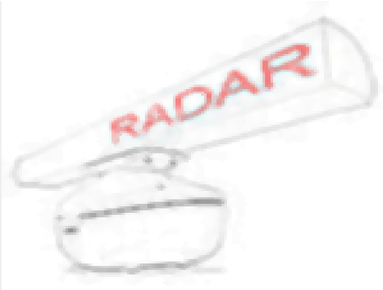
# Radiolocation 4

Detection at short and long distances

Dimensions of the echoes and possibilities of correcting them



# Radar horizon

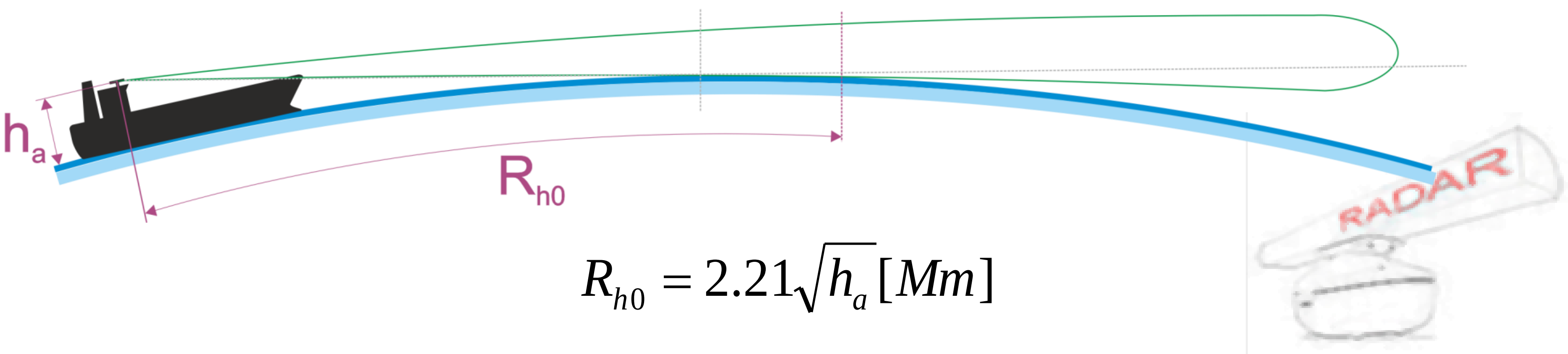
- For marine radar frequencies (ab. 10 i 3 GHz) the propagation path can be considered as a straight line ("line of sight") similar to the path of visible lights.
- The zero radar horizon is a segment of the tangent to the Earth's surface contained between the radar antenna and the point of contact:

$$R_{h0} = 1.93\sqrt{h_a} \quad [Mm]$$

- As a result, objects with low height $h_o$, that are located behind the zero radar horizon will not be detected.

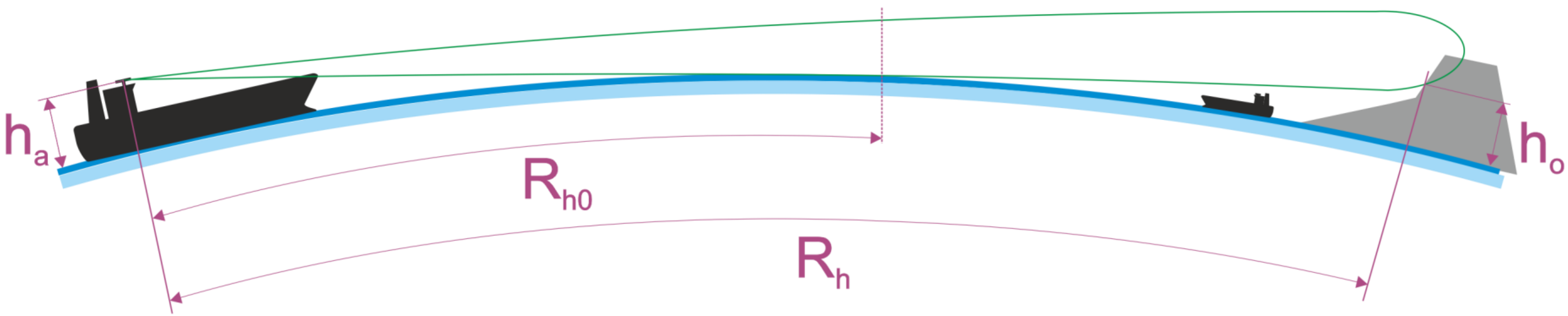
# Radar horizon

- During standard atmospheric conditions, the radar beam tends to bend slightly downward,
  - means: pressura = 1013 hPa decreasing 36 hPa with every 300 m of the altitude, temperature = 15°C decreasing with 2°C with every 300 m of altitude, relative humidity = 60% (constatnt with altitude).




$$R_{h0} = 2.21\sqrt{h_a}\,[Mm]$$

# Long distance detection

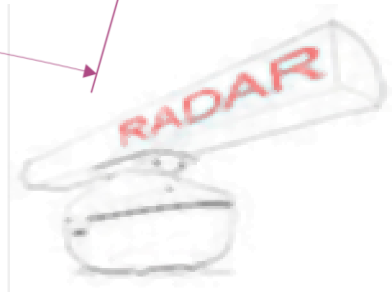



the ability to detect objects, beyond the horizon, depends on the height of the antenna and the height of the detected object. This corresponds to the formula:

$$R_h = 2.21\left(\sqrt{h_a} + \sqrt{h_o}\right)[Mm]$$

# Long distance detection

- Taking into consideration above equations, it can be concluded that in the case of a high object that is beyond the radar horizon zero, it is possible to detect it on the radar as far as the radar maximum range permits. Observing such an echo on the radar it has to be considered that the detected target can be the top of the mountain inland:

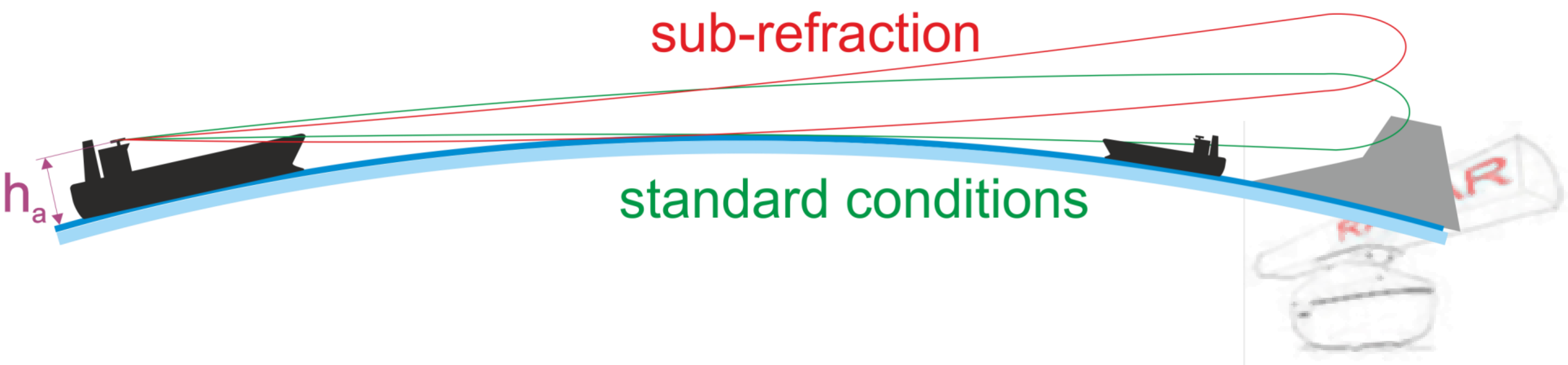



# Long distance detection

- The radar image should be interpreted with particular caution when approaching the mainland from the direction of the open sea.
- It often happens that echoes from objects beyond the radar zero horizon do not draw sharply on the radar screen.
- Then, these echoes should be interpreted as uncertain and not used to determine the position.
- Also, be careful when estimating the distance to land because the echo is not always echoed from the nearest fragment of land.

# Sub-refraction

- In sub-refraction conditions, the radar beam is bent upwards.
- This is the case when the (vertical composition of atmosphere).
  - air temperature rapid fall with the altitude
  - the humidity increases as the altitude increases

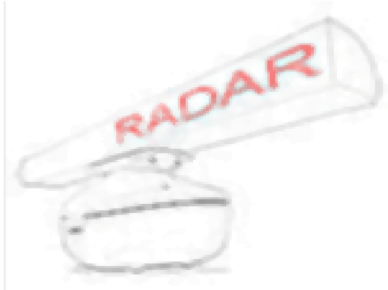


# Sub-refraction

- Mostly the conditions for the emergence of a sub-refraction occur when cold air moves over warm water.
- This is a typical phenomenon for the subarctic zone.
- This phenomenon may reduce the the radar horizon (standard conditions) even by 40%
- It can prevent the detection of small fishing boats, low icebergs, etc.

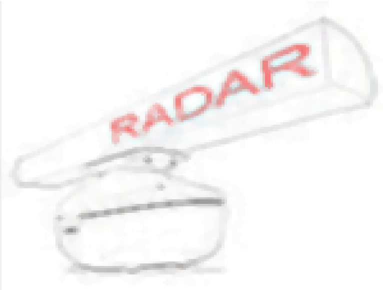
# Super-refraction

- In super-fraction, the radar beam is bent more down than under standard atmospheric conditions.

# Super-refraction

- Conditions conducive to the creation of super-fraction are when:
  - Temperature of air falling more slowly than standard, or even increasing with height
  - the humidity decreases with increasing height.
- This phenomenon increases the radar horizon even by 40%.

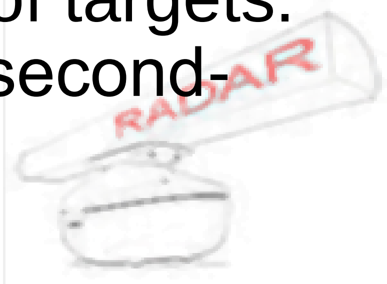


# Superrefrakcja

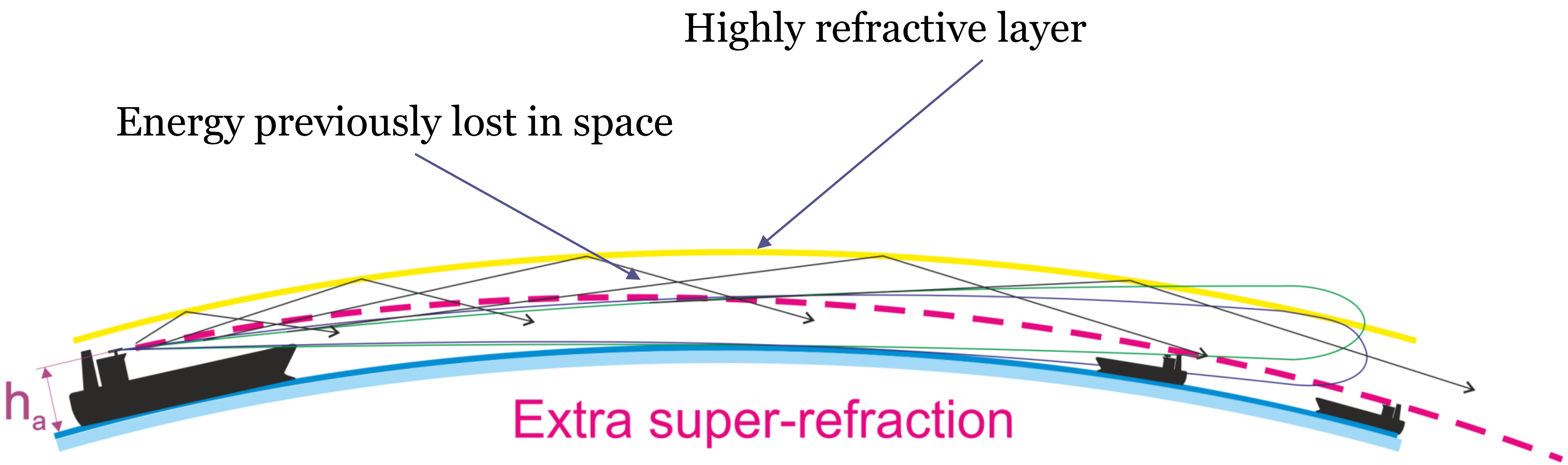
- Super-refraction conditions can occur when:
  - there is a horizontal movement of warm masses of air above the cooler sea water – then the temperature rises and the humidity decreases with the height,
  - There are high pressure conditions along with descending currents,
  - during windless sunny weather.
- This is a phenomenon characteristic for the tropical zone, but also possible to observe in the Baltic Sea during the summer.

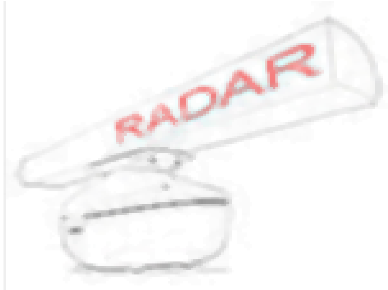
# Extra super-refraction

- Under these conditions, the pulse energy is trapped in a ‘duct’ formed by the Earth’s surface and a highly refractive layer which may be at 30 m altitiude above the ground.
- The effect is to concentrate energy which would otherwise have been lost into space together with the energy which would normally travel in the direction of the targets.
- This increased energy now follows the Earth’s surface, thus reducing the constraint of the radar horizon and considerably extending the detection ranges of targets.
- This can result in the detection of unwanted ‘second-trace echoes’



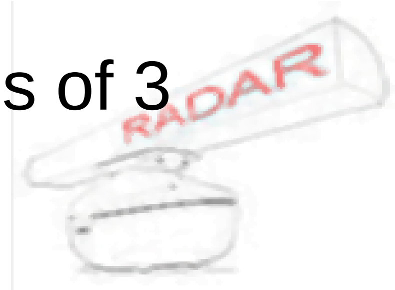
# Extra super-refraction



# Absorption of the pulse energy

- The radar equation determining the maximum radar range does not take into account losses due to the suppression of microwaves in the atmosphere.
- The main factors causing the suppression of microwaves can include: fog, rain, hail, snow, fumes, volatile industrial pollution.
- The influence of wave suppression on rainfall depends on its length.
- The research shows that waves with a length of 10 cm are subject to very small suppression by precipitation.
- Attenuation has a significant effect on waves of 3 cm in length.

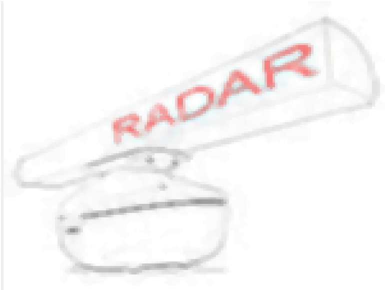


# Absorption of the pulse energy

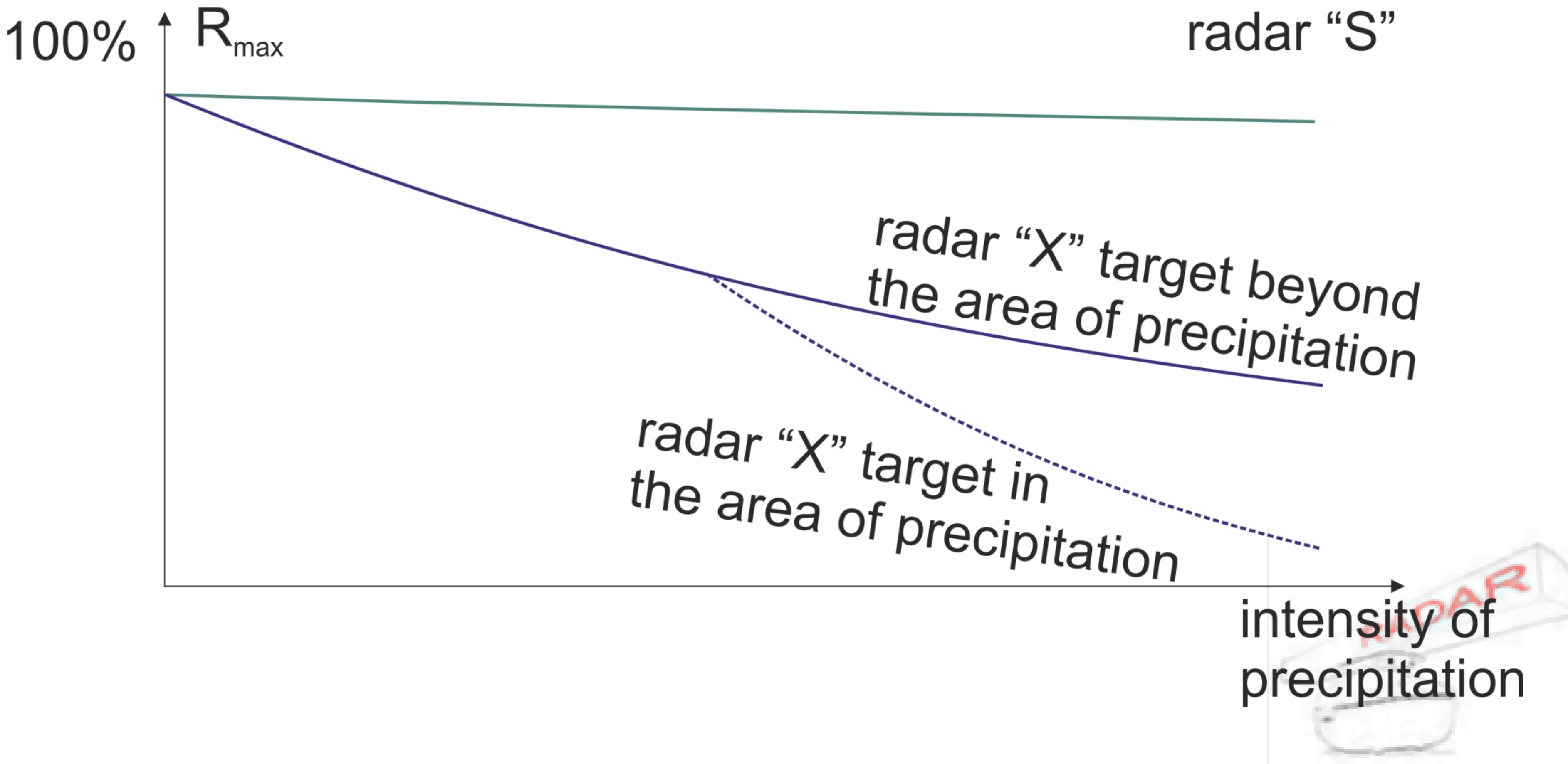
- ***Fog*** causes damping depending on the density and type. The research shows that only very dense fog in the Arctic regions can reduce the maximum radar range. Due to the small particle size of the fog, you can not see its echo on the radar.
- ***Rain*** reduces the maximum range of the radar due to the attenuation of the waves and the reflection of the impulses from the drops of water. The amount of damping depends on the intensity and type of rain. During high rain intensity, the range may reach 60% of the regular radar range. The detection range of the radar decreases more strongly when the object is in the area of precipitation in relation to the object located outside this area.
  Rainfall gives echoes on the radar, the strength of the response depends on the size of the drops.

# Absorption of the pulse energy

- ***Hail and snow*** cause less damping than rain and cause the occurrence of much larger response at the same intensity of precipitation.
- Hail and snow cause a significant reduction in the detection for objects located in the area of precipitation. The reduction of maximum range for objects beyond this area is small.

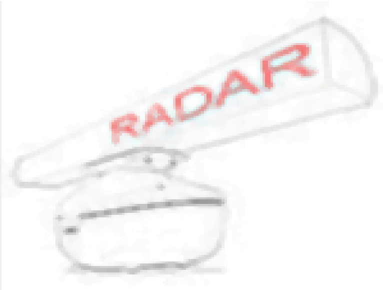


# Suppression of radar pulse by precipitation



# Short distance detection

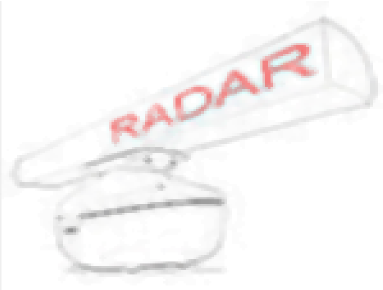
- Short distance detection can be limited by:
  - Minimum range
  - Dead zone
  - Vertical shadow



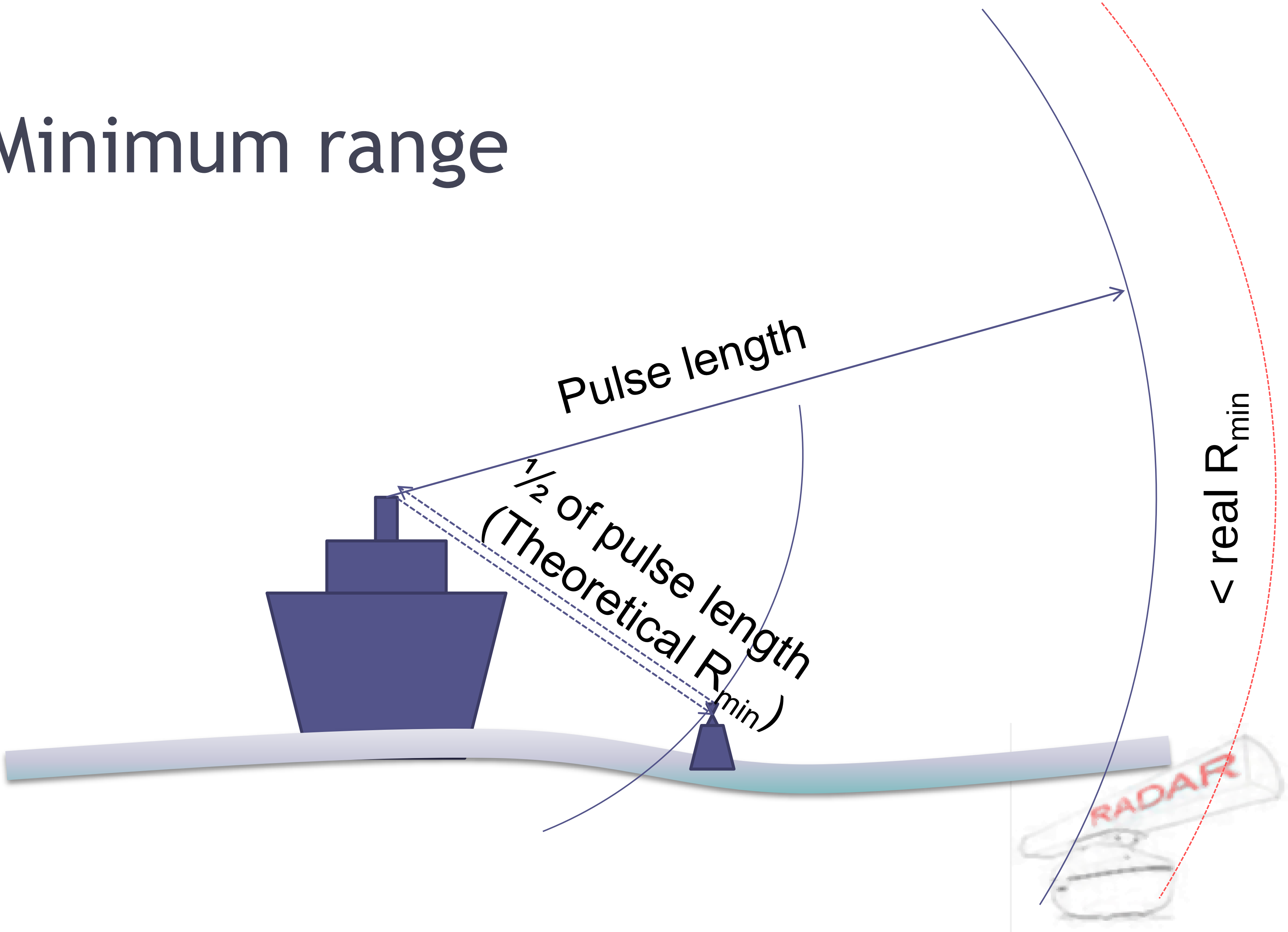
# Minimum range

- The radar is unable to receive a signal reflected from the object when it is in the process of sending a pulse or it is switching between transmitting and receiving.
- Theoretically radar can not detect objects closer than half the length of the pulse. However, due to the deactivation time of the T / R switch, it is longer.

$$D_{\min} = \frac{c\tau}{2} \qquad \rightarrow \qquad D_{\min} = (0.6 \div 1.2) c\tau$$



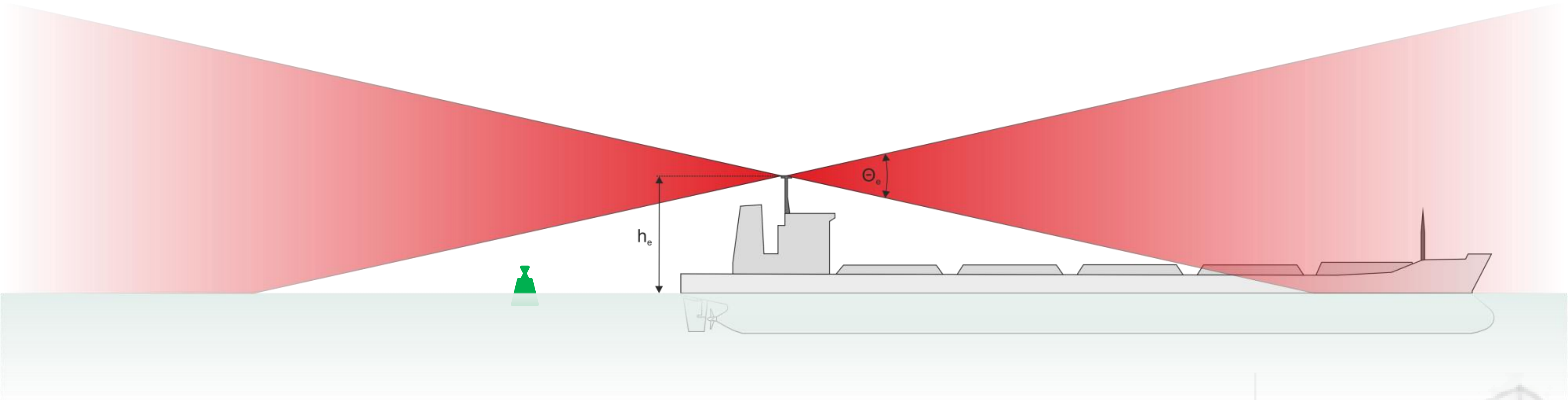
# Minimum range

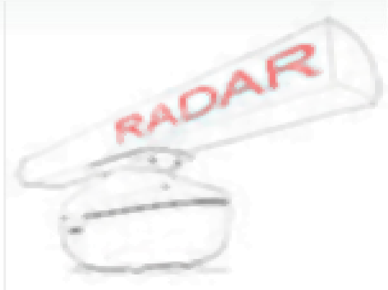


# Dead zone

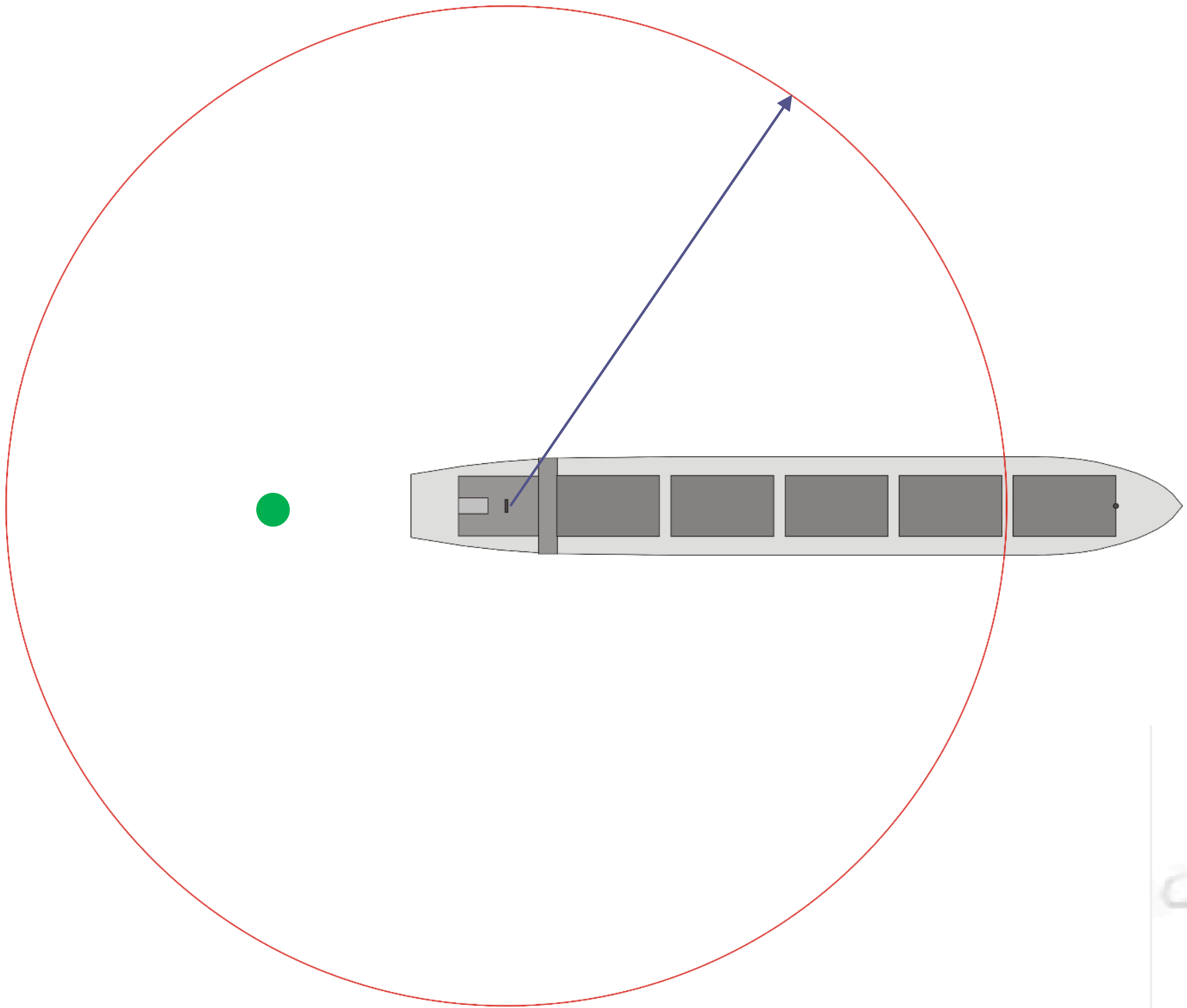
- Limitation of an object detection at short distances, which is results from the vertical antenna characteristics and its height.
- This is the distance between the position of the antenna and the point at which the radar beam is in contact with the surface of the Earth.
- Objects that are located below the radiation beam will theoretically not be detected by the radar.

# Dead zone



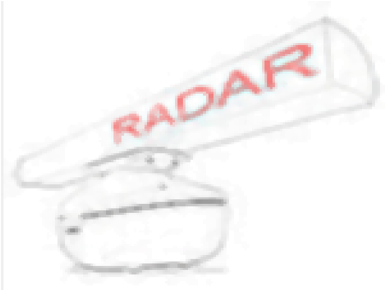



# Dead zone

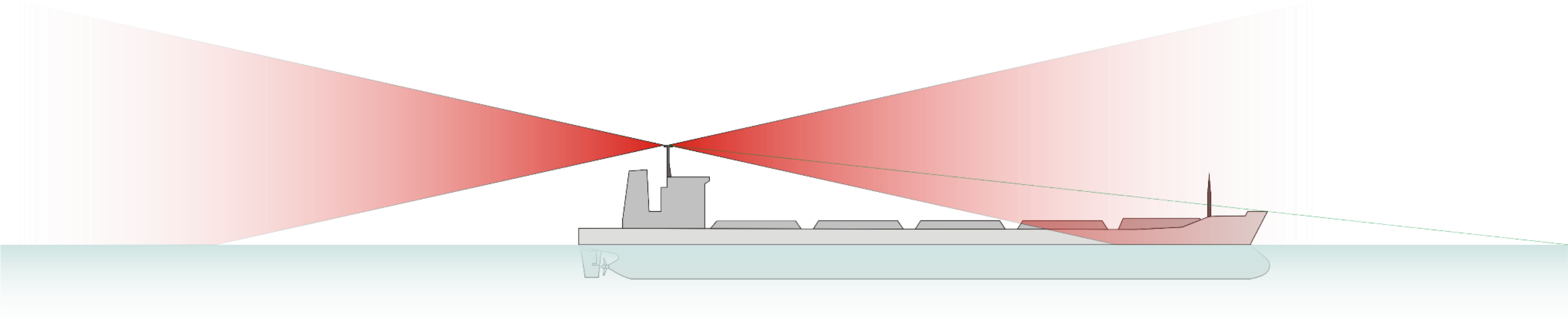


# Vertical shadow

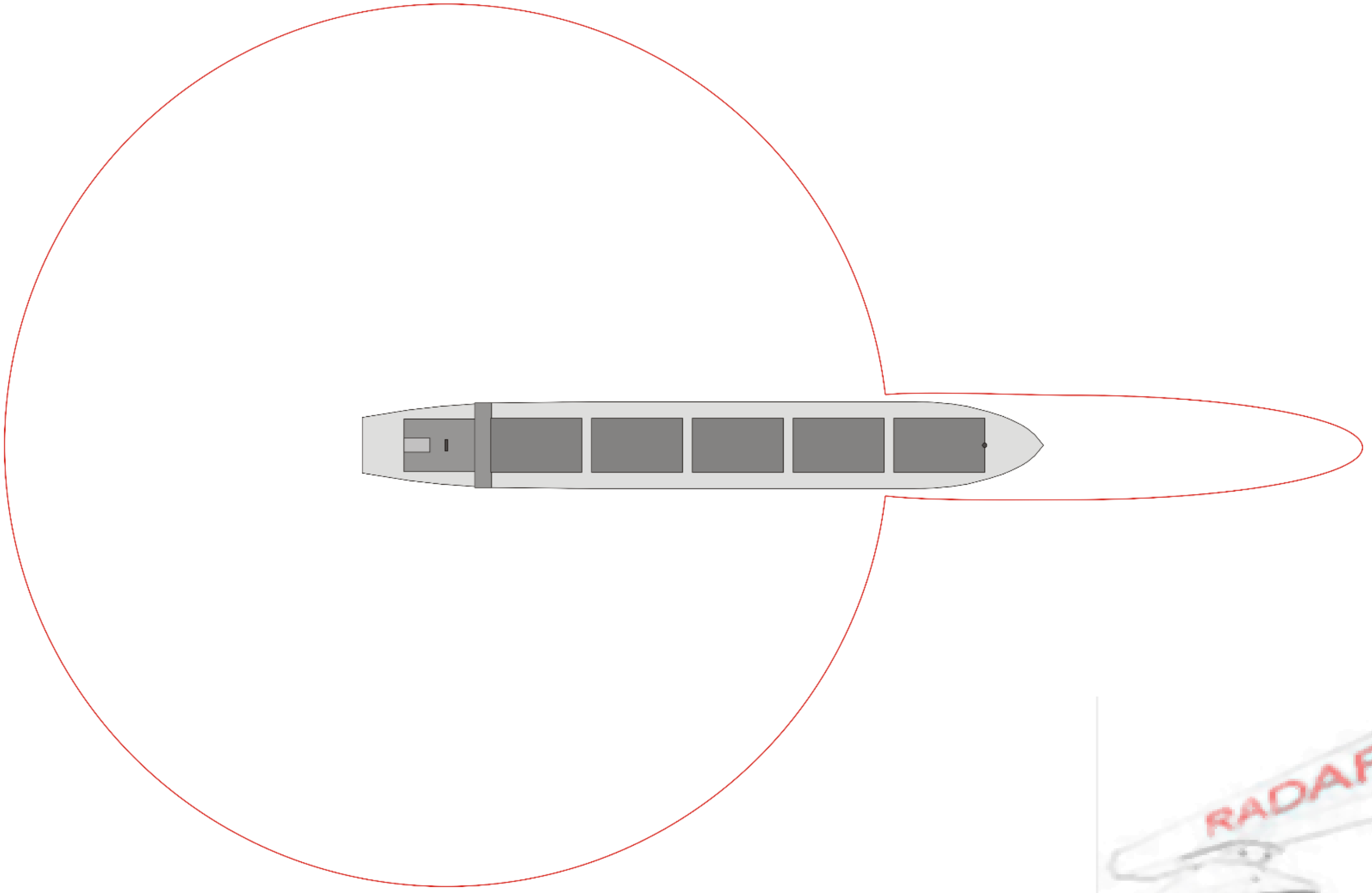
- It occurs when in the path of the rays is an obstacle impenetrable to microwaves which is lower than the antenna's high and blocks part of radar beam.
- This phenomenon often occurs on container ships, where highly stacked containers in the stern-stern direction block the radiation.
- If the object is within the vertical shadow, it will not be detected.

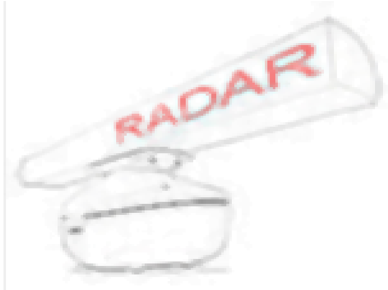


# Vertical shadow



# Vertical shadow



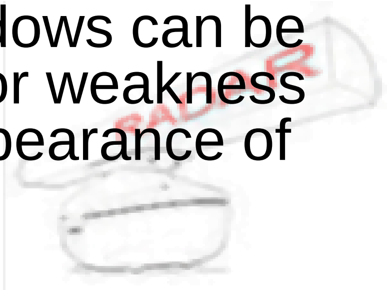


# Required minimum range

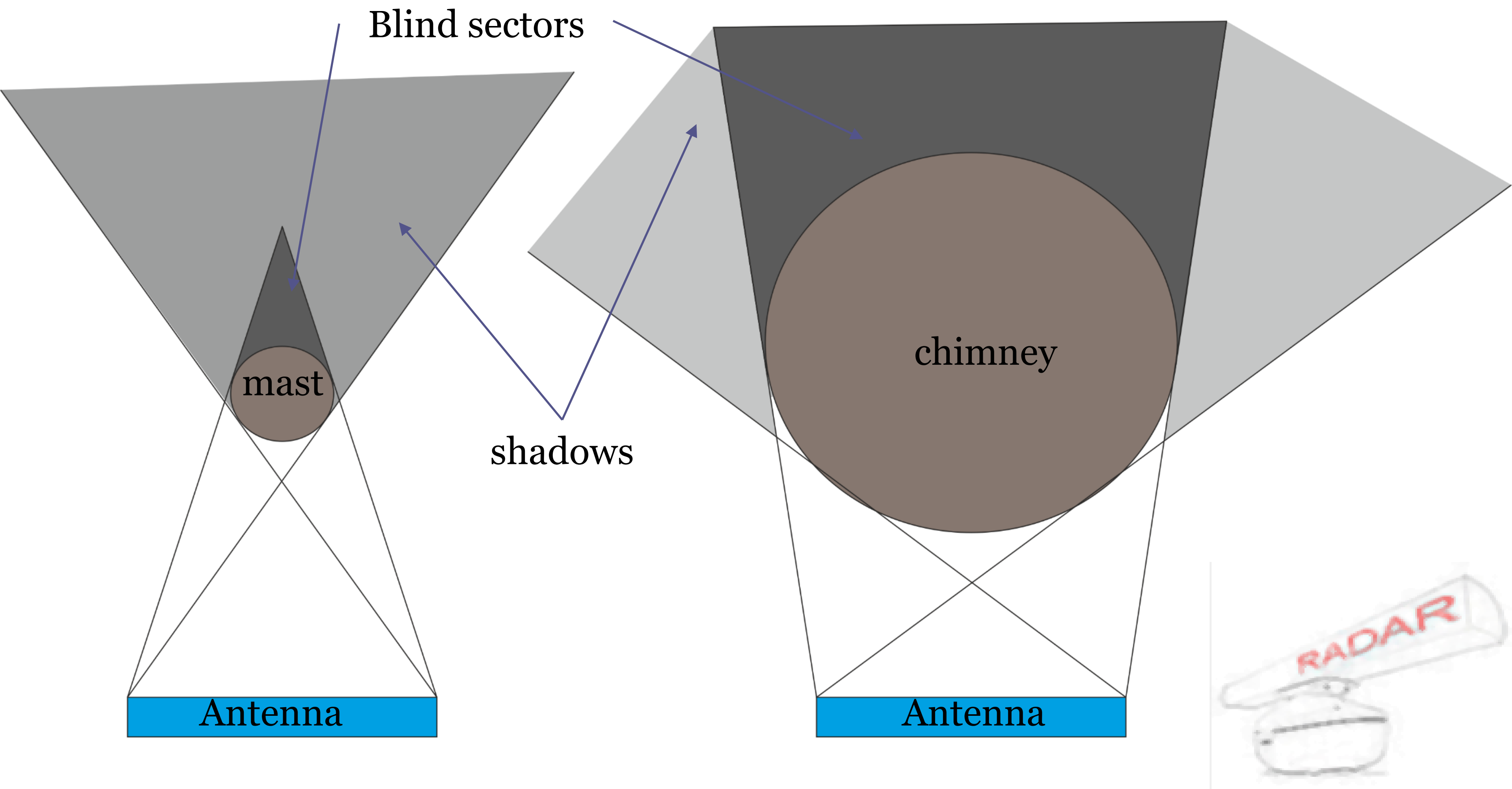
- According to IMO requirements (res. MSC 192) the minimum range for the navigational buoy:
  - for an antenna height of 15 m above the sea level
  - with own ship at zero speed
  - in calm conditions
- should be detected at a minimum horizontal range of 40 m from the antenna position and up to a range of 1 NM, without changing the setting of control functions other than the range scale selector.

# The detection limitations in horizontal plane

- Blind sectors and horizontal shadows - if the construction elements of the ship are on the path of microwaves propagation, they cause the emergence of radar blind sectors and shadows sectors.
- In these sectors, the range of radar decreases significantly, in some cases up to 0.
- The size of these sectors depends on the size of the obstacle, distance from the antenna, span (width) and type of antenna.
- If the width of the obstacle is greater than the width of the antenna, it is to be expected that a radar blind sector will be created covering all the space in a given direction.
- Ignorance of the position of the blind sectors and shadows can be dangerous because they cause a lack (no detection) or weakness (decreasing maximum range) of the echoes or the appearance of false echoes.



# Blind and shadow sectors



# A size of an echo

- An echo observed on the radar display can be interpreted in a dimension corresponding to the scale of the screen (range scale) and in the spatial dimension.
- In the screen scale, the echo size is measured in millimeters when its spatial dimension is measured in meters or nautical miles.
- In navigation practice, the spatial dimension is more useful for the navigator

# Creating of radar picture

- At the moment of transmitting the pulse by the transmitter
  - The system selects consecutive memory cells for a given work cycle
  - The speed of selecting the next cells is constant in the spatial dimension and equals c / 2, and in the screen dimension depends on the range scale on which the radar works - depends on the distance represented by the single memory cell.
- When the receiver receives an echo pulse,
  - The value of the currently selected cell (corresponding to the distance of the detected object) changes to other than zero value.

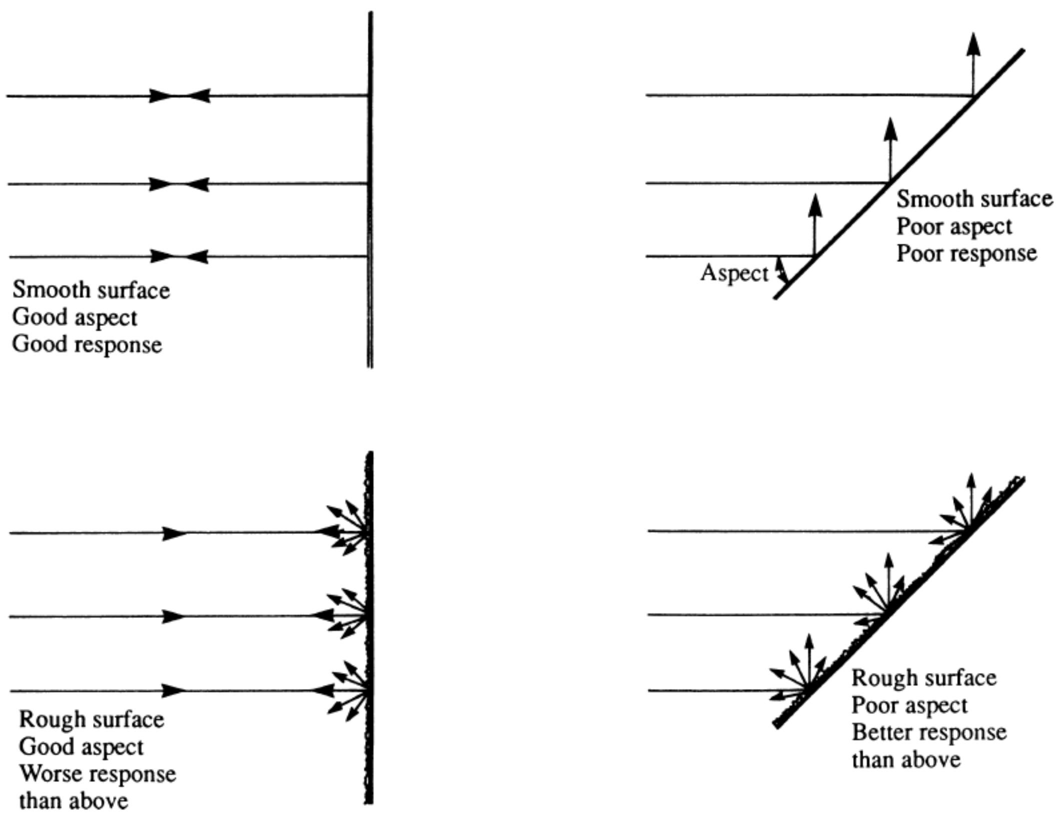
# Creating of radar picture

- Radial distance
  - Corresponds to a number of selected memory cell
  - Is proportional to a distance between radar and target.
- The angular position of the time base on the screen
  - is synchronized with the angular position of the antenna, which allows you to determine the direction in which the detected object is located.

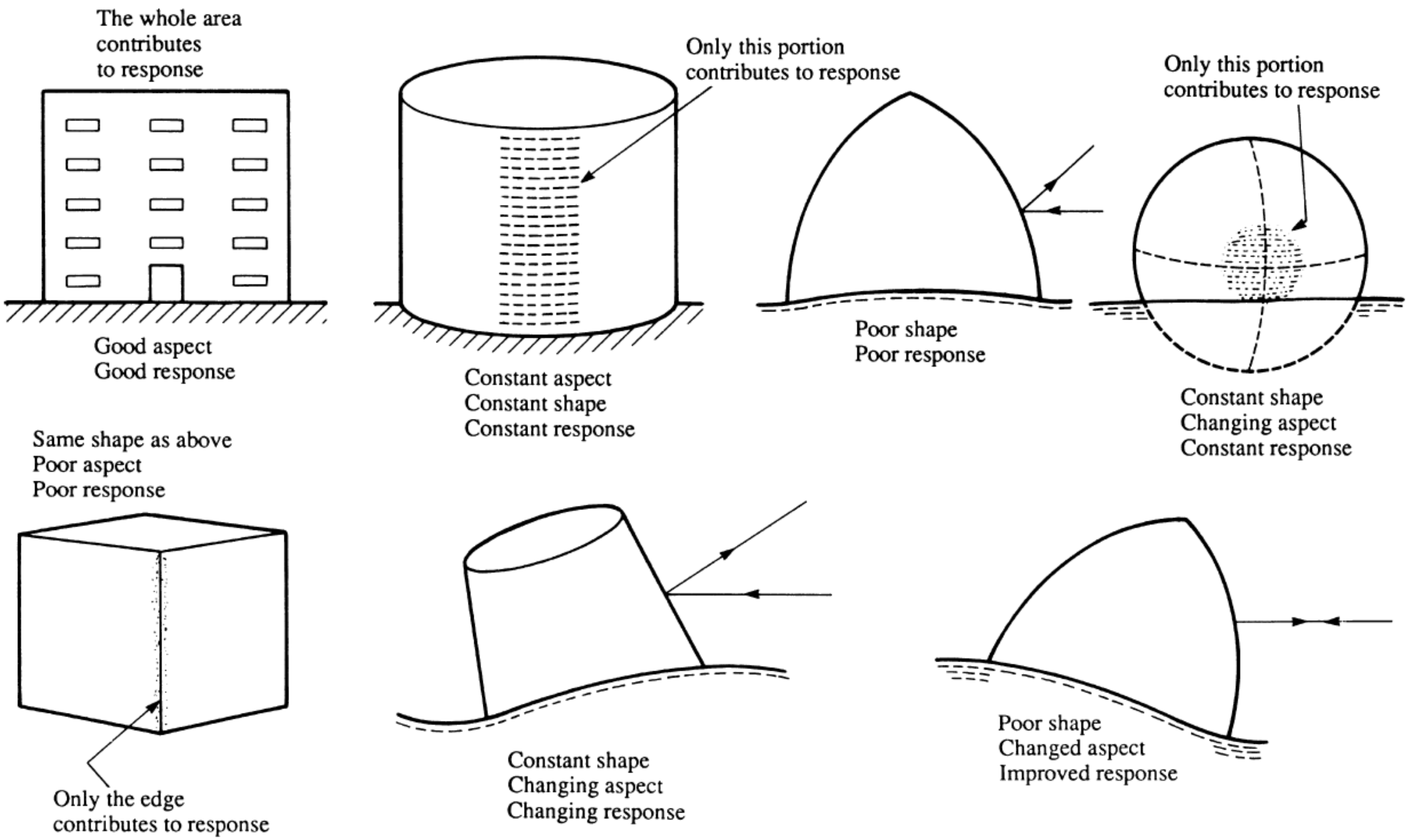
# Radial dimension of an echo

- The radial length of the echo is the sum of the diameter of the dot and half the length of the echo pulse.
- In turn, the duration of the echo pulse may take the smallest value equals to the time of the transmitted pulse or it may be greater by the value of the flying time of microwaves over the object.

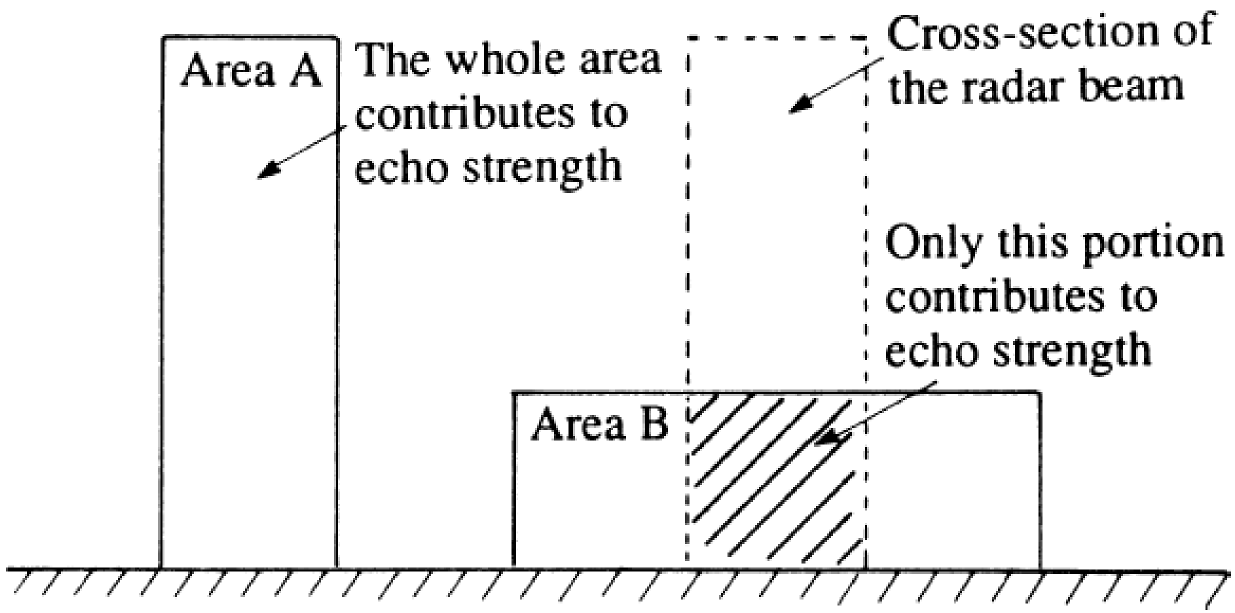
# The influence of the aspect on the target response



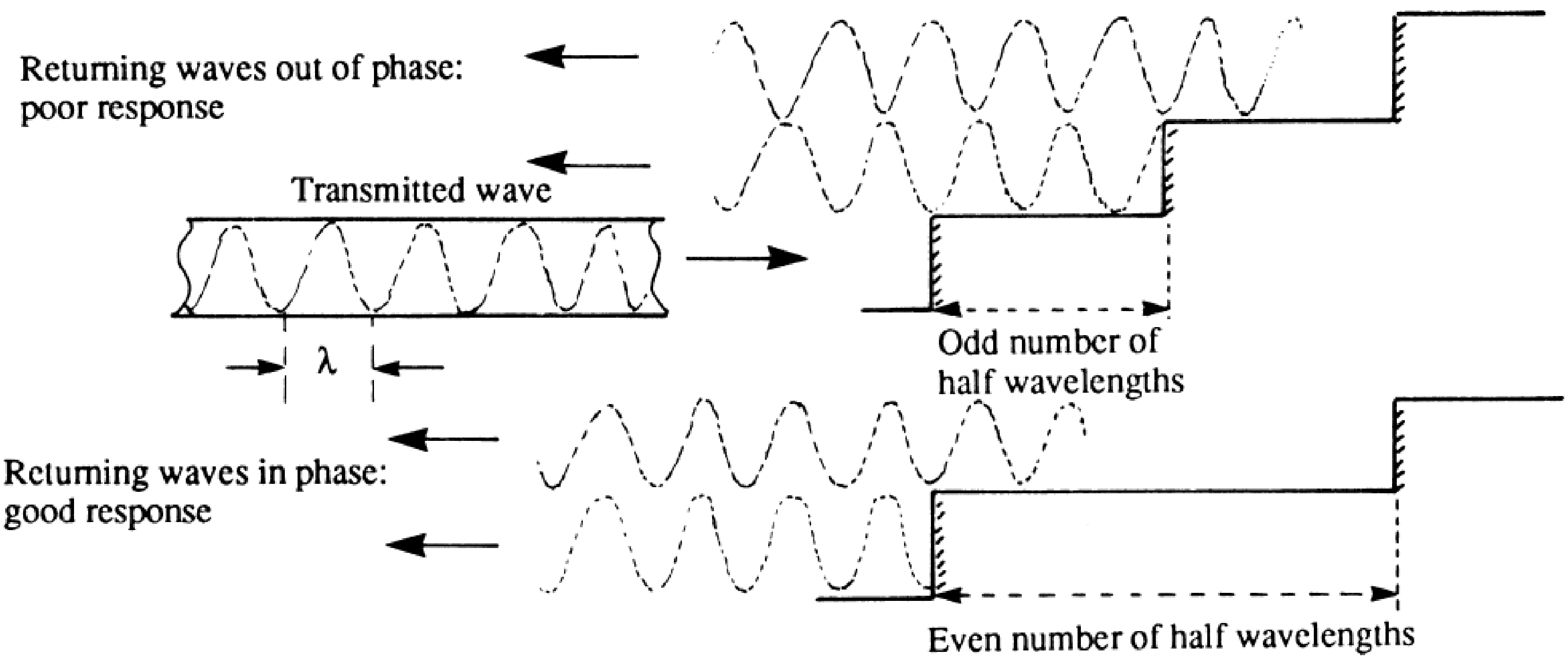
# The influence of the shape on the target response



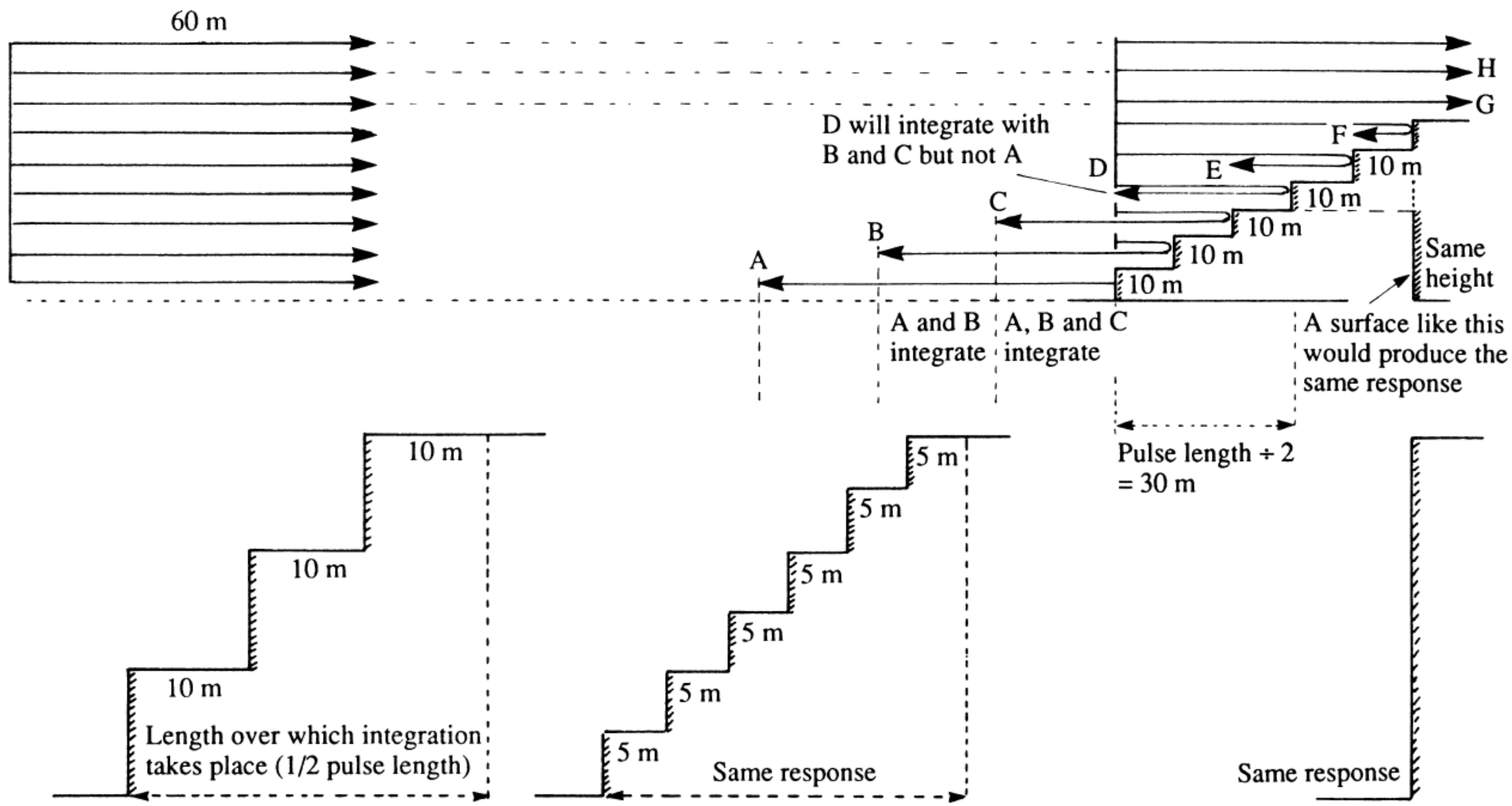
# The effect of irradiated area on target response



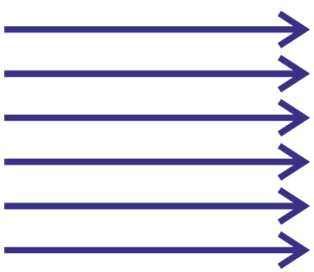
# The effect of coherence on echo strength

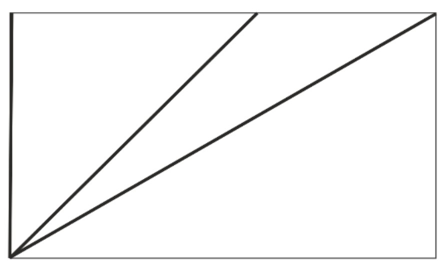


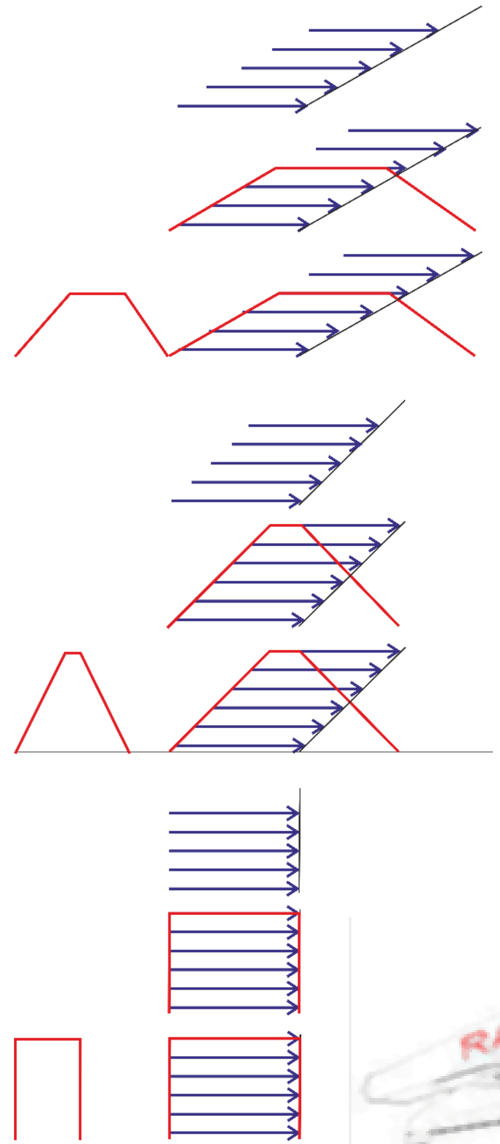
# Integration of signals from sloping surfaces



# Integration of signals from sloping surfaces





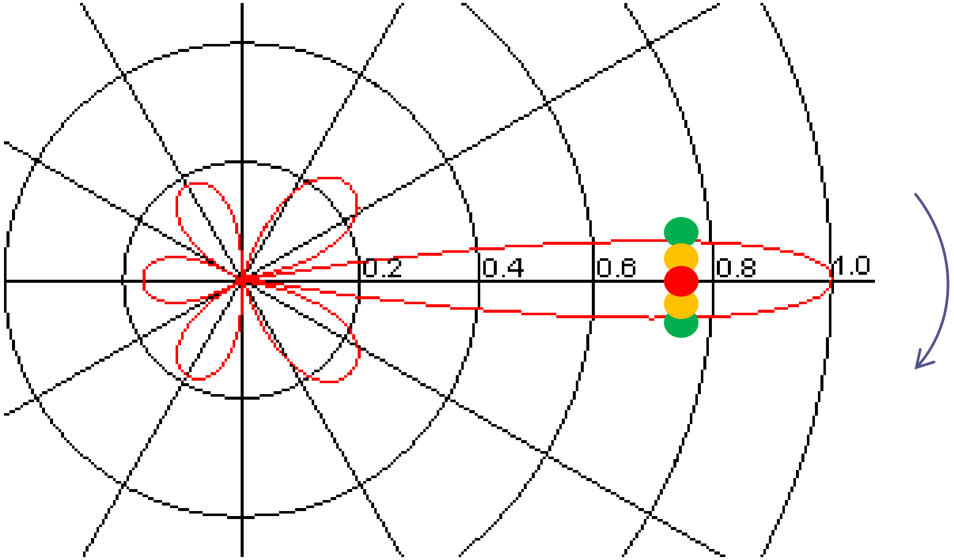


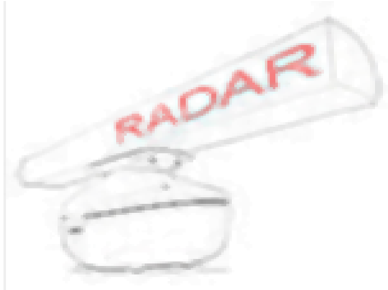
# Angular dimension of an echo

- If the next pulse also hits the object - this will cause the next light dots, shifted slightly in the direction of rotation of the time base but usually overlapping with the previous ones.
- Most often, several, dozen or several dozens of successive pulses hit the point object causing further flashes on the screen, which in effect gives a resultant picture of the echo on the screen.

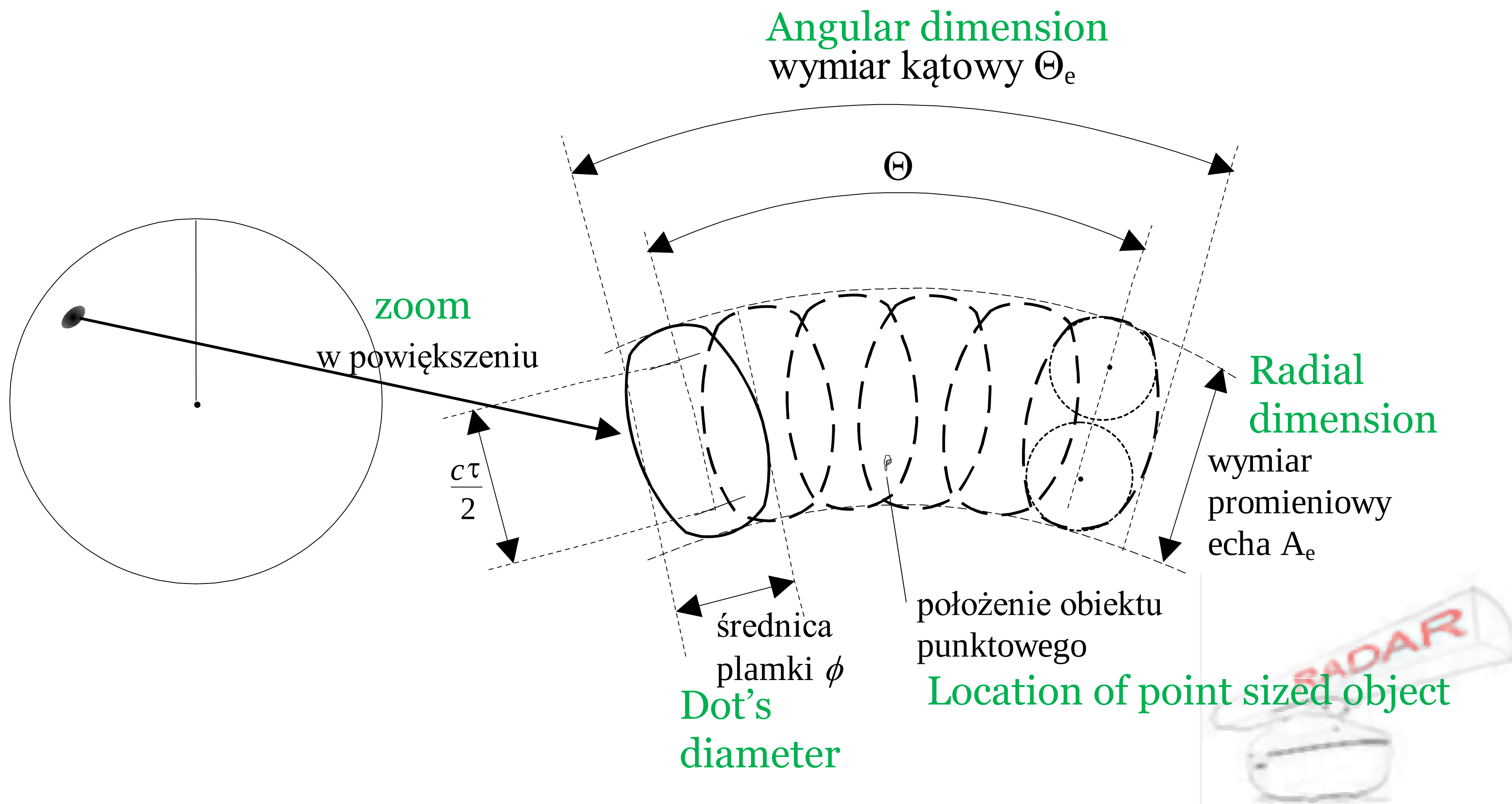
# Angular dimension of an echo

- The lightening of dots last until the whole cross section of the horizontal antenna characteristics move over the object



# The size of the echo from the point sized object



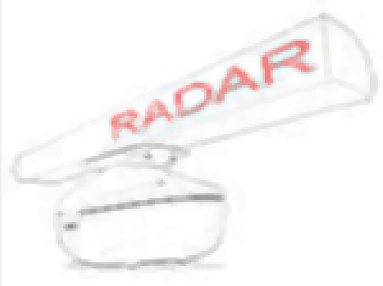
# Dimensions of the echo

- Generally, the dimensions of the echo can be determine by the following relationships:

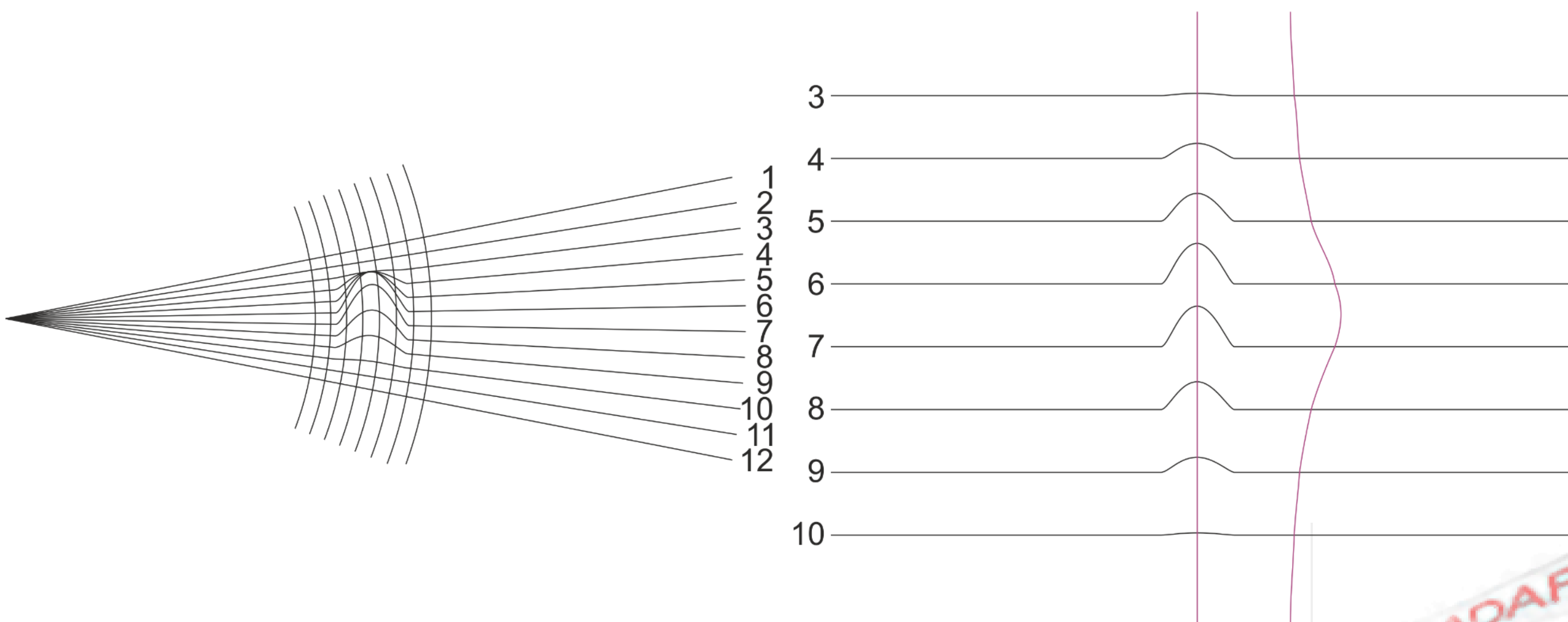
$$A_e = \frac{c\tau}{2} + \phi + r$$

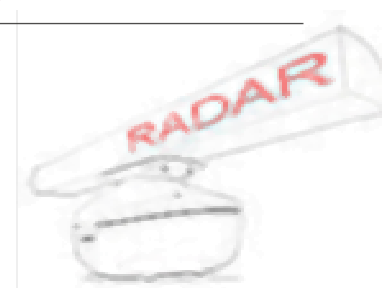
$$\Theta_e = \Theta + \angle\phi + \alpha$$

where :
$A_e$ – radial dimension of the echo,
$\Theta_e$ – angular dimension of the echo,
$r, \alpha$ - radial dimension of the object, the object's angle of view - provided that the object reflects the entire surface



# The echo’s shape



# Number of pulses which irradiates (hits) an object.

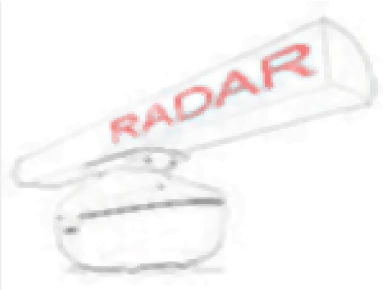
- The number of pulses (m) reflected from the point object during one rotation of the antenna depends on the pulse repetition frequency ($f_p$), the width of the radiation characteristic in the horizontal plane ($\Theta$) and the antenna rotation speed (n), is given by:

$$m = \frac{\Theta * f_p}{6 * n} [bezwym.]$$

dimensionless.

where:

$\Theta$ [°],
$f_p$ [Hz],
n [rot/min]

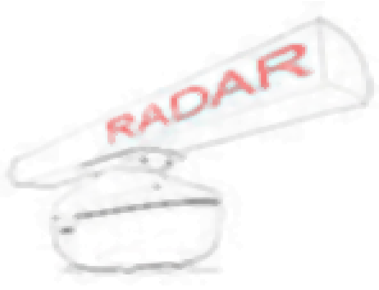


# Variation of the angular dimension of an echo

- It is possible that the first (or last) pulse from the number determined by the equation will not be reflected from the object, as a result of which the width of the echo will decrease.
- The angular width between the two pulses ($\aleph$) is :

$$\aleph = \frac{6*n}{f_p}[^\circ]$$

reduction of the echo width - the echo pulsation would be equal $\aleph$.



The end