Radar: Basics – scenario 9a

Pulse Repetition Frequency (PRF), Pulse Repetition Interval (PRI), Pulse length/width and range resolution

- A pulsed, as opposed to continuous wave (CW), radar will transmit pulses with a certain repetition frequency (PRF) and interval (PRI) between them. PRF and PRI are inverses of each other.

- The repetition of pulses (PRF) is often in hundreds of Hz and the interval between them (PRI) is often a few milliseconds. e.g. PRF = 361 Hz and PRF = 2.77 msecs (2,770 usecs). The distance between these pulses is 831km.

- The pulsewidth is often a few microseconds (usecs) down to a fraction of a microsecond and the length of the pulse a few kilometres. e.g. a 10usec pulsewidth would have a length of 3 km and, if the PRI were 2.77 msecs, then the distance between pulses would be 277 times the pulse length (831 km). The radar has a duty cycle of only 0.4% as the pulselength is so short compared with the PRI.

- The range resolution is half the pulse length, so for a 10usec pulsewidth the resolution would be 1.5km. The pulse would contact and reflect from the target in 10usecs. Each 'range gate' would be 1.5km.

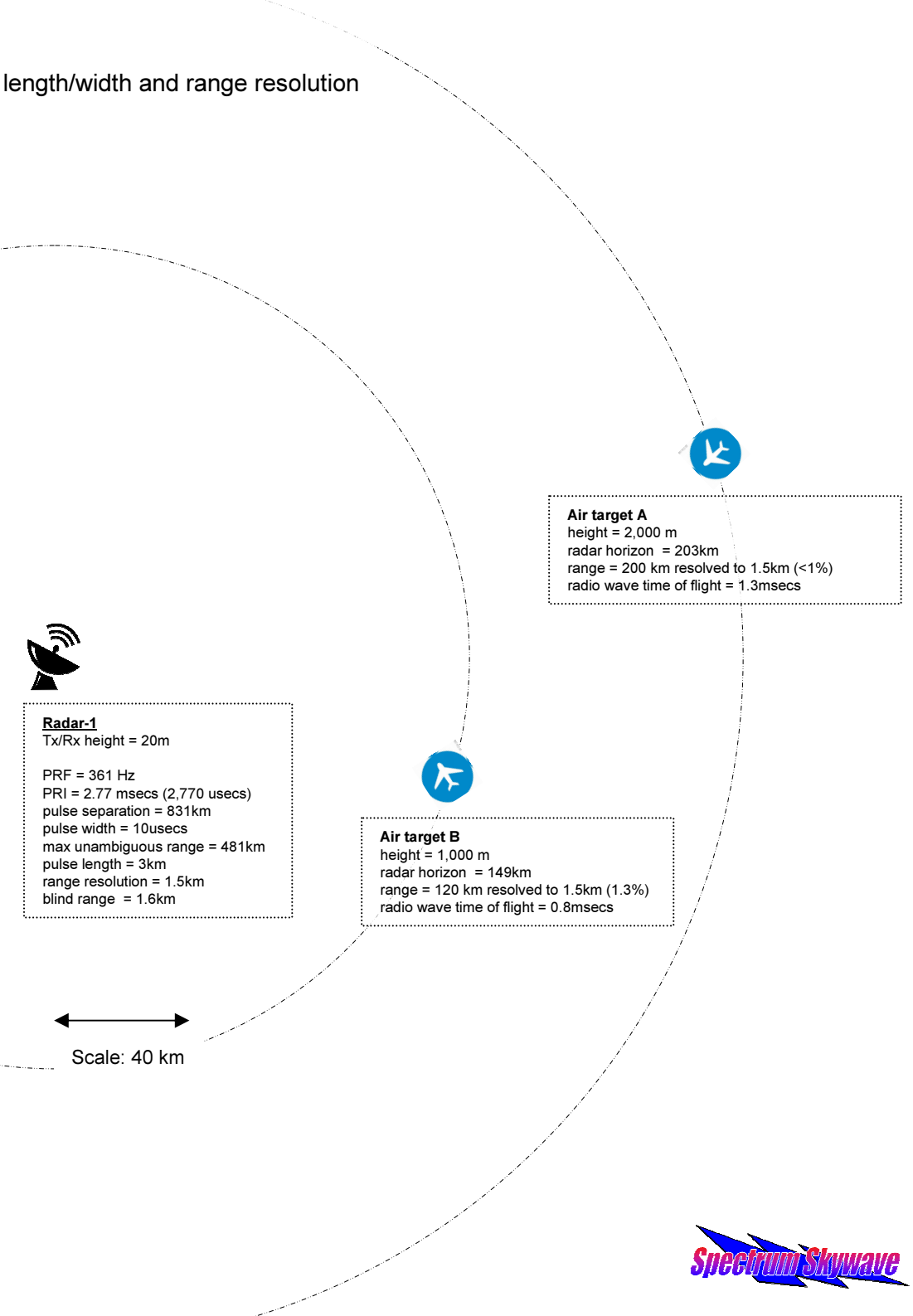
- Maximum unambiguous range, before the round trip time from target reflection exceeds the time between pulses, is determined by PRI and pulsewidth, particularly PRI. A PRI of 2.77msecs and pulsewidth of 10usecs implies a maximum unambiguous range of 418km. It should be noted that the radar horizon may be closer than this, e.g. if the Tx/Rx height = 20m and and the target has an altitude of 2000m, then the horizon is only 203km.

- Often lower PRI (higher PRF) is used for shorter ranges (e.g. tracking) and higher PRI (lower PRF) for longer ranges (e.g. search).

- There is also a minimal measuring range Rmin or "blind range" below which there are no returns. This is slightly higher than the range resolution to allow for 'recovery' by the Rx. For a pulsewidth of 10usecs the blind range is 1.6km.

- For the air targets shown, both are inside the respective radar horizons for their height, which are also inside the maximum unambiguous range. The time of flight for the radio wave to the targets and back is less than the 2.77msecs between pulses, 47% of inter-pulse time for Target A and 29% for Target B.

- The high range resolution of 1.5km ensures both targets have range determined with an error of less than 1.5%. Target A would be in the 133rd range gate and Target B in the 80th.



Radar: Basics – scenario 9b

Modulation on Pulse (MOP) to improve range resolution – phase coding

- A different radar is shown with lower PRF and longer pulse-width than scenario 9a, perhaps optimised for longer ranges as a tracking radar. The radar parameters are shown in the box.

- Due to the long pulse-width, lessening instantaneous Tx power required, the 'range resolution 1' is poor. Target B lies in the 2nd range gate and would only be known to be between 64.4km and 128.8km. Target A lies in the 4th range gate and would only known to be between 193.2km and 257.6km.

- The range resolution may be substantially improved by using Modulation on Pulse (MOP) or 'pulse compression' techniques. These may be achieved by phase or frequency coding.

- The phase coding breaks the pulse into a certain number of bits, which when decoded by the Rx, substantially improves the resolution. 'Range resolution 2' uses a 13 bit code (e.g. 'old' Barker code) to achieve 4.7km which is 13 times higher resolution.

- Target B is now in the 25th range gate and distance determined with 3.9% accuracy (13 times improvement) to be located between 117.5km and 122.2km.

- Target A is in the 42nd range gate and distance determined with 2.4% accuracy (13 times improvement) to be between 197.4km and 202.1km.

Radar-2
Tx/Rx height = 20m

PRF = 241 Hz
PRI = 4.15 msecs (4,150 usecs)
pulse separation = 1,245km
pulse width = 410usecs
max unambiguous range = 567km
pulse length = 123km
blind range = 64.4km

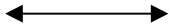
range resolution 1 = 61.5km
range resolution 2 = 4.7km

Air target A
height = 2,000 m
radar horizon = 203km
range = 200 km

resolution 1 = 31%. 4th range gate
resolution 2 = 2.4% (13X improvement) . 42nd range gate

Air target B
height = 1,000 m
radar horizon = 149km
range = 120 km

resolution 1 = 51%. 2nd range gate.
resolution 2 = 3.9% (13X improvement) . 25th range gate



Scale: 40 km

Radar: Basics – scenario 9c

Modulation on Pulse (MOP) to improve range resolution – frequency coding ('chirp')

- In this scenario the range resolution is improved by using the Modulation on Pulse (MOP), 'pulse compression' technique or frequency coding.

- The frequency coding puts a frequency modulation ramp or 'chirp' across the pulse which substantially improves the resolution. The higher the 'frequency excursion' bandwidth, the greater the improvement. 'Range resolution 2' uses a 100kHz bandwidth to achieve 1.5km resolution, an improvement of 41 times on resolution 1.

- As the pulse-width is 410usecs, across which the 100kHz ramp occurs, the scan rate is 240Hz/usec or 240kHz/msec.

- Target B is now in the 81st range gate and distance determined with 1.3% accuracy (41 times improvement) to be located between 120km and 121.5km.

- Target A is in the 136th range gate and distance determined with 0.7% accuracy (41 times improvement) to be between 202.5km and 204.0km.

- Note the 1.5km range resolution is the same as using 10usec pulse-width in scenario 9a.

Radar-2
Tx/Rx height = 20m

PRF = 241 Hz
PRI = 4.15 msecs (4,150 usecs)
pulse separation = 1,245km
pulse width = 410usecs
max unambiguous range = 567km
pulse length = 123km
blind range = 64.4km

range resolution 1 = 61.5km
range resolution 2 = 1.5km

Air target A
height = 2,000 m
radar horizon = 203km
range = 200 km

resolution 1 = 31%. 4th range gate
resolution 2 = 0.7% (41X improvement) . 136th range gate

Air target B
height = 1,000 m
radar horizon = 149km
range = 120 km

resolution 1 = 51%. 2nd range gate.
resolution 2 = 1.3% (41X improvement). 81st range gate

Scale: 40 km