Radar: Basics – scenario 4a

Probability of Detection P(D): Variation with Tx power

- The effectiveness of increasing Tx power to overcome low probability of detection will be examined using a high propagation loss scenario where the surface targets are outside the Fresnel Zone (5km) and two-ray loss applies. The radar horizon is 27.7km, beyond Target A.

- The ship target has a radar cross section typical of a vessel of a few hundred tonnes and centre 5m above the waterline.

- Radar-1 using Tx power of 2kW cannot observe Target A at 20km range, and only achieves 55% probability for Target B at 16 km range.

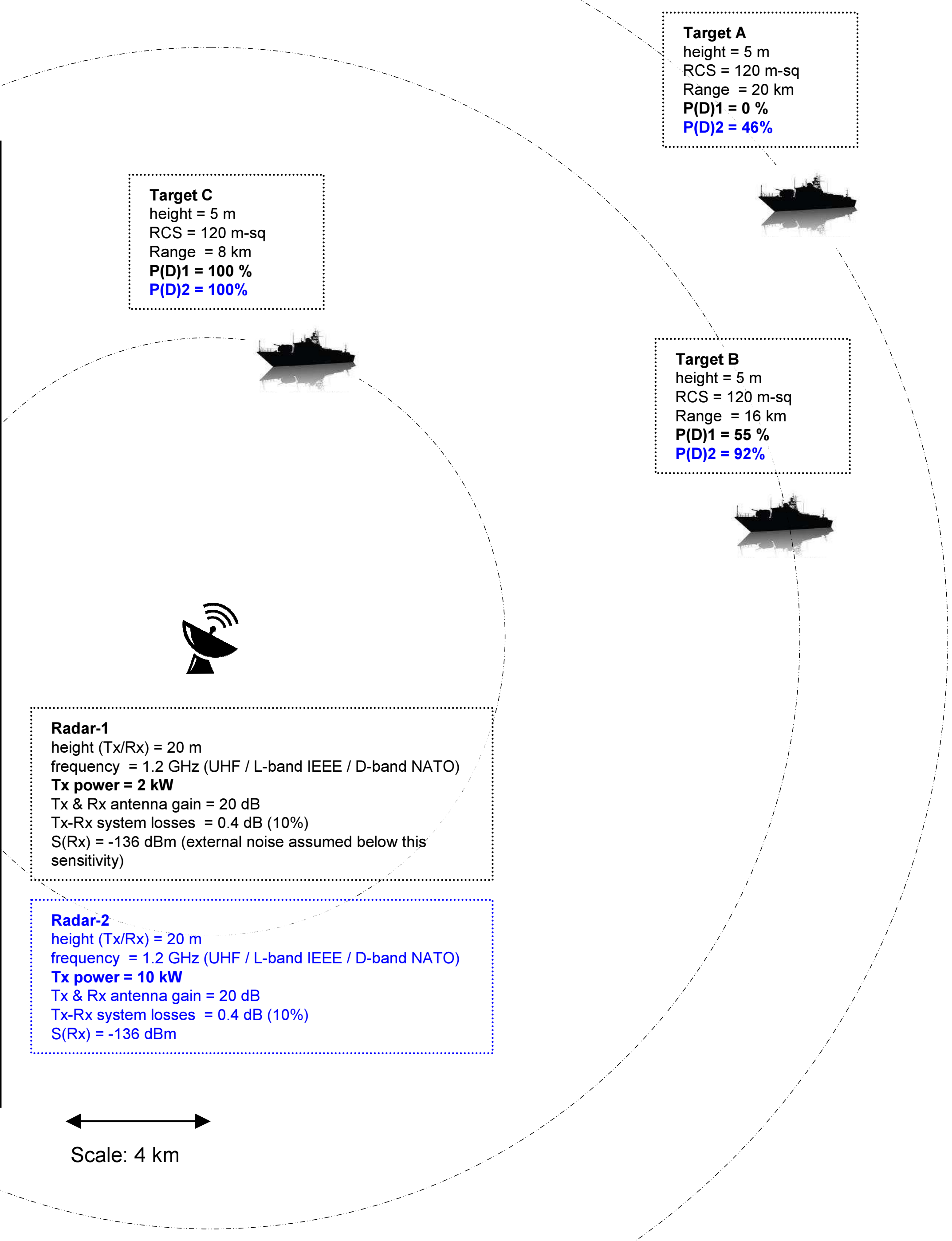
- To achieve only a marginal 46% probability of detection at 20km range (Target A), a considerable Tx power of 10kW is required, as used by Radar-2. At 16km range (Target B) a fairly high 92% probability of detection is achieved, far better than the 55% for 2kW for Radar-1.

- At close range of 8km (Target C) both Tx powers provide 100% probability of detection. However, the excess SNR above the threshold is much greater for Radar-2 10kW as a buffer against a rise in the noise floor or introduction of extra propagation attenuation.

- A Tx power of 10kW may be excessive for some smaller systems in terms of expense or EM radiation hazard, and perhaps not the most efficient way to increase detection probability.

- For an observer at 20m height and a 5m high target, the actual horizon would be 20.7km range and the optical horizon at 23.4km.

- Use of radar at these ranges may seem redundant in perfect optical visibility, but if the visibility is less than optimal in haze, fog or rain then the vessel may not be visible even at 8km range.



Target A
height = 5 m
RCS = 120 m-sq
Range = 20 km
P(D)1 = 0 %
P(D)2 = 46%

Target C
height = 5 m
RCS = 120 m-sq
Range = 8 km
P(D)1 = 100 %
P(D)2 = 100%

Target B
height = 5 m
RCS = 120 m-sq
Range = 16 km
P(D)1 = 55 %
P(D)2 = 92%

Radar-1
height (Tx/Rx) = 20 m
frequency = 1.2 GHz (UHF / L-band IEEE / D-band NATO)
Tx power = 2 kW
Tx & Rx antenna gain = 20 dB
Tx-Rx system losses = 0.4 dB (10%)
S(Rx) = -136 dBm (external noise assumed below this sensitivity)

Radar-2
height (Tx/Rx) = 20 m
frequency = 1.2 GHz (UHF / L-band IEEE / D-band NATO)
Tx power = 10 kW
Tx & Rx antenna gain = 20 dB
Tx-Rx system losses = 0.4 dB (10%)
S(Rx) = -136 dBm

Scale: 4 km

Spectrum Skywave

Radar: Basics – scenario 4b

Probability of Detection P(D): Variation with antenna gain

- An alternative to increasing Tx power is to use higher gain antennas. In this case where a mono-static radar uses the same antenna for Tx and Rx, the increase in antenna gain over isotropic (dBi) is applied twice, once for the transmitted signal and again for the received one. The Tx power is held constant at 2kW for Radars 1 and 2.

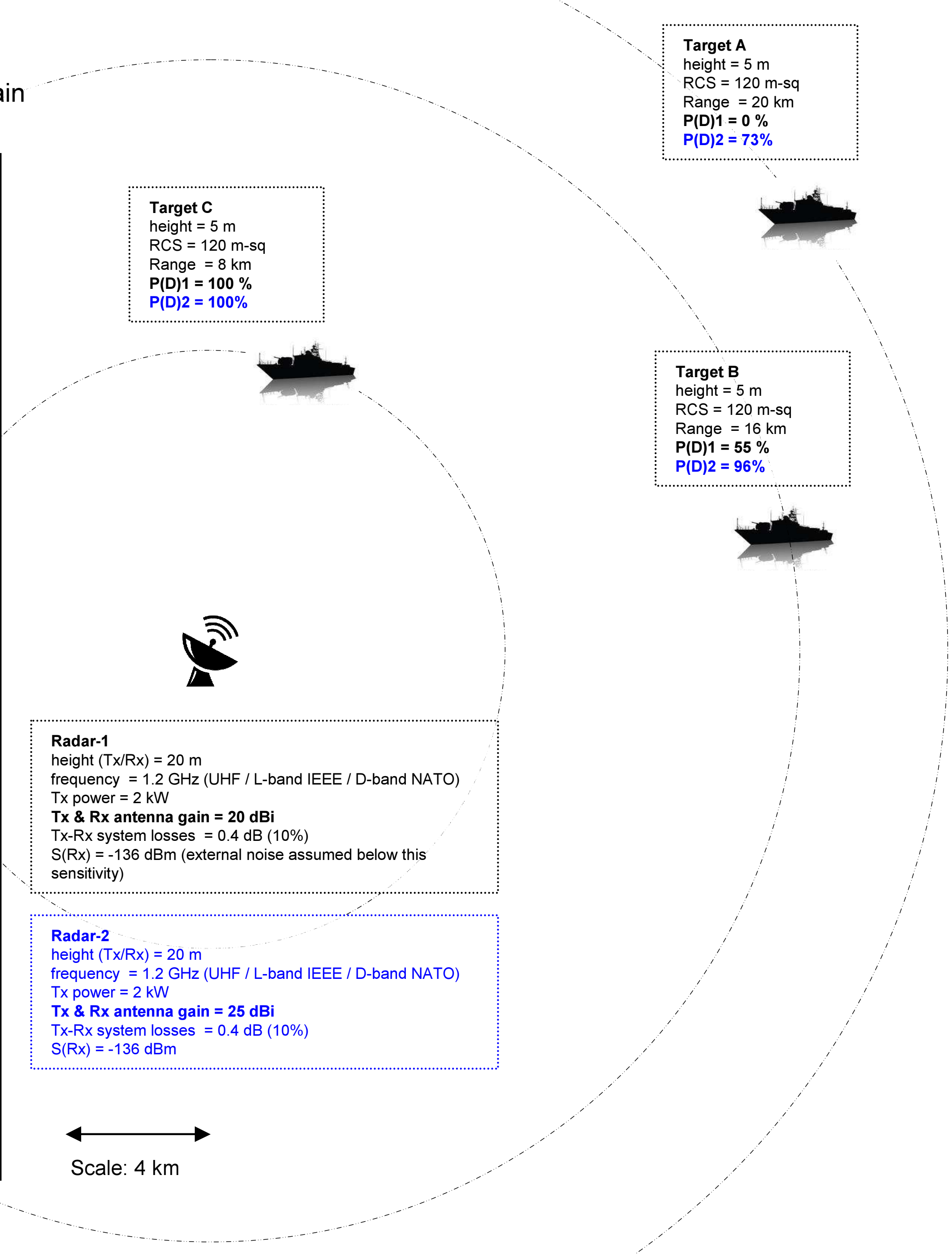
- Radar-2 antenna has an extra 5dBi of gain over Radar-1, increasing from 20dBi to 25dBi. Hence there is a 10dBi increase overall. This is 3dB more than the increase in Tx power from 2kW to 10kW in scenario 4a.

- At a range of 20km for Target A, where a 20dBi antenna gain does not permit detection, a 25dBi antenna results in a useable 73% probability of detection. At 16km for Target B the probability is a high 96%.

- The antenna size to achieve 20dBi of gain at 1.2GHz would be ~0.5 m-sq, 71cm per side for a square panel or 80cm diameter for a dish. A 25dBi antenna would be ~1.6 m-sq , 126cm per side for a square panel and 143cm diameter for a dish. The 5dB increase requires less than double the length on each side of a square panel and slightly over double the diameter for a dish. The size is still relatively small and the cost may be less than a 10kW transmitter.

- If a typical 55% efficiency parabolic antenna were used then 20dBi gain implies a 3dB beamwidth of 18 degrees, whereas a 25dBi gain implies 10 degree beamwidth, also improving angular resolution of the targets.

- A more efficient but also more expensive antenna would be a phased array. To achieve 25dBi gain an array of 360 elements (20 x 18), each element an isotropic 0dBi, could be used. The very rapidly electronically steered beam would have a 3dB beamwidth of only ~0.3 degrees and would have at least 25dBi gain within 12 degrees of boresight. The panel could be mechanically steered to re-align the boresight as per a normal single element antenna.



Target A
height = 5 m
RCS = 120 m-sq
Range = 20 km
P(D)1 = 0 %
P(D)2 = 73%

Target C
height = 5 m
RCS = 120 m-sq
Range = 8 km
P(D)1 = 100 %
P(D)2 = 100%

Target B
height = 5 m
RCS = 120 m-sq
Range = 16 km
P(D)1 = 55 %
P(D)2 = 96%

Radar-1
height (Tx/Rx) = 20 m
frequency = 1.2 GHz (UHF / L-band IEEE / D-band NATO)
Tx power = 2 kW
Tx & Rx antenna gain = 20 dBi
Tx-Rx system losses = 0.4 dB (10%)
S(Rx) = -136 dBm (external noise assumed below this sensitivity)

Radar-2
height (Tx/Rx) = 20 m
frequency = 1.2 GHz (UHF / L-band IEEE / D-band NATO)
Tx power = 2 kW
Tx & Rx antenna gain = 25 dBi
Tx-Rx system losses = 0.4 dB (10%)
S(Rx) = -136 dBm

Scale: 4 km