

Concentric Indexing – a straight forward approach to controlled turns

Captain Paul Chapman

Senior Marine Pilot – Pilotage Service Gladstone
Maritime Safety Queensland, P.O. Box 1249 Gladstone Queensland 4680 Australia
E-mail : pilot_chapman@bigpond.com

1. Introduction

A key to the safe conduct of large vessels in confined waters is the control of turns, bringing vessels accurately from one track to the next.

A simple radar technique provides for controlled turns without complex planning or the need for sophisticated movement sensors and instrumentation.

2 Radar Presentation

When a vessel follows the circular path of a turn, fixed targets displayed on a radar in the Head Up orientation will follow a predictable track concentric to the turn's centre. (See Figure 1)

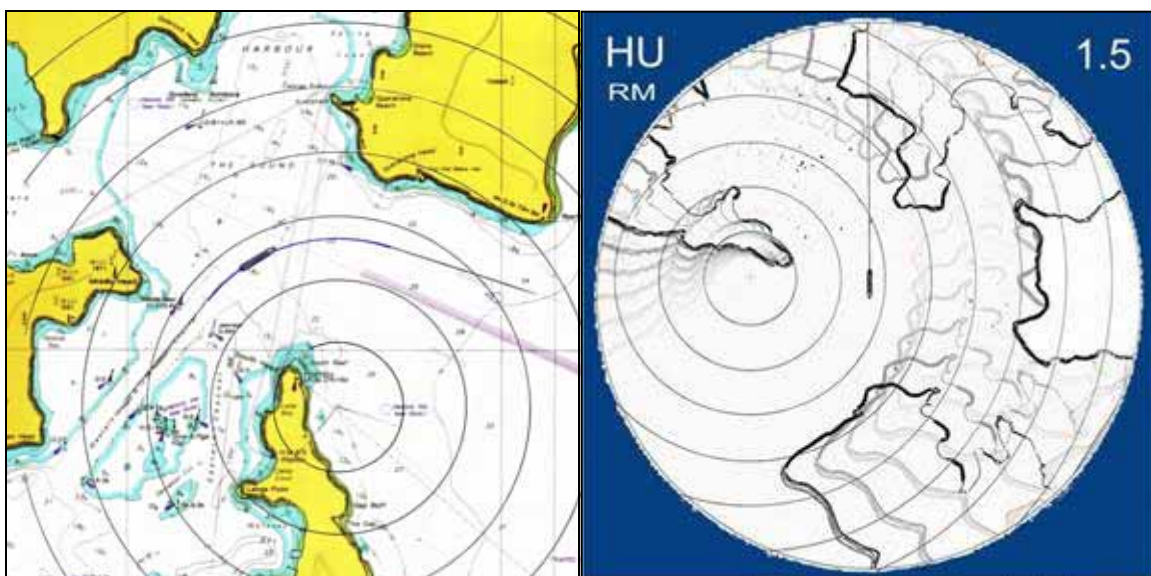


Figure 1 Concentric movement of fixed targets on Head Up display during a turn.

Notable features of the Head Up orientation during a turn are;

- A target at the turn centre will remain stationary
- All other fixed targets will follow a circular path around the turn centre.
- The amount of movement of a target is proportional to its distance from the turn centre.

The characteristics of Head Up orientation during a turn may be used for planning, executing and monitoring turns. This particularly applies to radars that allow the Variable Range Marker (VRM) ring to be offset. Many radars have this ability coupled with an unstabilised display and the presentation of target wakes or trails.

3. Procedure

The procedure for performing a planned turn with a radar in the Head Up orientation involves three steps:- planning the turn from a chart, setting up the radar and executing the turn.

3.1 Planning from the chart.

3.1.1 The desired turn centre is identified, either by bisecting the initial track and next track or drawing lines parallel to the initial and next track at a distance of a desired radius. (See Figure 2a) The turn radius is noted. (See figure 2b)

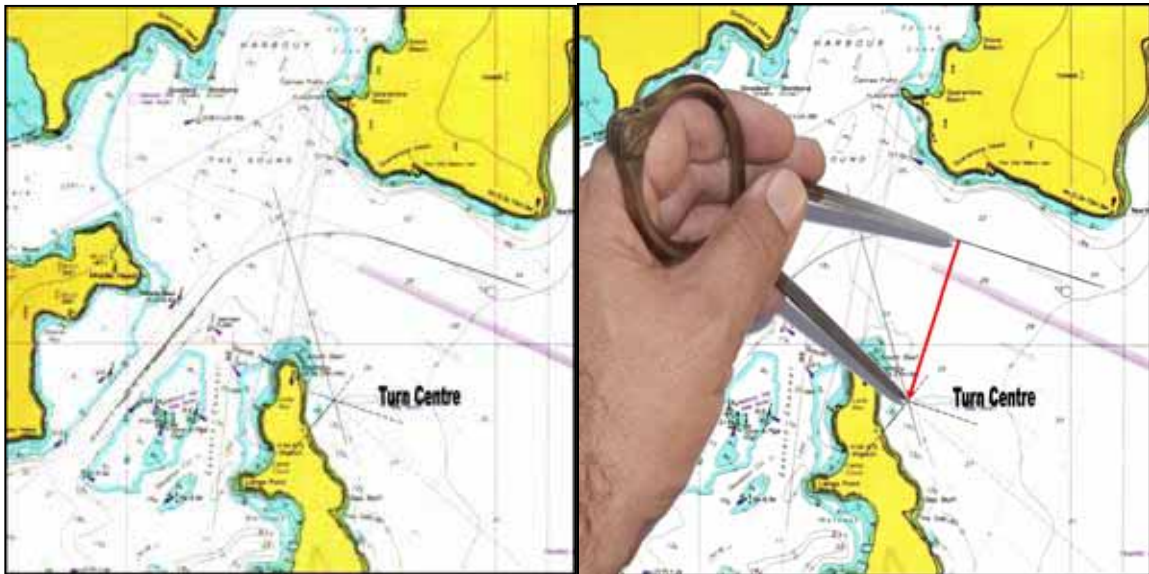


Figure 2a Establishing the the turn centre

Figure 2b Noting turn radius

3.1.2 A conspicuous radar target is selected as the reference point (ideally the reference point will be abeam when the vessel completes the turn and steadies on the next track).

3.1.3 The distance of the reference point from the turn centre is measured. (See Figure 3)



Figure 3 Measuring the Reference Point Distance from the turn centre.

3.2 Setting up the radar. (See Figure 4)

3.2.1 The Head-Up orientation is selected with a range scale suitable for monitoring the turn.
(Target wakes/trails feature is selected if available)

3.2.2 The VRM centre is offset abeam of the bow at the turn radius distance.

3.2.3 The VRM is set at the Reference Point Distance from the turn centre.

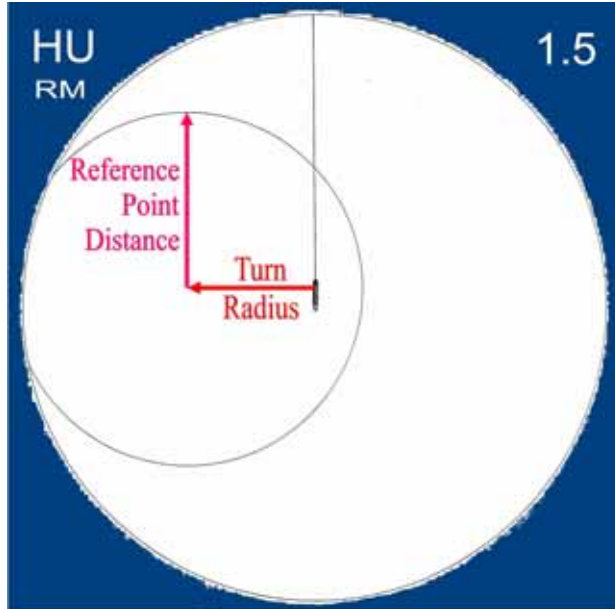


Figure 4 Setting up the radar

3.3 Executing and monitoring the turn (See Figure 5)

When the selected reference point is about a ship's length or less from touching the VRM, the turn is started. In a manner similar to parallel indexing to follow a straight track, the apparent path of the reference point can be kept on the circular path of the offset range ring by adjusting the vessel's rate of turn.

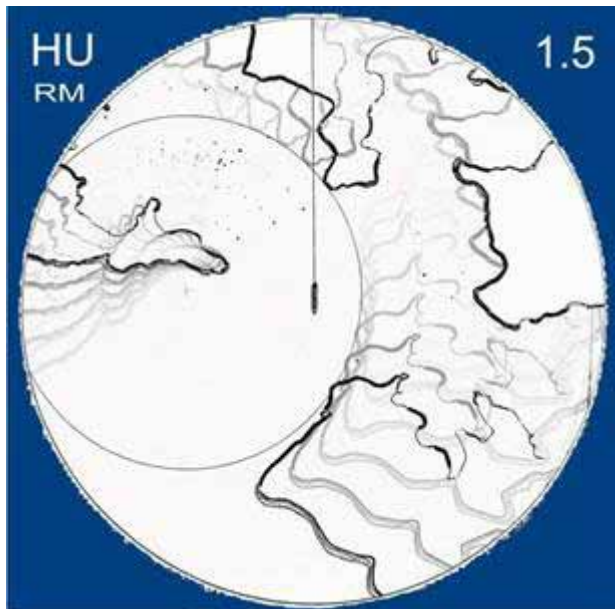


Figure 5 Circular path of Reference Point

Required rate of turn adjustments are immediately apparent by any divergence of the reference point's track from the predicted relative track.

If the rate of turn is too *low*, the reference point will move *below* the VRM (figure 6a). In such a case the rate of turn must be increased to bring the reference point “back on track” (figure 6b)

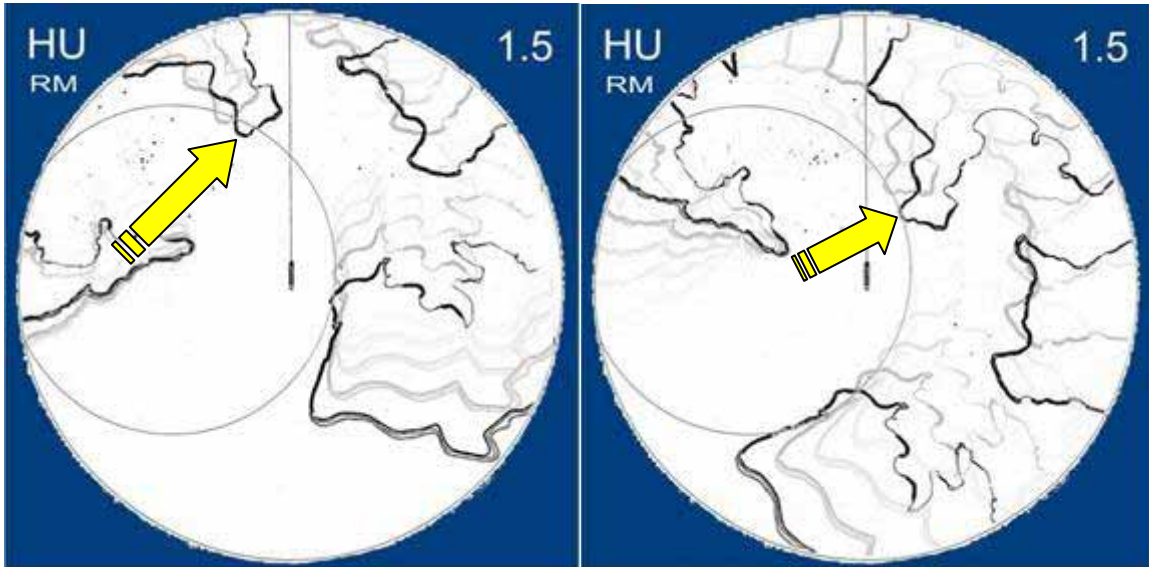


Figure 6a Initial turn rate too low

Figure 6b Turn rate increased

If the rate of turn is too *high*, the reference point will move *above* the VRM (figure 7a). In such a case the rate of turn must be decreased to bring the reference point “back on track” (figure 7b)

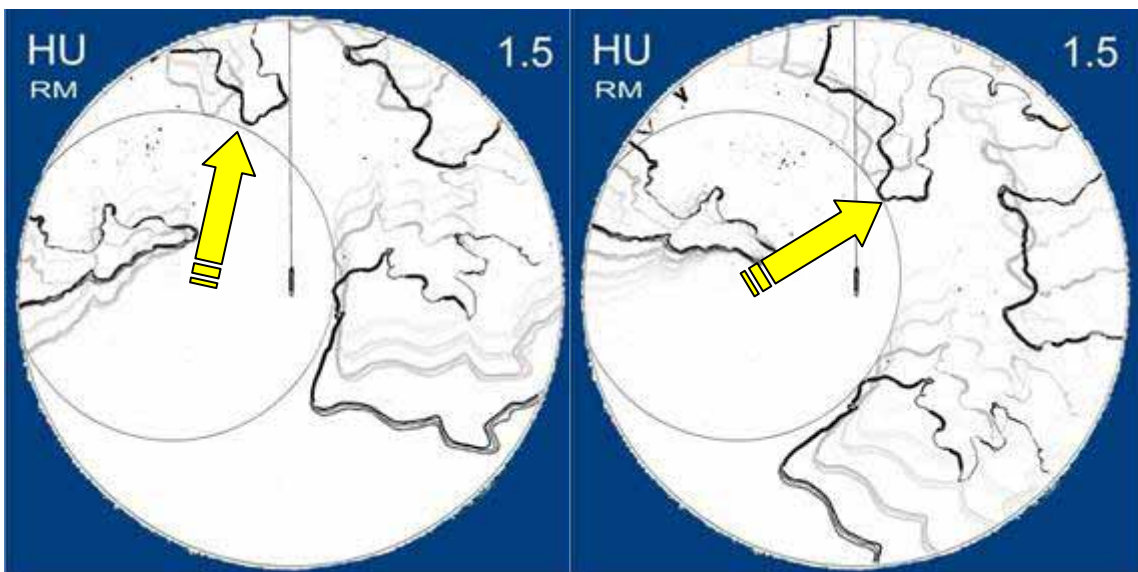


Figure 7a Initial turn rate too high

Figure 7b Turn rate decreased

It can be seen that if the turn is started too early or too late, the rate of turn can be adjusted to bring the reference point onto the VRM ring and thus bring the vessel back to the intended turn track.

4. Sensitivity

It is evident that;

- Reference points directly above or below the VRM centre are the most sensitive to turn radius changes.
- Reference points directly above and below the turn centre have a horizontal path.
- Reference points on the beam are not sensitive to turn radius changes as their track is parallel to the vessel.

These factors are important in selecting the optimum target to monitor the turn or conversely, form part of the positioning criteria for navigation markers.

5. Planning considerations – Reference Point selection

The Reference Point used should :-

- be visible on a range scale suitable to the manoeuvre
- be sensitive to turn radius changes to ensure completing the turn on the next track
- ideally have a distance from the turn centre greater than the turn radius
- not be lost to radar shadow sectors or sea clutter.

This discussion assumes the vessel closely follows the initial planned track, which is usually the case when navigating in confined waters. Subject to the reference point used, there may be considerable tolerance for cross track error on the initial track. Should that not be the case, a composite method can be employed. With a "wheel over" line (parallel to the next track) and the desired radius to come round to the next track, the VRM centre is offset at the desired radius, when the wheel over line is reached, the VRM is adjusted out to the reference point. The turn is then executed as discussed.

6. Error Sources

There are two sources of error on Head Up orientation, heading flash alignment and range.

The heading flash alignment can be checked against an object ahead and if required, a centred Electronic Bearing Line (EBL) can be substituted for the heading flash. Error in distance can be identified from distortion of straight lines perpendicular to the vessel (such as trails from passing beacons or the straight face of wharves or breakwaters.) Accommodating such errors in range is complex and depending on the magnitude, may render the radar unfit for navigation in confined waters.

7. Adapting the technique to the radar available.

All radars offer Head Up orientation but have different features. It can be seen from the preceding images that trails and being able to offset the VRM make monitoring the turn easy. (See Figures 5, 6 & 7). Some models do not have trails available on Head Up mode, others curiously have stabilised trails on the head up mode.

With radars that do not have the option to offset the VRM, the EBL can be offset with the range marker set at the reference point distance. This ranged EBL can be used to monitor the reference point path against the planned turn by rotating the EBL. (See Figure 8a & 8b)

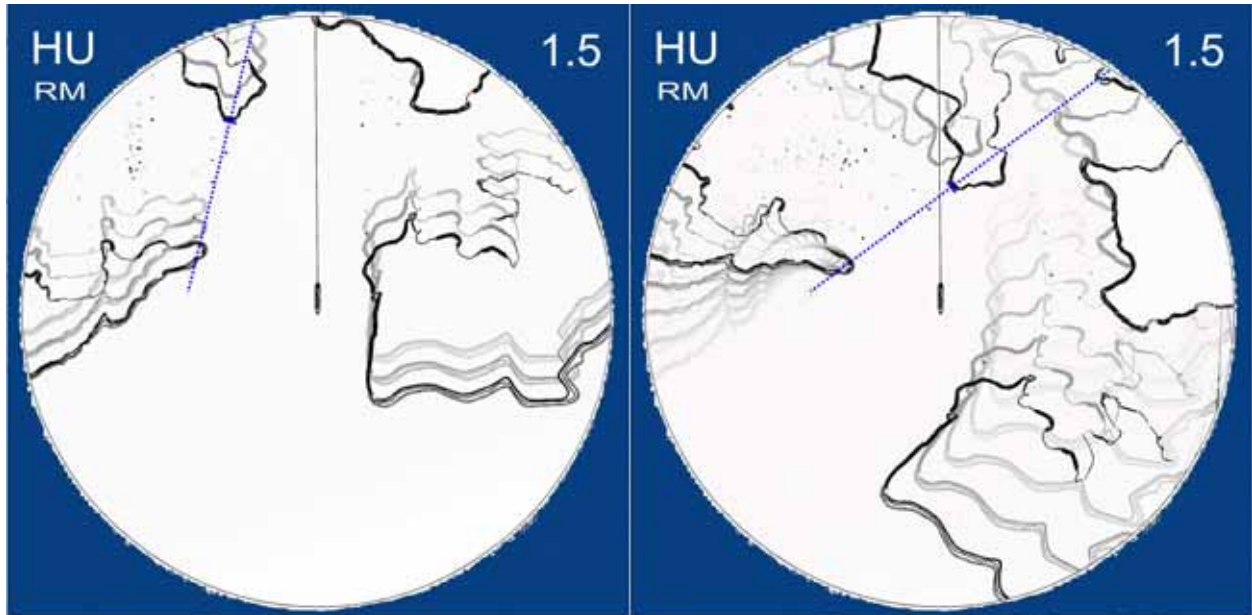


Figure 8 Using a ranged EBL to scribe the arc the reference point is to follow

Alternatively, it can be seen in Figure 9 that segments of the arc the reference point is to follow can be closely replaced by a line. In pilotage, where familiarity with the waters allows the pilot to know the path reference points should follow, head up with rings may be sufficient to monitor a turn and allows for the turn to have segments of different radii.

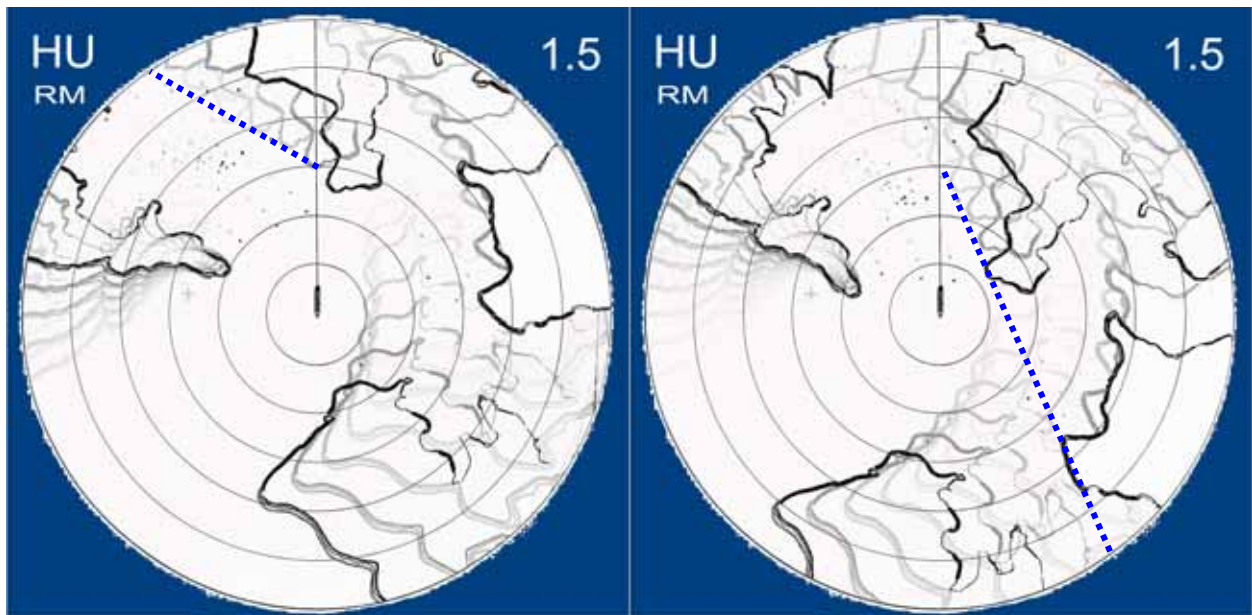


Figure 9 offsetting the EBL to replace the arc the reference point is to follow.

8. Use of Stabilised Electronic Bearing Line (EBL)

So far, gyro input has been excluded from this paper. In pilotage, gyro compasses are frequently observed to be in error, lag during turns and sometime just wander. Perhaps new compass technology will increase the confidence in which heading input can be relied upon. Whilst some radars only have relative bearings in the Head Up orientaiton, others have or offer stabilised EBLs or true bearings . In such cases, the range and bearing of the reference point from the turn centre can be set on the EBL that is offset abeam at the desired radius. The presentation is similar to Figure 8. If the stabilisation is reliable, targets on the beam become sensitive to turn rate with the same guide that if the target is above the bearing line, the turn rate is too high and if the target is below the bearing line, the turn rate is too low.

9. North Up Presentation

The principles of this technique can be applied in North Up mode provided the offsetting of the EBL and VRM are relative to the vessel. (See Figure 10) However, with both the reference point and the index moving, this method retreats from the simplicity and resilience of the Head Up method and loses the effective amplification of target movement, usefulness of trails and the predictability of vessels path.

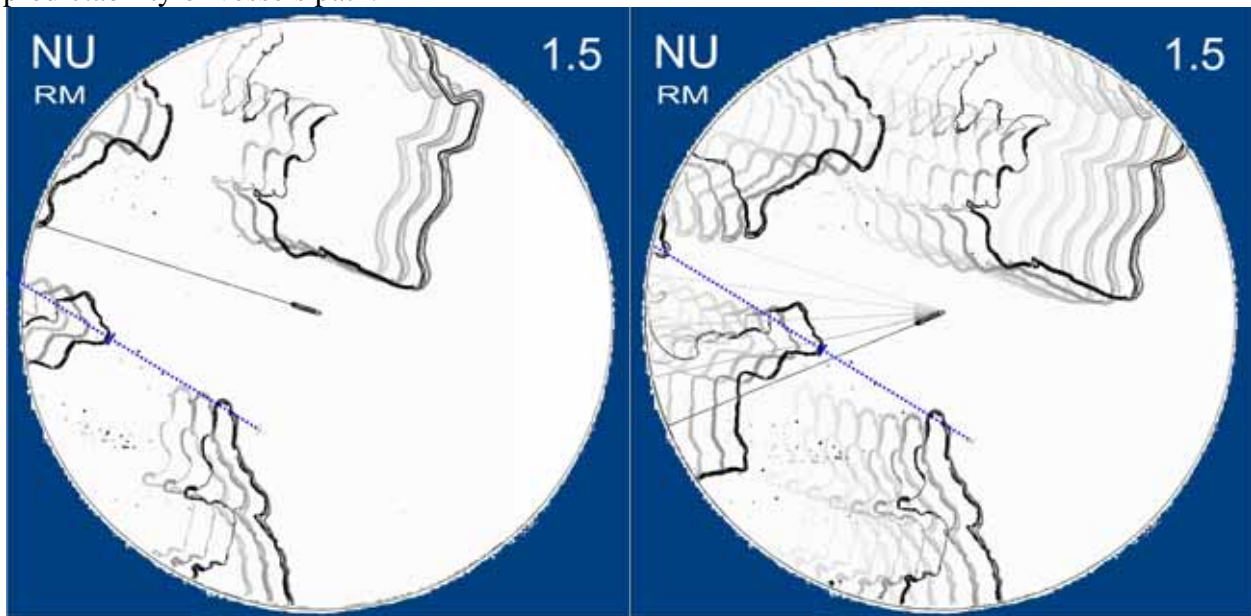


Figure 10 North Up using ranged EBL offset relative to ship's head

The comparison between the two displays is evident from Figure 11 capturing the same position 40° into the turn. It can be seen at a glance that the Head Up orientation informs the observer what path the vessel has been following and predicts the vessels trend. The north up orientation is not as informative.

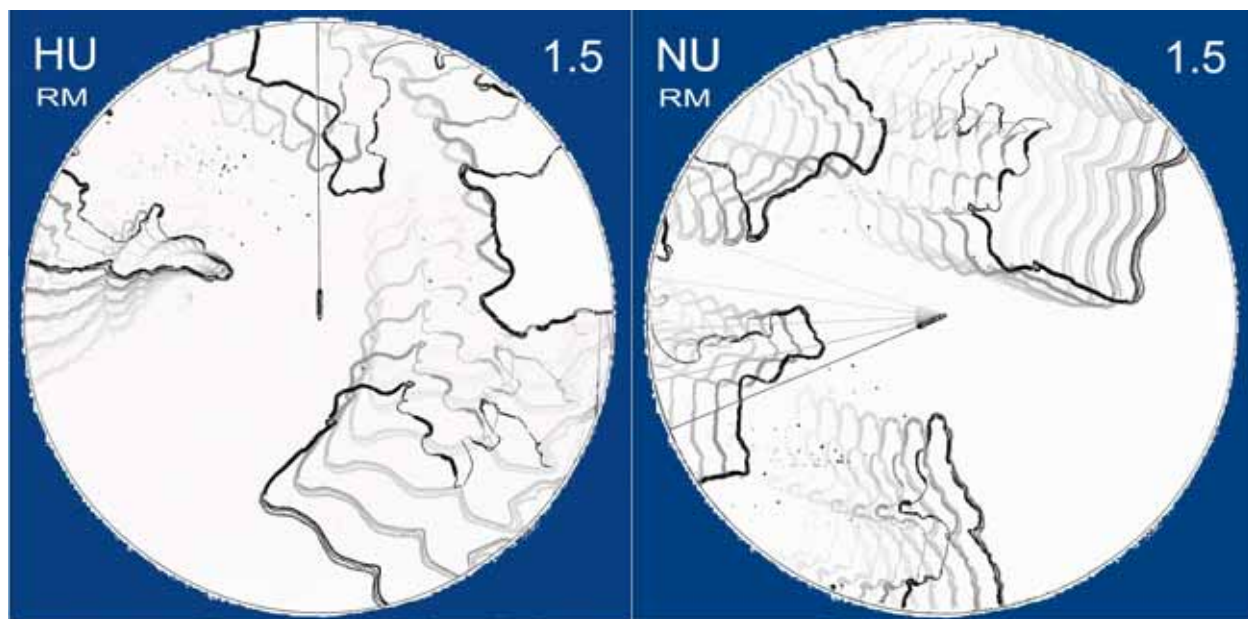


Figure 11 Comparing Head Up and Noth Up orientation during a turn.

10. Limitations

When using this technique, the performance limitations of the radar and the vessel must be borne in mind. In particular, awareness of the radar's range accuracy (IMO's minimum standard is 30metres or 1% of the range scale in use) and that turn radii selected must be comfortably achievable by the vessel.

11. Conclusion

This method of conducting controlled turns is straight forward and easy to use. The planning is simple and results in turns being defined by their radius and a reference point's distance from the turn centre. These two values allow for a quick and simple radar set up to provide continuous realtime monitoring from a single source. Further, as the turn is referenced from the seascape being navigated, it is evident that the effects of set and drift will be detected and can be compensated for by rate of turn adjustments.

Similar to the role of parallel indexing in passage planning, the safe navigation of vessels in confined waters would be enhanced if this technique was widely understood and radar designs allowed for its simple application.