Radar: Basics – scenario 8a

Target Doppler velocities and Receiver Bandwidth

- Radar reflections from a moving target are returned to the Rx with a Doppler shifted frequency away from the Tx frequency, proportional to the frequency used and the target line-of-sight (LOS) speed.

- The Rx frequency and bandwidth (BW) must be arranged to accommodate the range of possible target Doppler velocities, both towards and away from the radar. Faster moving air targets perhaps requiring a wider BW than slower moving surface ones, to correctly resolve speeds.

- The bandwidth (BW) used by the Rx is important is determining in the Rx sensitivity S(Rx) and external noise passed into the Rx, as a wider BW decreases sensitivity and raises the noise admitted.

- BW = 450Hz will be used initially to limit the noise. External noise is the “rural” level of -165dBm at 1.2GHz and the 450Hz bandwidth. This noise level is 29dB below the S(Rx) and hence the Rx is ‘internally noise limited’.

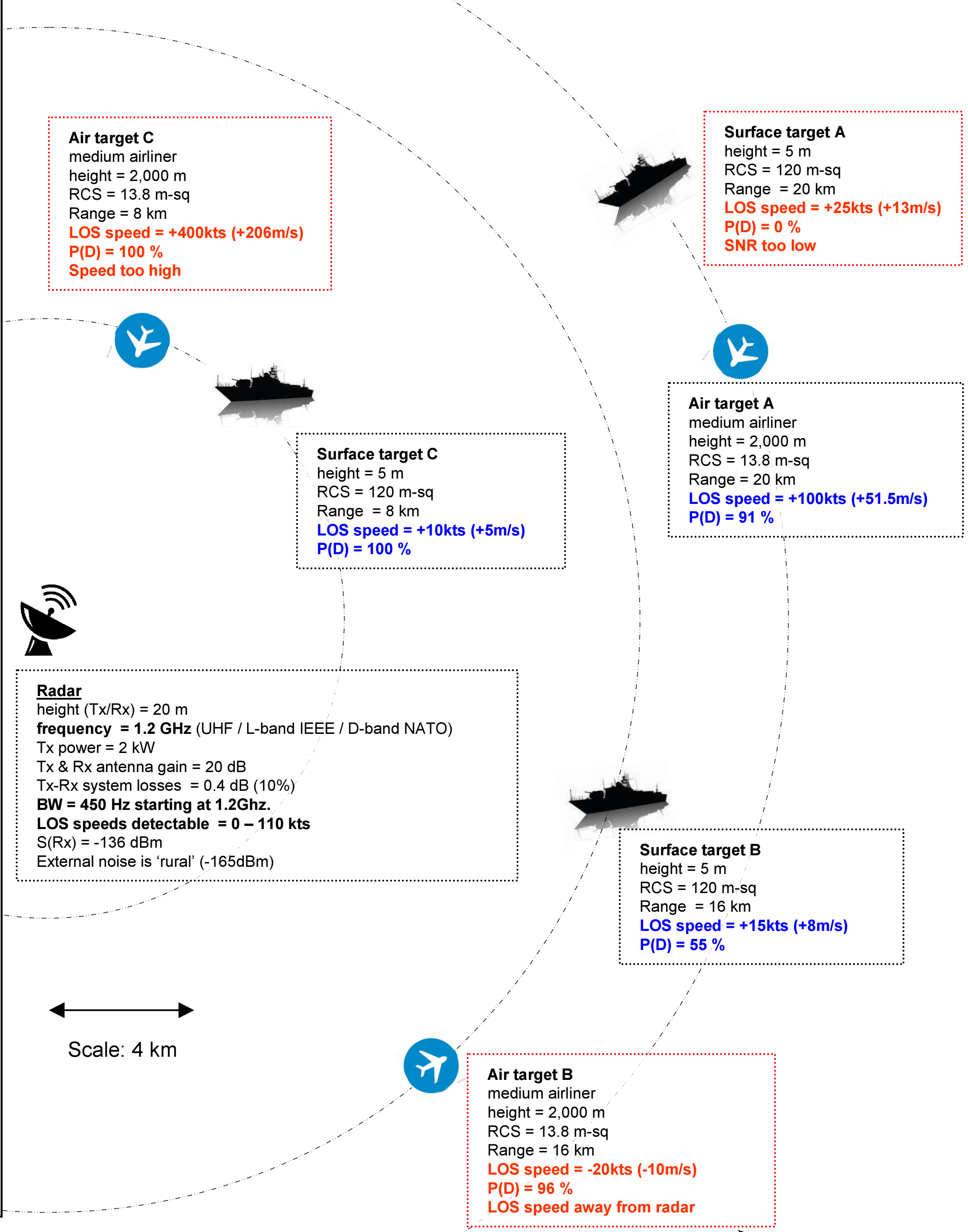
- Air and Surface targets at different ranges and LOS speeds are shown. If the Surface targets are travelling at 25kts and the Air targets at 400kts then the LOS speeds are determined by the orientation of the target and the velocity component towards or away from the radar.

- The probability of detection P(D), based on SNR is also shown. Some targets Doppler velocity may fall within the Rx BW but the target may not be detectable, and vice versa.

- For BW = 450Hz at 1.2GHz the ***maximum resolvable Doppler velocity is +56 m/s (110 kts, 203 km/hr)*** towards the radar.
- If the BW low end is at the Tx frequency of 1.2GHz, then targets up to the full +56 m/s may be resolved, but only towards the radar. *This case is shown here.* Negative LOS speed (e.g. Air target B) for targets receding cannot be observed. Usually the BW would be evenly distributed around the Tx frequency to observe targets moving towards and away, but only up to half of 56m/s (-28 m/s to +28 m/s).

- Any target with a LOS speed greater than that resolvable by the Rx BW will have it’s reflected signal Doppler shifted outside the BW and will not be heard.

- For the example targets, the LOS speed and P(D) are highlighted in **blue** if the target is observable in both SNR and Doppler and **red** if it is not. Air Targets B and C cannot be observed as their reflected frequencies fall outside the Rx BW even though P(D) is high. Surface target A cannot be seen as the SNR and P(D) is too low even though the LOS speed is low enough.



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Radar: Basics – scenario 8b

Target Doppler velocities and Receiver Bandwidth: Wide bandwidth to cover all speeds

- A more realistic wider bandwidth (BW), both sides of the Tx frequency, will be chosen to observe all the target LOS speeds. However, this will increase the Rx sensitivity S(Rx) threshold (less sensitive) and the noise floor, lowering the level of the signal above the sensitivity and hence the detection probability P(D).

- The highest LOS speed is +400kts for Air target C so a BW should be chosen to encompass at least Doppler shifts from -400 kts to +400kts. A speed of 485kts (~900km/hr) will cause a frequency shift of 2kHz at 1.2GHz.

- ***A BW = 4kHz will be used to cover LOS speeds up to +/- 485kts***. This is 889 times the previous bandwidth of 450Hz. The S(Rx) increases 9dB (less sensitive) from -136dBm to -127dBm. The external noise admitted to the Rx for the "rural" level increases 9dB from -165dBm at 450Hz BW to -156dBm at 4kHz BW, still 29dB below the S(Rx) and hence the Rx is still 'internally noise limited'.

- With such a high Rx sensitivity, the reflected power is too low for Surface targets A and B to get a positive SNR and hence P(D) = 0% for them. Air target A has a positive but very low P(D) of 17% and Air target B only a useable 66%.

- Hence a very wide Rx BW is not a practical solution to observing the Doppler shifted frequency at the Rx for a wide range of LOS speeds and a different approach is required.

- An expensive solution is to use higher Tx power, raise the Tx/Rx antennas heights, or increase the antenna sizes for more gain. These will result in a high SNR.

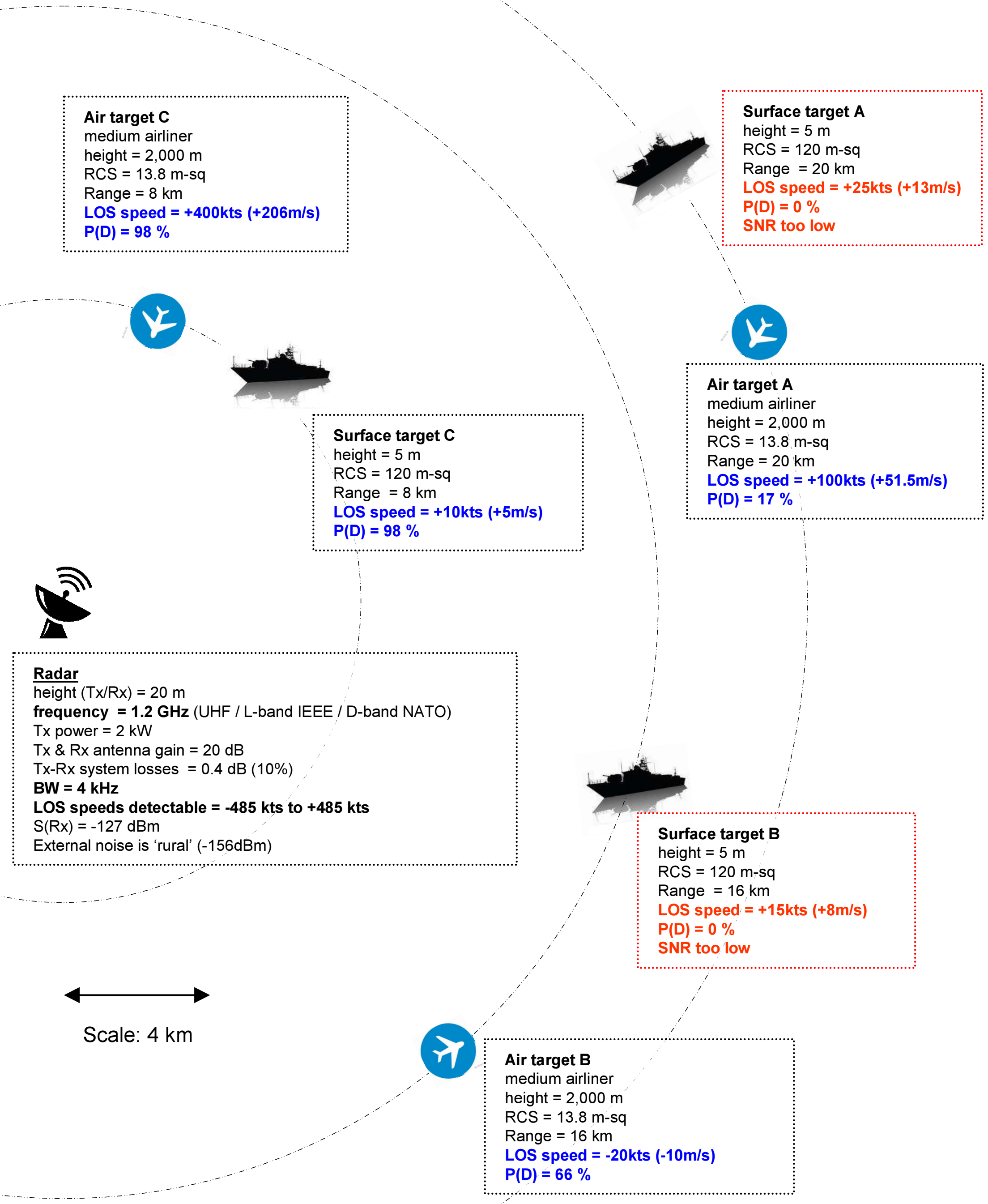
- It would be more efficient to use a narrower Rx BW and either;

(a) set the Rx frequency near where LOS speeds are expected

(b) scan the Rx in frequency using the narrower BW to detect the Doppler shifted returns when they coincide, or

(c) use multiple Rx for different LOS speeds and Doppler shifts, each with narrow BW.

- Option (b), scanning the possible Doppler shifted frequencies with a low BW Rx will be examined.



Radar: Basics – scenario 8c

Target Doppler velocities and Receiver Bandwidth: Scanning Rx using narrow BW

- Returning to the original Tx power, Tx/Rx antenna gains and heights of scenario 8a, if a narrow enough Rx BW can be used then perhaps even the Surface target A can be seen, that had previously too low SNR.

- The problem then will be how many frequency bins to scan the Rx across to cover the possible range of all target speeds, towards and away from the radar. When combined with angular scanning, the frequency scan may present an unfeasibly large number of combinations.

- If a very low Rx BW of 50Hz is used then the Rx sensitivity drops by 10dB to -146dBm (with external noise to -175dBm), and Surface target A has a P(D) of 70%, which is useable. A smaller BW than 50Hz is possibly not viable.

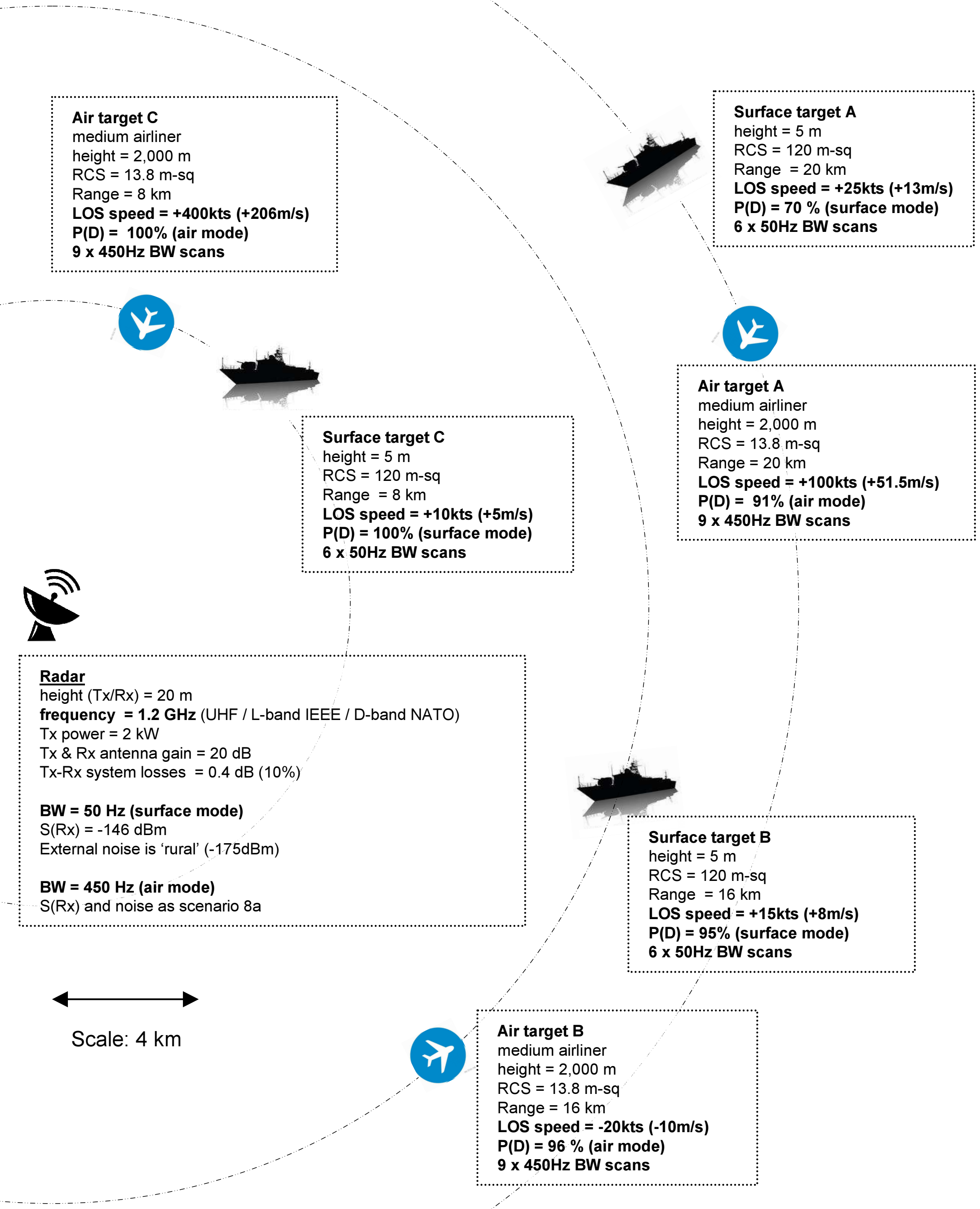
- Surface target A has a LOS speed of +25kts (+13m/s) and so the returned Doppler velocity to the Rx will be 103Hz above the transmitted 1.2GHz. If six 50Hz BW scans were made from 150Hz below 1.2GHz to 150Hz above then target speeds of -36kts to +36 kts would be detected, enough for all the surface targets with maximum speeds of 25kts.

- If the range of air target speeds was +/- 485kts (~ +/- 900 km/hr), then the maximum Doppler shifts would be +/- 2kHz, which is 4kHz wide and 80 bins of 50Hz BW. A fairly frequency agile Rx might manage 100 frequency changes per second, so scanning 80 bins would require only 0.8 secs. However, the angular beam for a typical efficiency parabolic antenna of 20dB gain is 18 degrees, so a 360 degree sweep would take 16 secs, perhaps a little slow for air targets.

- Also the 50Hz bandwidth raises the SNR for the air targets such that Target A has P(D) = 99% and Target B is 100%, so there is some SNR margin to trade for scan speed.

- If the radar had an *'air mode'*, with BW of the previous 450Hz, then the P(D) for Air target A would be an acceptable 91% and Air target B would be 96% (as in scenario 8a).

- If the BW = 50Hz were a *'surface mode'* then the air mode with 9 times wider BW would scan 9 times faster, requiring only 9 frequency scans to cover 4kHz. Hence the 16 sec scan for a 360 degree sweep would be reduced to 1.8 secs, more viable for rapidly moving air targets.



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