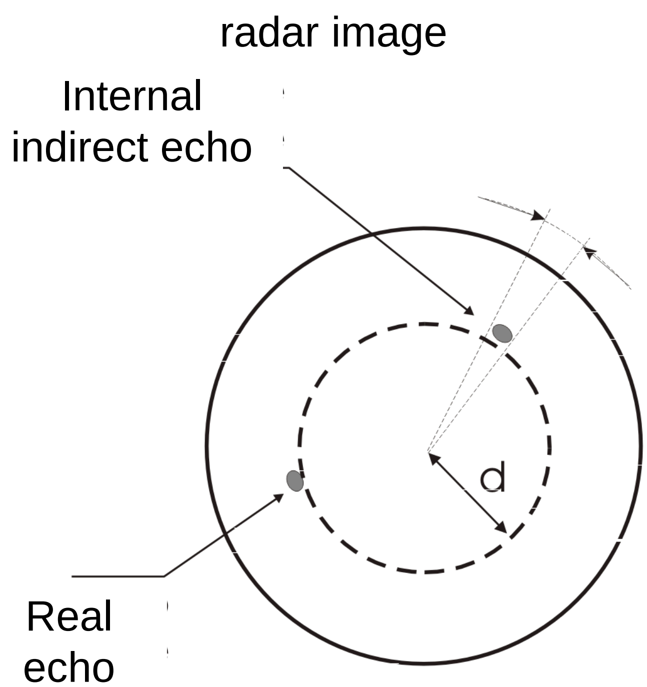


Indirect echoes - internal

- They arise as a result of reflections of signals by the structural elements of the ship, such as :
  - masts,
  - Cranes, booms,
  - Chimneys, ventilators etc.
- These elements are the reason for the presence of radar blind sectors in which there is the greatest probability of occurrence of indirect internal echoes.
- A characteristic feature of these echoes is :
  - the distance is approximately equal to the distance of the real echo of the object,
  - these echoes always appear in the directions of the location of the construction elements causing the radar blind sectors

Indirect echoes - internal



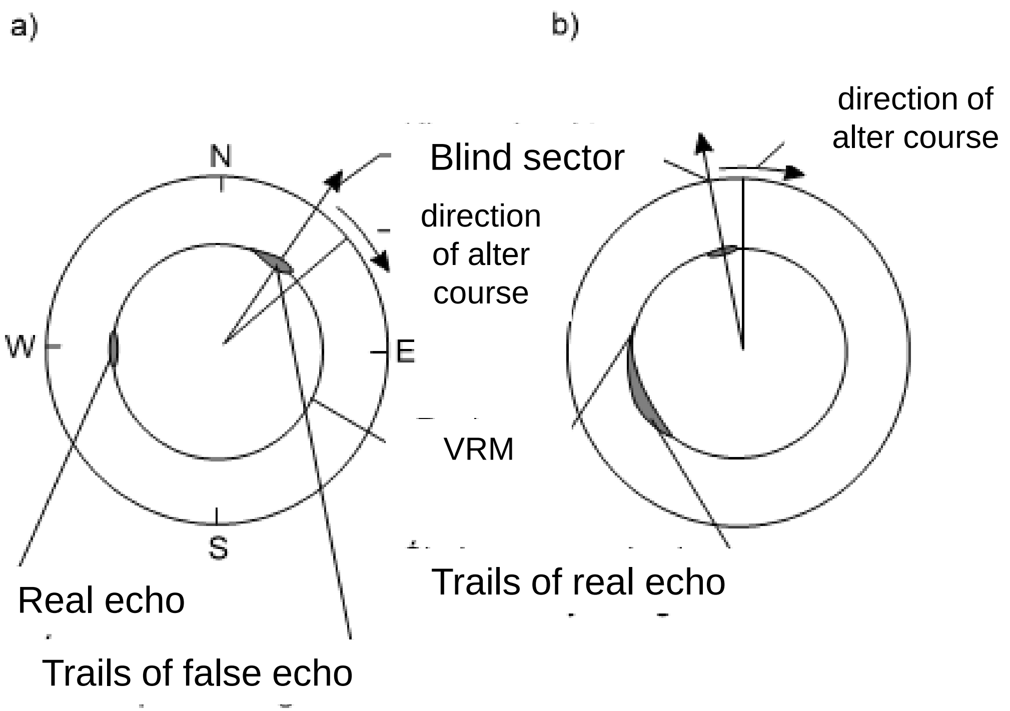


Indirect echoes - internal

- In order to weakening or completely eliminating, special screens made of corrugated sheet are used. They are fixed on the elements of the ship which cause reflections. These screens scatter microwave energy in the vertical direction, which prevents indirect echoes.
- Information on horizontal shadow sectors, if any, must be provided on each ship for each installed radar.
- Any echo appearing in the shadow sector is most likely a false echo.

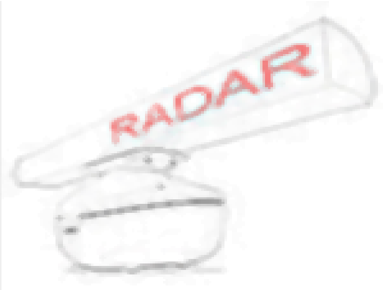
Indirect echoes - internal

- They are weaker than real echoes and for their elimination one can use the A/C SEA (in the case of echoes from objects located close to) or A/C RAIN for distant one



Identification of indirect internal echoes with following picture orientation :

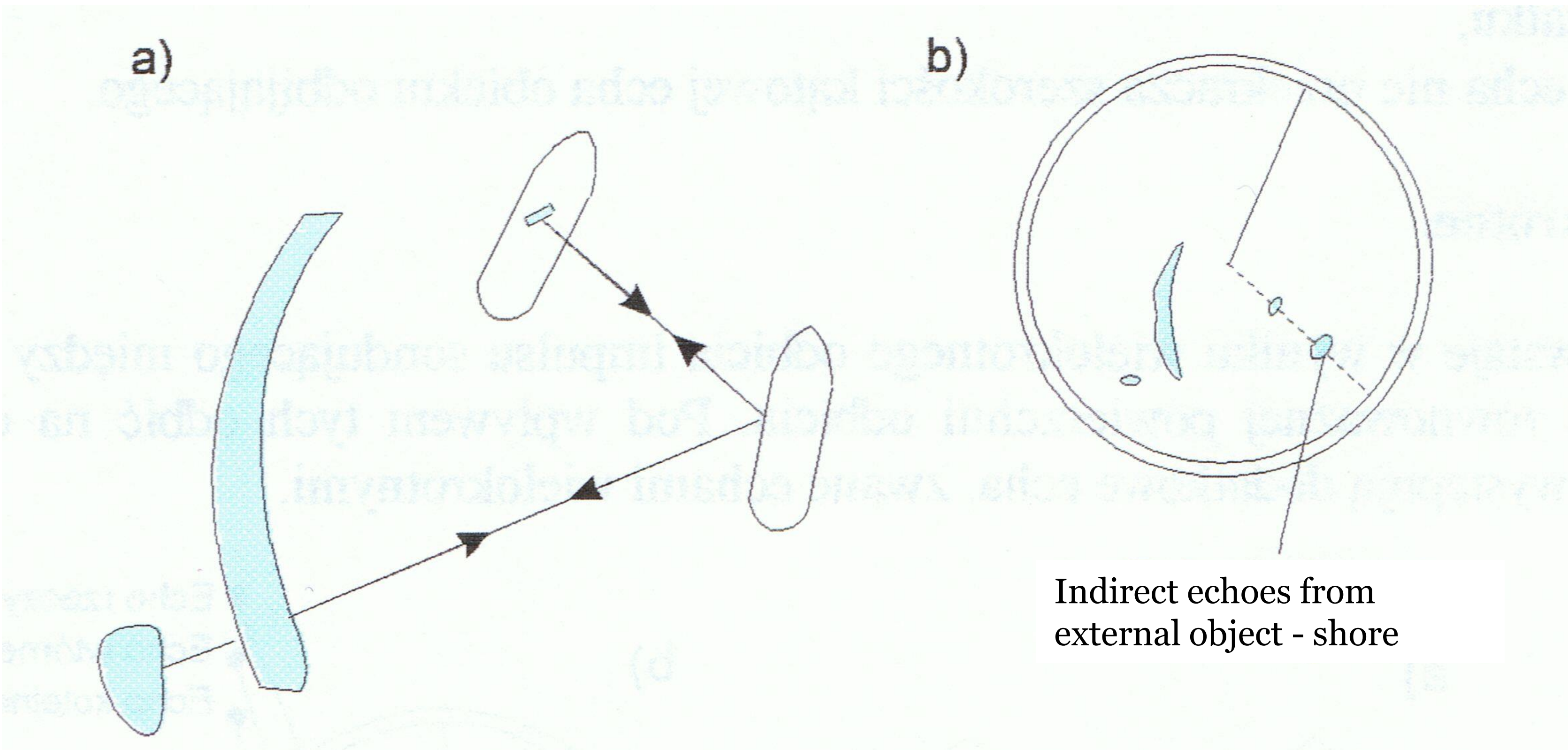
a) North up
b) Head up.



Indirect echoes - external

- They arise as a result of reflections of signals by objects as :
  - Large vessels,
  - buildings,
  - cliffs.
- They mostly occur during sailing in narrow passages, canals, etc.
- They are characterized by the fact that they appear in the direction of reflecting objects, but at a greater distance than the echoes of these objects.

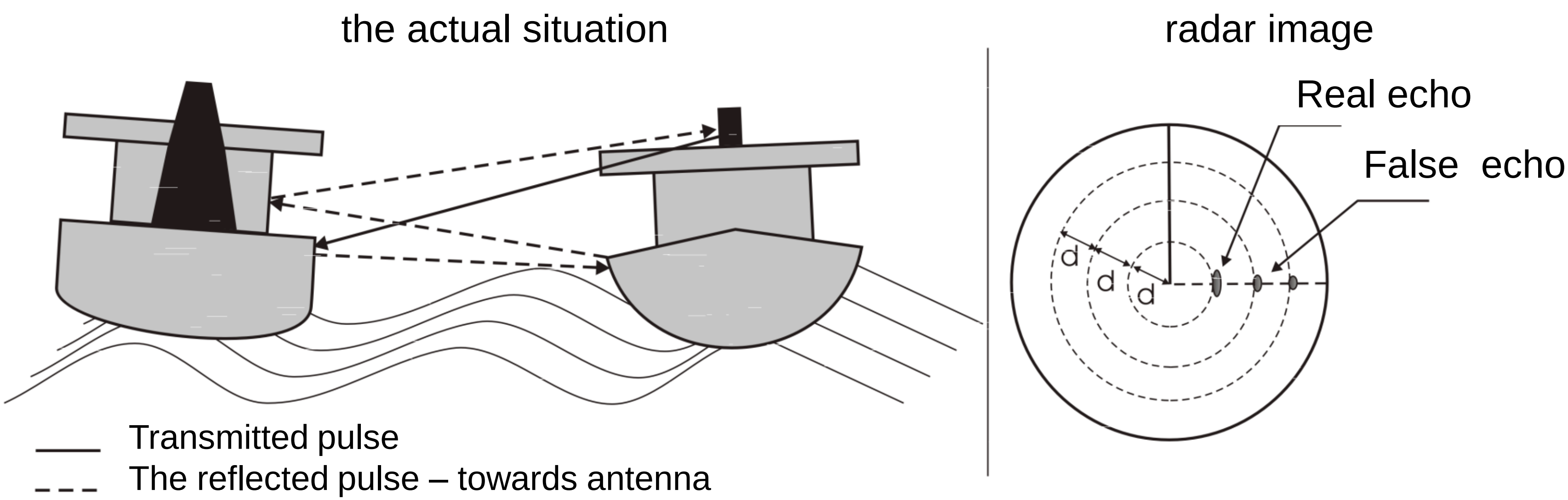
Indirect echoes - external



Indirect echoes from external object - shore

Multiple echoes

- They arise as a result of repeated rebound of the pulse between the own ship and the object with a large radar cross section (RCS).

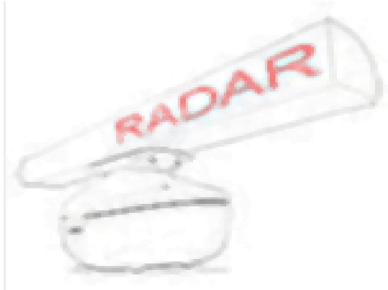


Multiple echoes

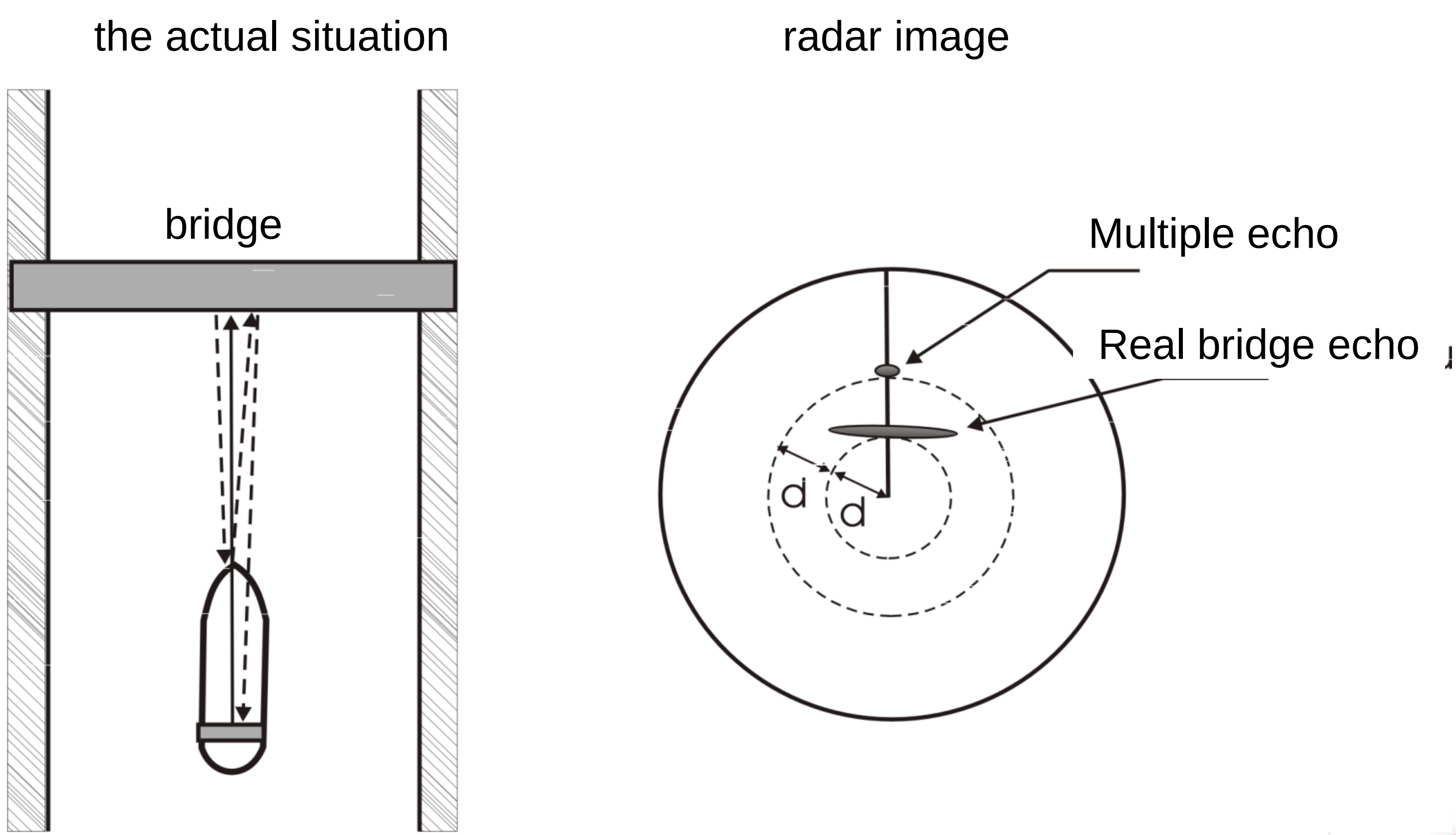
- Properties of multiple echoes:
    - they are in the same direction as the real echo,
    - distances to these echoes are a multiple of the distance to the real echo from the position of your own ship.

Multiple echoes

- These echoes can occur in :
  - near the traverses while passing in parallel with larger ships,
  - when approaching the bridge. in this case multiple echoes will be on the opposite side of the bridge, giving the impression of a ship sailing towards us (dangerous when sailing in limited visibility).



Multiple echoes



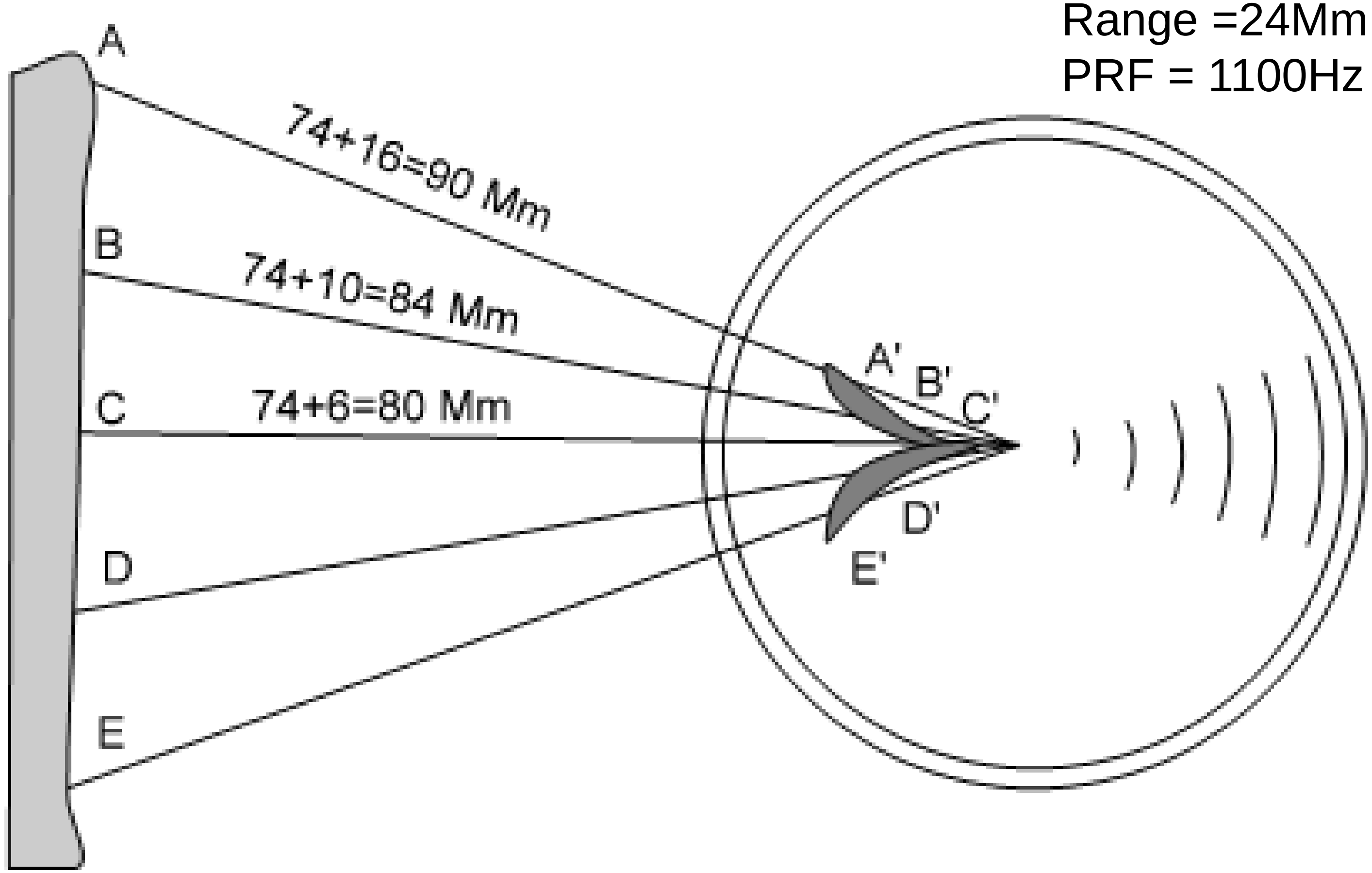
Multiple echoes are weaker than the real echoes. Because they only occur at short distances, they are eliminated with A/C SEA.

Second-trace echo

- During the very good atmospheric conditions for microwaves propagation, on the radar screen may occur echoes from objects located several times larger than the range scale on which the radar is currently working.
- These echoes appear on the screen due to receiving signals from the pulse sent by the transmitter during the previous radar cycle.
- Objects detected this way should have a large RCS, necessary to obtain a suitably increased maximum range.

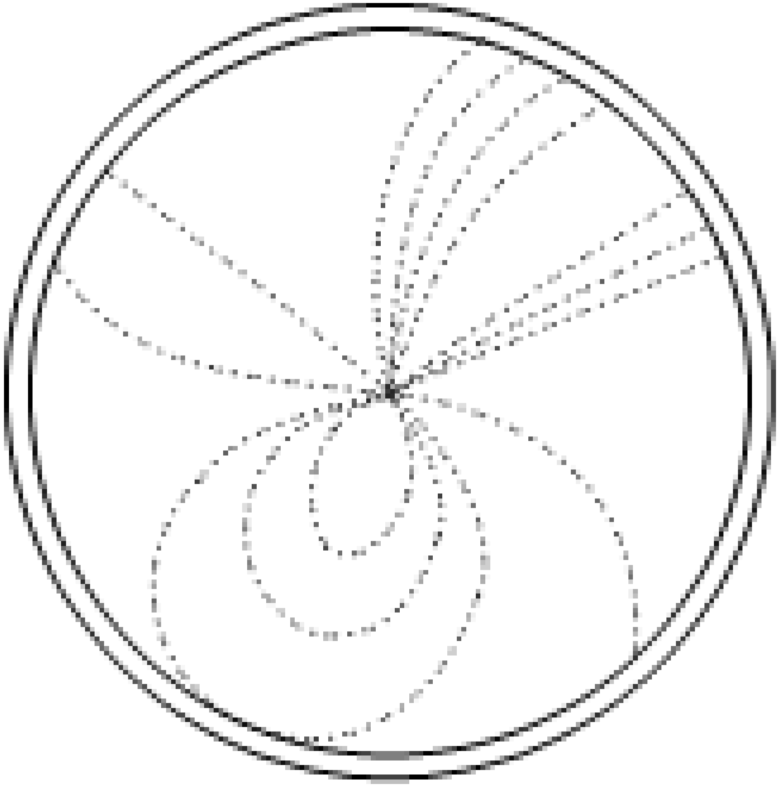
Second trace echo

Range =24Mm
PRF = 1100Hz



Radar-to-radar interferences

- They arise as a result of receiving radar pulses sent by other radars, working on a similar frequency.
- They appear on the screen in the form of clearly visible points or dashes drawing characteristic patterns on the screen

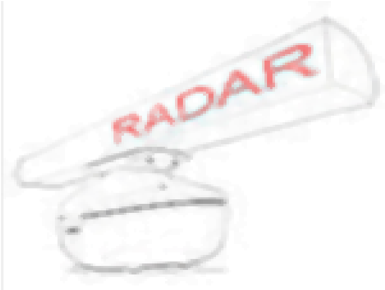


Radar-to-radar interferences

- They occur in areas of high ship traffic and in the case of two radars installed on the same ship at a short distance from each other.
- The size of interferences depends on the distance and power of the radar and on the range scale of its own radar.
- In large range scales, the interferences occur in the form of very strong backlighting of the screen. Because in these ranges the magnitude of echoes from individual objects is very small, they can be difficult to recognize them on the interferences background.
- In the smaller range scales, the interferences occur in the form of lines of low brightness and less obstruct the observation of radar image.
- The use of Interference Reject (IR function) in practice results in complete elimination of these disturbances.

Radar measurements

- RADAR in maritime navigation on merchant ships is mainly used for two tasks:
  - avoiding situations of excessive approchement or collision with another vessel or navigational obstacle,
  - determining a position where the observer is located.

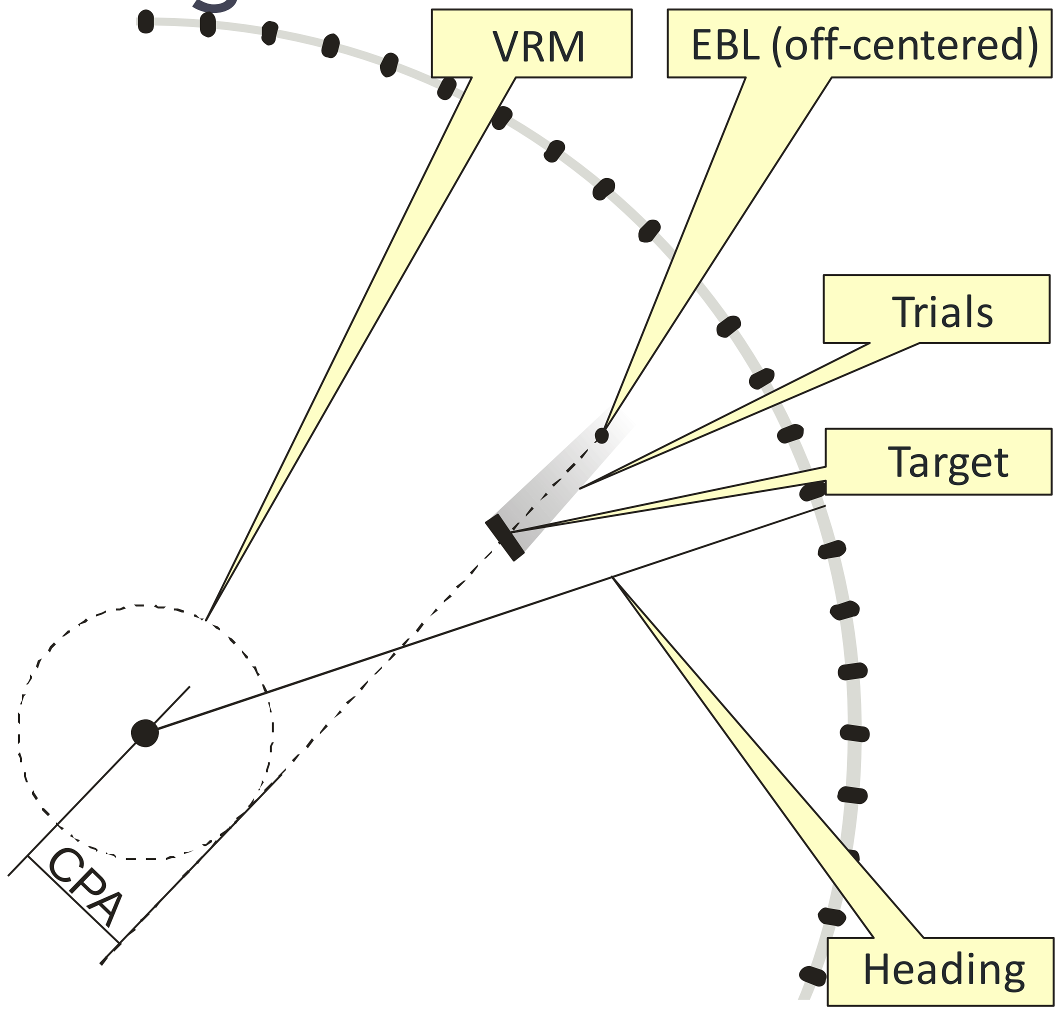


Measuring markers

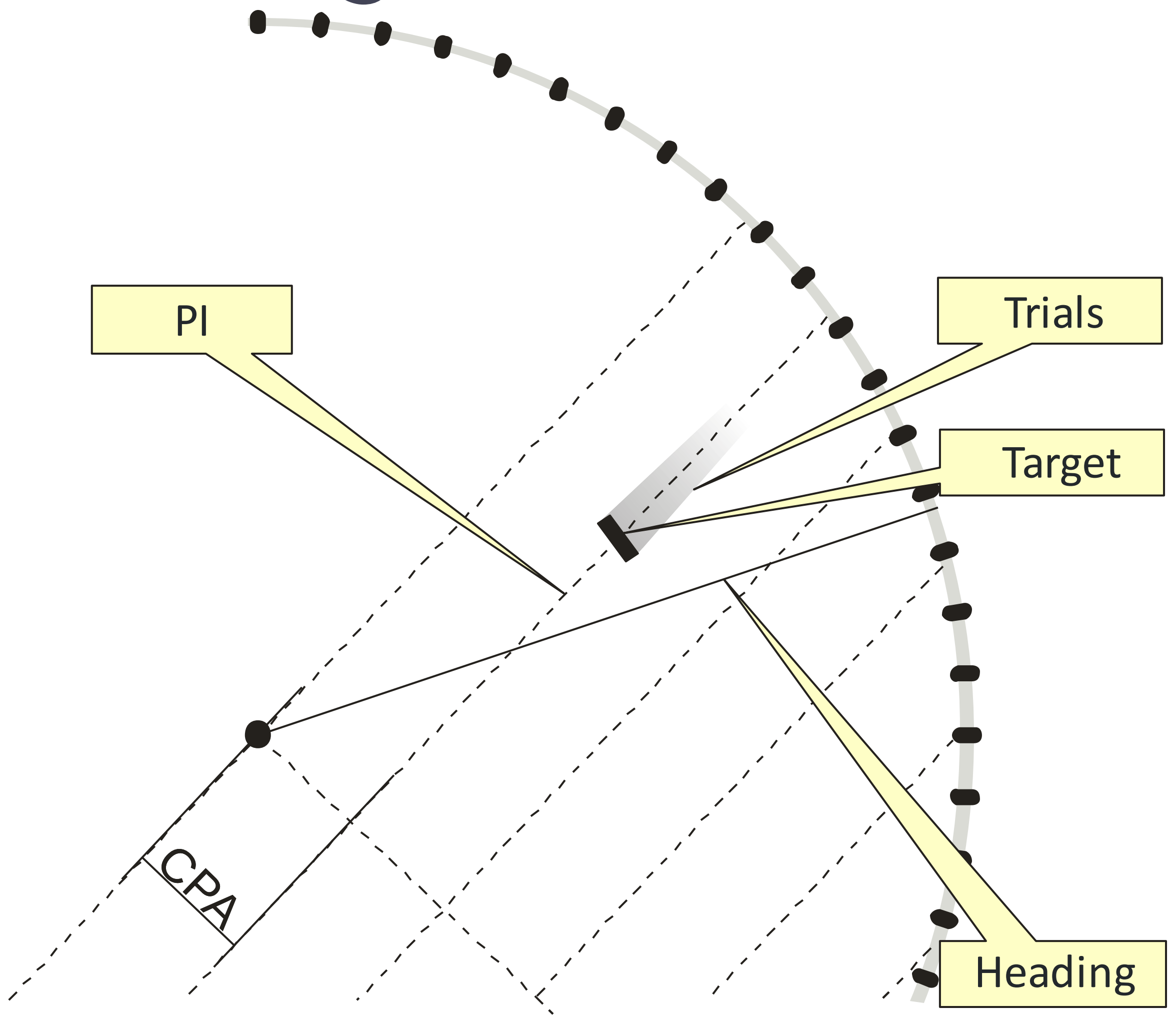
Marker	Number	Accuracy of distance measurement	Accuracy of angle measurement
Fixed Range Rings	According to range scale	30m or 1% of the range scale	-
Variable Range Marker (VRM)	at least 2		
Electronic Bearing Line (EBL)	at least 2	-	1°
Parallel Index Lines (PI)	at least 4	30m or 1% of the range scale	
User Cursor	1		

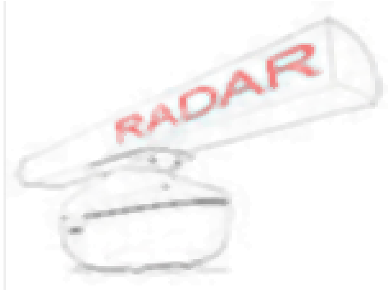
Additionally a bearing scale outside of the operational display area

Determining of CPA

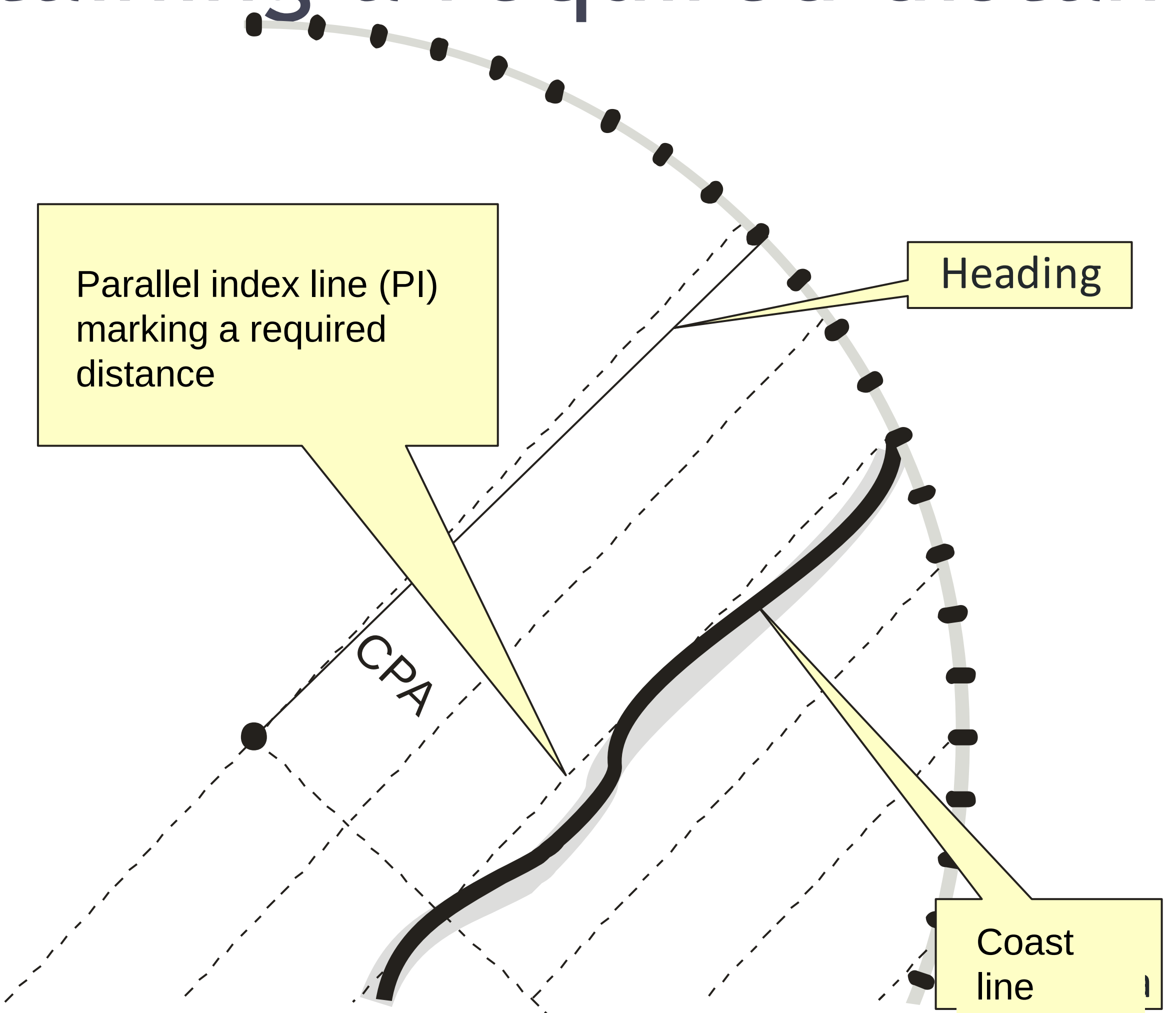


Determining of CPA



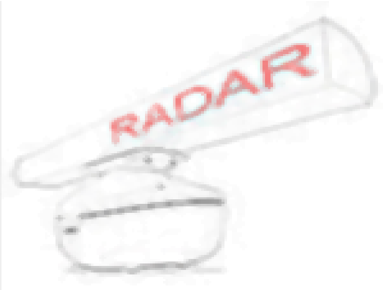


Maintaining a required distance



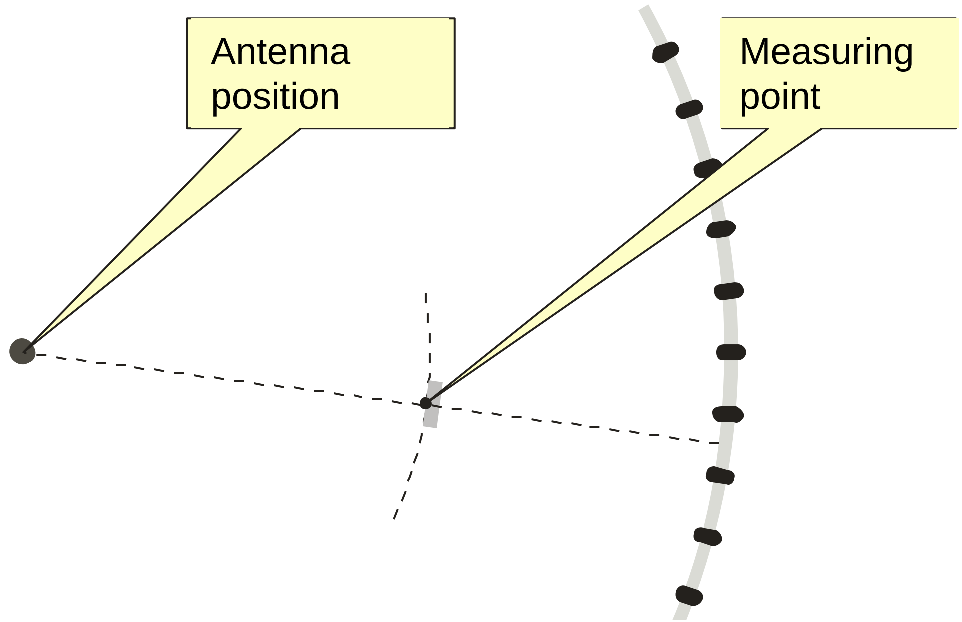
Determining a position

- Radar position can be obtained using following measurements:
  - Two bearings,
  - Two distances,
  - A bearing and a distance.



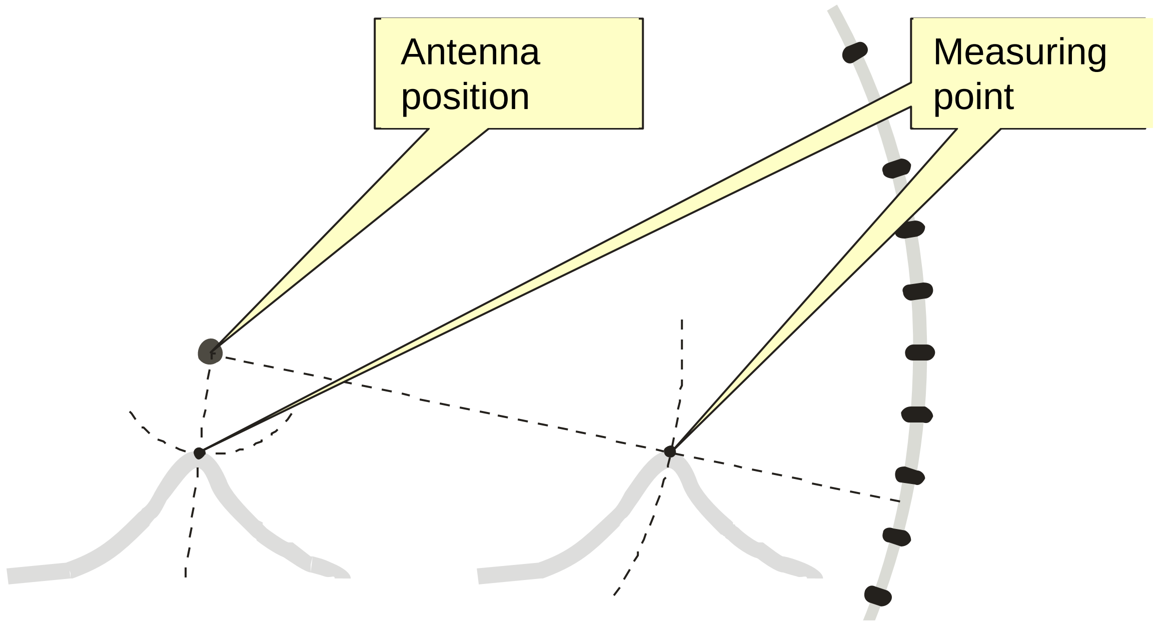
Measuring point

- A compact object



Measuring point

- A segment of coast line

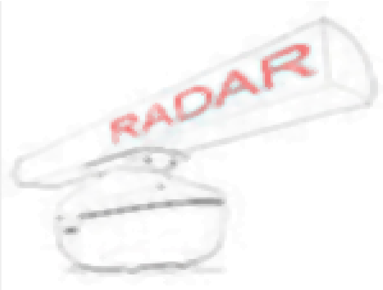


CCRP

- All measurements should be made in relation to the reference point: **CCRP** (*Consistent Common Reference Point*).
- This point, known as the observer's point, is most often located on the navigating bridge in the ship's symmetry axis at the location of an optical bearing finder.
- If the position of the antenna or radar does not coincide with the **CCRP**, this offset should be properly compensated.
- In the case of a system with several radar antennas, shifts to **CCRP** should be taken into account automatically when selecting a given antenna.

Accuracy of the position

- One of the basic indicators of an accuracy the of a position is a root mean square error of position (RMS, M_0).
- The probability of finding the actual position of the ship within the error (confidence level) is not homogenous and ranges from 0.632 to 0.683,
- on average, it is accepted as 0.66



Two bearings

- The error depends largely on the distance to the objects

$$M_0 = \frac{1}{\sin\theta} \cdot \sqrt{\left(\frac{m_{NR} \cdot D_1}{57.3}\right)^2 + \left(\frac{m_{NR} \cdot D_2}{57.3}\right)^2} = \frac{m_{NR}}{57.3 \cdot \sin\theta} \cdot \sqrt{D_1^2 + D_2^2}$$

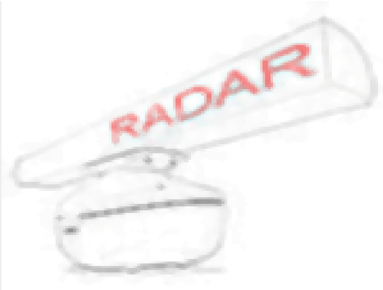
where:

M_0 - root mean square error of position [m]

Θ - angle between LOP (lines of position)

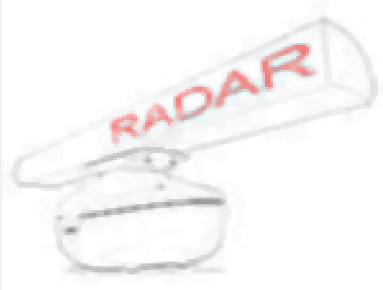
m_{NR} - mean error of bearing [°]

D_1, D_2 - distances to the objects [m]



Non-simultaneous bearings

- In order to minimize the error, the following rules must be followed:
  - firstly take the bearing to the target, which is located near the traverse and then measure the bearing to the target towards the stern or bow,
  - measurements should be made in such a way that the time between consecutive measurements is as short as possible.



Two distances

- The most accurate position

$$M_0 = \frac{1}{\sin\theta} \cdot \sqrt{m_{D1}^2 + m_{D2}^2} = \frac{m_D}{\sin\theta} \cdot \sqrt{2}$$

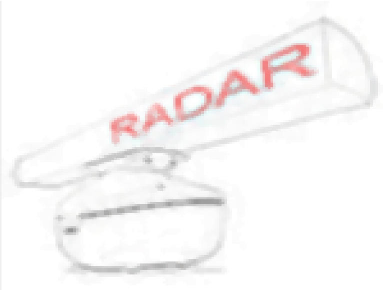
where:

m_{D1} ,m_{D1}, m_D - mean error of distance measurement [m]

Jeżeli pomiary odległości do obiektów dokonywane są na tym samym zakresie wówczas średnie błędy m_{D1} i m_{D2} są takie same i można wówczas uprościć zależność

Non-simultaneous measurements

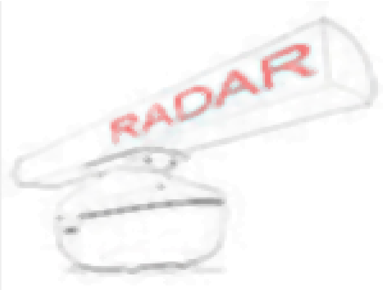
- firstly take the measurement of the distance to the target, which is in the bow or the stern direction bow and then is to a target located near the traverse,
- measurements should be made in such a way that the time between consecutive measurements is as short as possible.



The bearing and distance

- The most natural method

$$M_0 = \frac{1}{\sin\theta} \cdot \sqrt{\left(\frac{m_{NR} \cdot D}{57.3}\right)^2 + m_D^2} = \sqrt{\left(\frac{m_{NR} \cdot D}{57.3}\right)^2 + m_D^2}$$



The end