Radar: Basics – scenario 2a

Probability of Detection P(D): variation with distance and relation to the horizon

Probability of Detection P(D)

• The reflected radar signal strength [dBm or dBW] returned from a target may be calculated using the radar equation and measured or estimated values of radar and target parameters.

• The target Radar Cross-Section (RCS) [metres-squared] can been estimated from the target type (medium airliner) and radar frequency.

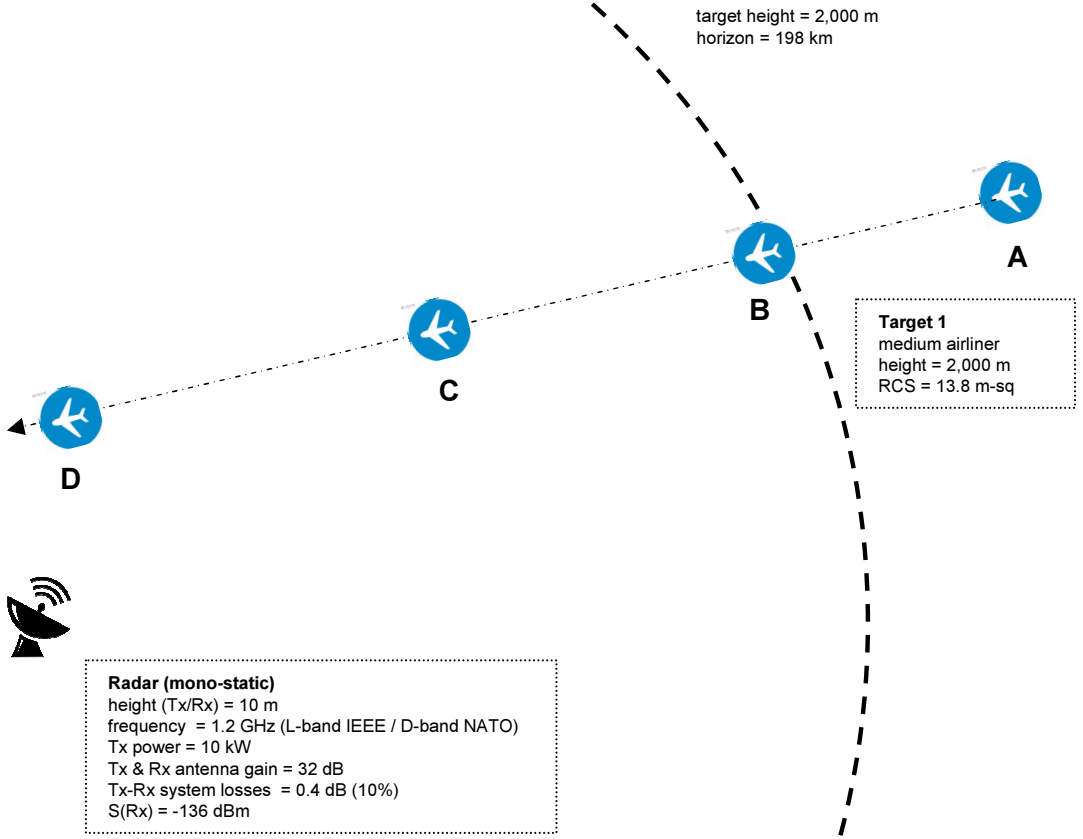
• Once the target signal strength has been determined, a Signal to Noise Ratio (SNR) may be calculated by using the estimated or measured external noise floor or the receiver sensitivity S(Rx), whichever is the higher. In this scenario the external noise is assumed to be below the S(Rx).

• The SNR provides the 'percentage outage' and thus the Probability of Detection P(D) as a percentage.

• As the target has quite a large RCS, it is at least partially visible as it crosses the radio horizon for the given target and radar heights.

• No matter how large the RCS, the target will not be seen beyond the horizon.

• For simplification a mono-static radar, co-located Tx and Rx antennas, is used rather than a bi-static radar with physically separated antennas.



A: range = 255 km , P(D) = 0% (outside radar horizon)

B: range = 197 km, P(D) = 30% (crossing horizon)

C: range = 120 km, P(D) = 90%

D: range = 50km , P(D) = 100%

Scale: 40 km

Spectrum Skywave

Radar: Basics – scenario 2b

Probability of Detection P(D): Smaller RCS target and relation to the horizon

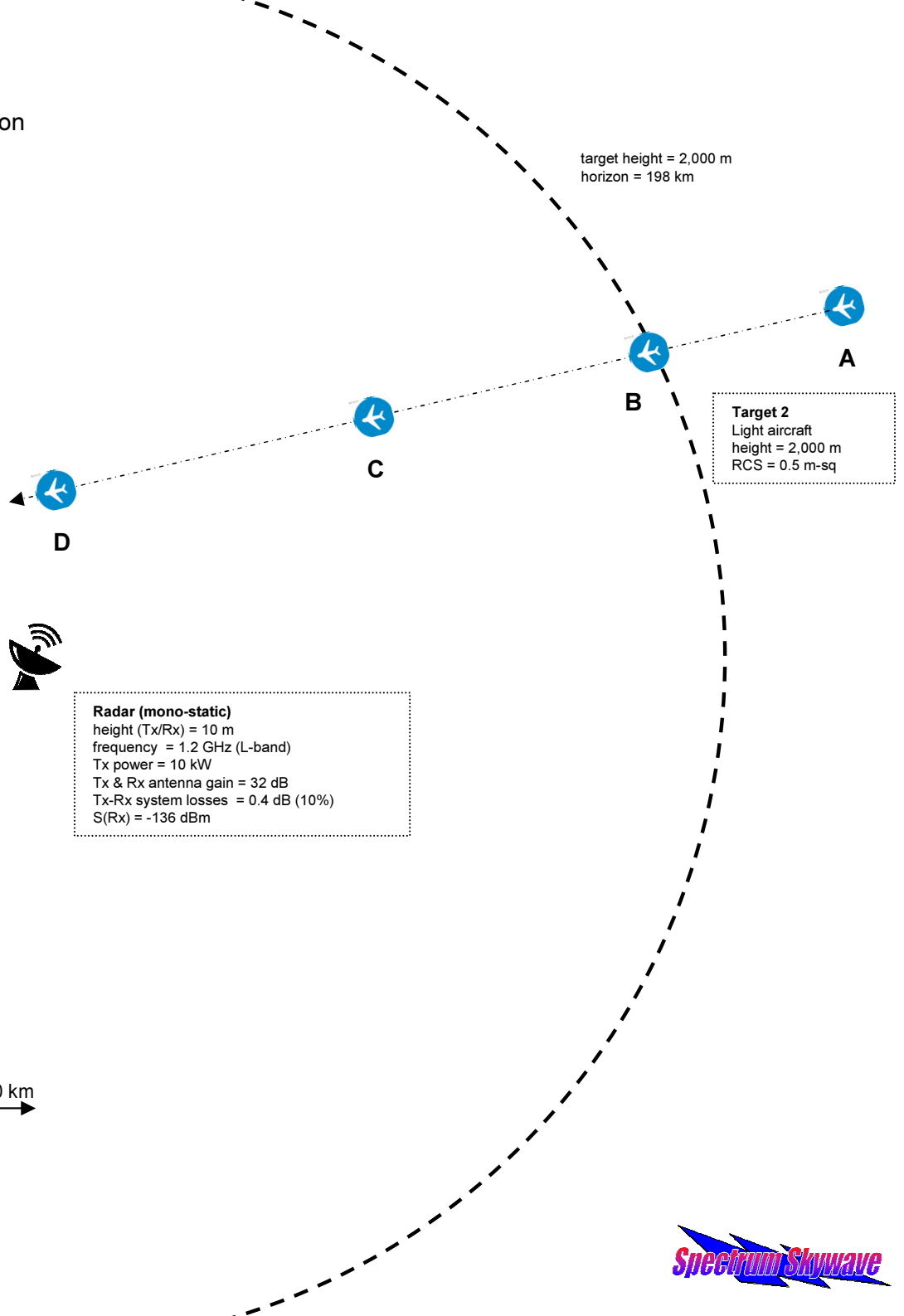
- The light aircraft target has a much lower RCS than the medium airliner from the previous scenario.
- The target cannot be seen outside the horizon, as for the airliner, but differently from the airliner it cannot be seen as it crosses the horizon, as the reflected signal is too weak to be detected.
- The target cannot be detected at 120km range (point C), despite the relatively high Tx power (10kW) and antenna gains (32dB).
- At 50km range the probability of detection is quite high at 92%. The target crossed the 50% detection threshold at ~80km.

A: range = 255 km , P(D) = 0 % (outside radar horizon)

B: range = 197 km, P(D) = 0 % (crossing horizon)

C: range = 120 km, P(D) = 0 %

D: range = 50km , P(D) = 92 %



Radar: Basics – scenario 2c

Probability of Detection P(D): Ground reflection loss for surface targets

- For land and maritime scenarios where the targets are near ground or sea level, and the radars are mounted on vehicles or ships at heights of a few metres, the radio waves suffer extra attenuation or 'two-ray loss' from ground reflection as the direct and reflected rays interfere.

- Two-ray loss occurs outside the Fresnel Zone which depends on radar and target heights, and the frequency used. Inside the Fresnel Zone there is only 'free-space loss' which is lower than two-ray loss.

- Two targets are shown to illustrate the difference. The air target has a lower RCS than the surface target but is much higher altitude.

- The air target is well within the Fresnel Zone (2,000 km) for it's altitude and the radio signals only suffer free space loss (in both directions).

- The surface target has a Freznel Zone of only 5 km and suffers two-ray loss (in both directions) for the signals from all the targets shown.

- It can be seen at 20km range the surface target is undetectable, whereas the air target has a high 91% probability of detection, despite being much smaller.

- As the range is decreased to 16 km the surface target is usefully detectable at 55% but still much lower than the 96% for the air target.

- At a range of 8 km, despite being outside the 5km Fresnel Zone and still suffering two-ray loss, the surface target is 100% detectable due to the Tx power and antenna gains overwhelming the loss.

- If the Tx power or antenna gains were lowered, the surface target would lose detection probability faster than the air target whilst both were outside the Fresnel Zone (5 km) of the surface target, as the surface target suffers two-ray loss but the air target only free-space loss.