Maritime Zone Boundary Generation from Straight Baselines Defined as Geodesics

Brian Murphy
GeoFix Pty Ltd
Canberra, Australia
E-mail: bmurphy@spirit.com.au

Philip Collier and David Mitchell
Department of Geomatics
The University of Melbourne
Melbourne, Australia
E-mail: p.collier@eng.unimelb.edu.au

Bill Hirst
Australian Surveying and Land Information Group (AUSLIG)
Canberra, Australia
E-mail: billhirst@auslig.gov.au

ABSTRACT

Articles 7, 9, 10 and 47 of the United Nations Convention on the Law of the Sea define the circumstances under which coastal States can construct straight, closing and archipelagic baselines. However, the subject Articles do not specify, or require coastal States to specify, the geometric or technical properties of these lines. As a consequence, coastal States are free to apply any interpretation they choose in the technical definition of straight baselines, whether these are loxodromes, arcs of great circles, arcs of small circles, grid lines, normal sections from either terminal of a segment or geodesics. Coastal States have occasionally defined the technical properties of straight baselines through promulgation in national maritime legislation or in international maritime boundary delimitation treaties, but this has been very much the exception rather than the rule.

This paper provides a general overview of some of the technical problems that can arise when maritime zone boundaries are generated from straight baselines legally defined as geodesics, as is the case with Australian national maritime legislation. It also outlines a practical application of the method of *tracés parallèles*, which is the essence of the *Anglo-Norwegian Fisheries Case* judgment handed down by the International Court of Justice in 1951. Lastly, the paper briefly overviews the implications of the requirements set out in the recently published "*Scientific and Technical Guidelines of the Commission on the Limits of the Continental Shelf*" in relation to the geometric properties and use of straight baselines.

1. Introduction

Straight lines are an integral part of any boundary system, whether onshore or offshore. The geometric properties of straight lines are usually defined in terms of a rectangular grid system or a map or chart projection system.

Under the provisions of the United Nations Convention on the Law of the Sea (UNCLOS), coastal States are permitted to use straight lines as components of the baseline from which specific maritime zone boundaries are measured. Articles 7, 9, 10 and 47 define the circumstances under which straight lines can be drawn, respectively:

- across the mouth of a river (Article 7)
- across the mouth of a juridical or historical bay (Article 9)
- as part of a system of straight baselines (Article 10)
- as part of an archipelagic straight baseline system (Article 47)

The subject Articles do not specify, or require coastal States to specify, the geometric or technical properties of the straight lines. Coastal States are, therefore, free to define these lines as loxodromes, arcs of great circles, arcs of small circles, grid lines, normal sections from either terminal of a segment, geodesics or any combination thereof.

An examination of straight, closing and archipelagic baseline legislation promulgated by coastal States will reveal that the definition of the geometric properties of straight lines is very much the exception rather than the rule. In the great majority of cases, the legislation simply refers to straight lines joining named coastal features defined by geographical coordinates, or by lines joining points on the normal baseline defined by geographical coordinates, or by a combination of both of these methods. In some cases, the legislation refers to large or small-scale charts or maps, officially recognised by the coastal State, that are appended to the legislation and upon which the straight lines have been drawn. However, the cartographic depiction of such lines on paper charts, or their digital equivalents, raises a number of technical questions relating to their legal status. This is especially the case where straight baselines legally promulgated and defined as geodesics are plotted on hydrographic charts. However, these issues are beyond the scope of this paper.

The absence of definition of the geometric properties of straight, closing or archipelagic baselines from national maritime legislation is undoubtedly due to the non-explicit nature of the wording of UNCLOS Articles 7, 9, 10 and 47. It could be argued that this situation has not been improved by some coastal States simply following the precedent set by others in the wording of their own legislation. However, coastal States can take advantage of this situation as it enables the choice of a particular line type that can be used to gain a territorial advantage. For example, under certain circumstances, the use of loxodromes rather than geodesics can sometimes lead to a significant maritime territorial gain, especially where long lines are involved. The converse case can also occur, with a geodesic offering an advantage over the use of a loxodrome.

2. The Accuracy of Straight Baseline Determination

As the terminal points of straight, closing or archipelagic baselines are normally chosen so that they are coincident with points on the normal baseline, any error in the location of the latter will be translated directly into the maritime zone boundary. In general terms, the legal view is that once the baseline terminal point coordinates have been promulgated in national maritime legislation, the location of the line joining the

points defined by those coordinates is absolutely defined. This view is based on the assumption that the location of the normal baseline, as depicted on charts officially recognised by the coastal State, is accurately defined.

However, in many cases, the location of the normal baseline has not been accurately known and the locations of straight baseline terminal points have been determined purely by inspection and scaling of coordinates from the best available charting or mapping information. The scaled coordinates have then been promulgated in national maritime legislation. In the case of the Australian legislation, the lines joining terminal point locations are explicitly defined as geodesics.

Recognising the errors that may be inherent in the mapping and charting information used to define the location of the normal baseline, the maritime legislation of some coastal States, including Australia, allows the *scaled* locations of baseline terminal points to be shifted. The shift enables the points to be located in positions which are consistent with the situation on the ground, such as would arise where the location of the normal baseline has been determined by hydrographic survey. However, the Australian legislation permits only the shift to a point on the normal baseline that is *closest to* the scaled location and experience has shown that the implementation of this legal mechanism can sometimes lead to ambiguous situations. Additionally, distances of up to three nautical miles between the originally scaled and shifted locations of baseline terminal points have been encountered which has made straight baseline and associated zone boundary definition extremely complex.

Some coastal States, notably the Republic of Indonesia and Norway, have undertaken detailed surveys to determine the location and coordinates of straight baseline terminal points. Invariably, these points have been connected to permanent onshore reference monuments that have been coordinated in a geocentric reference system, such as the International Terrestrial Reference System (ITRS) or WGS84. These surveys have been undertaken for different purposes. In the case of Norway, the surveys were related to international maritime boundary delimitation negotiations with the United Kingdom in the North Sea, where a difference of one metre in the agreed boundary location equated to $US3 million (1984) in terms of the underlying oil reserves (Harsson, 1996).

There is a clearly demonstrated need for an unambiguous and technically sound definition of straight baselines. Modern positioning technologies such as the Global Positioning System (GPS) now make it possible to achieve relative positioning accuracies at the sub-metre level in mid-oceanic regions. The Norway-UK negotiation is but one example of this need and the positioning capabilities of GPS demonstrate that this need is more than just a theoretical or legal nicety; it is an achievable and practical necessity.

3. The Geodesic Defined

As mentioned above, coastal States are entitled to use any one or a combination of several geometric line definitions, including the geodesic, when defining straight, closing and archipelagic baselines. Although the properties of the geodesic can be found in many standard reference textbooks on geodesy, it will be useful, in the context of this paper, to summarise the more commonly known features:

- a geodesic is the line of shortest distance that can be drawn on the surface of the reference ellipsoid between any two points;
- where both terminal points lie on the same side of the equator, the geodesic is a line of double curvature;
- the geodesic generally lies between the plane curves drawn between the terminal points;
- when both terminal points lie on a meridian, the geodesic and both plane curves coincide with the meridian;
- if both terminal points are in nearly the same latitude, the geodesic may cross one of the plane curves; and
- at every point along it, the geodesic satisfies the following equation (Clark, 1963):

$$R_p \sin \phi = \nu \cos \phi \sin \alpha = \text{constant}$$

Where:

R_p = radius of a parallel of latitude
α = geodetic azimuth
ν = radius of curvature of the prime vertical section
ϕ = geodetic latitude

As the geodesic is a complex line, the task of offsetting a maritime zone boundary from such a line is no less complex. A recommended method by which this process can be undertaken is known as the method of *tracés parallèles* and is defined in a judgment handed down by the International Court of Justice (ICJ) on 18 December 1951.

4. The Method of *Tracés Parallèles*

The ICJ, in the judgement relating to what is now known as the *Anglo-Norwegian Fisheries Case* of 1951, originally prescribed the method of *tracés parallèles* for the delimitation of maritime zone boundaries from straight baselines. Article 4 of the 1958 Convention on the Territorial Sea and the Contiguous Zone embodied the essence of the ICJ judgment. Essentially, the method is a generalisation of the method of envelopes of arcs that is applied to points on the normal baseline. Many sets of national maritime legislation now reflect the application of this method of delimiting zone boundaries from straight baselines through inclusion of the following, or similar, phraseology:

> *"...by a line every point of which is at a distance of ... miles from the respective baseline"*

A number of technical issues arise when the *"the respective baseline"* is legally defined as a geodesic, as is the case with Australian national maritime legislation. By far the most significant of these is the fact that, on the surface of the reference ellipsoid, it is geometrically impossible to define a geodesic that is offset from and at all points parallel to a given geodesic which has been legally defined as a straight, closing or archipelagic baseline.

When delimiting maritime zone boundaries from straight, closing and archipelagic baselines defined as geodesics, it is computationally invalid to simply offset by the maritime zone width along the normals constructed from each of the baseline terminal points and to then join the constructed points with another geodesic (as illustrated in Figure 1). This approach can lead to significant errors, as can be seen from Table 1. The table shows the mid-point separation between a geodesic baseline and an offset geodesic using various maritime zone widths applied to the maximum permissible archipelagic straight baseline length of 125 nautical miles (M), as specified in UNCLOS Article 47 (2).

The above construction is even less valid, and can lead to significantly greater errors, when undertaken on nautical charts that use a variety of map projections.

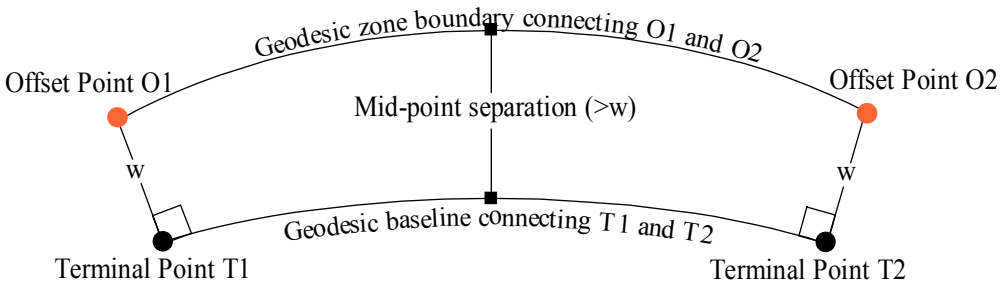

Figure 1 – The variation in zone width (w) caused by offsetting a maritime zone boundary from the terminal points of a geodesic straight baseline

Maximum Archipelagic Baseline Length 125 M **Baseline Origin: 45° North or South Latitude** **Baseline Azimuth: 45°, 135°, 225°, 315°** **Ellipsoid: GRS80**		
Maritime Zone Width (M/m)	Separation Between Mid-points of Baseline and Zone Boundary Geodesics (m)	Difference (= Error) (m)
12/22224	22227.66	+3.66
24/44448	44455.32	+7.32
200/370400	370460.86	+60.86

Table 1 – The error in zone width at the mid-point of a geodesic 125 M in length for zone widths of 12 M, 24 M and 200 M

In theory, the rigorous application of the method of *tracés parallèles* - when applied to a geodesic straight, closing or archipelagic baseline - requires the interpolation of an infinite number of points along that baseline. A normal (which is also a geodesic) is then constructed at each terminal and interpolated point and extended by the required maritime zone width (w), as illustrated in Figure 2. This process can be computationally intensive and will produce as many points defining the required maritime zone boundary as the number of points the user chooses to interpolate along the baseline.

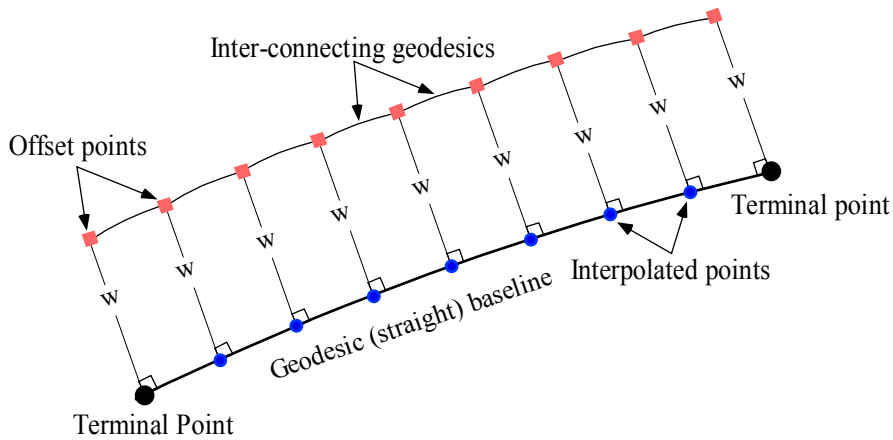

Figure 2 – Implementing the method of *tracés parallèles* to delimit a zone boundary from a geodesic straight baseline

As the offset points defining the required maritime zone boundary are computed on the surface of the reference ellipsoid, the lines of shortest distance inter-connecting adjacent offset points will become, by definition, geodesics. These geodesics will have a different orientation, or azimuth, to the corresponding segments of the baseline geodesics. Furthermore, the required maritime zone width (w) will only be true when measured directly between the interpolated and offset points. All points on the geodesics inter-connecting adjacent offset points will lie at a distance that exceeds the maritime zone width as measured from the corresponding segments of the baseline geodesic, irrespective of how short these segments are.

A practical approach is required in the determination of zone boundaries offset from geodesic straight baselines. This approach, which would never replace the rigorous method of *tracés parallèles* where that was required to be applied, must be related to the maximum tolerable error in the location of the boundaries. This error will always bear a direct relationship to the relative accuracy with which points defining the zone boundary can be defined in relation to the straight baseline terminal points and the stated precision of the coordinates used to define points on the boundary.

5. A Practical Application of the Method of *Tracés Parallèles*

A practical solution for the implementation of the method of *tracés parallèles* is suggested here. This solution will give results that closely approximate those obtainable from a rigorous implementation (if that were computationally possible). The proposal enables the use of geodesics to define maritime zone boundaries offset from straight baselines also defined as geodesics. It will also reduce the computational intensity and the large amounts of data produced by the use of a rigorous method of *tracés parallèles*. Application of the method results in the mid-points of the offset geodesics being located at a distance from the mid-points of the corresponding baseline geodesic segments *that does not exceed the subject maritime zone width by more than a user-defined distance, typically by not more than a few tens of centimetres*. For example, a user may require that the maximum offset error in the maritime zone width not exceed 10 centimetres. The application of this method will prove useful in a number of practical situations, such as where the offset geodesics are to be cartographically represented. A brief description of the method follows.

When implemented on the surface of the reference ellipsoid, the method of *tracés parallèles* can be rationalised so that the baseline geodesics are divided into a finite number of segments of equal length, as illustrated in Figure 2. The segmentation length is determined from, and is directly related to, a user-defined maximum tolerable error in the maritime zone width (δw) between the mid-point of the baseline segment and the mid-point of the corresponding geodesic defining the subject maritime zone boundary (see Figure 3).

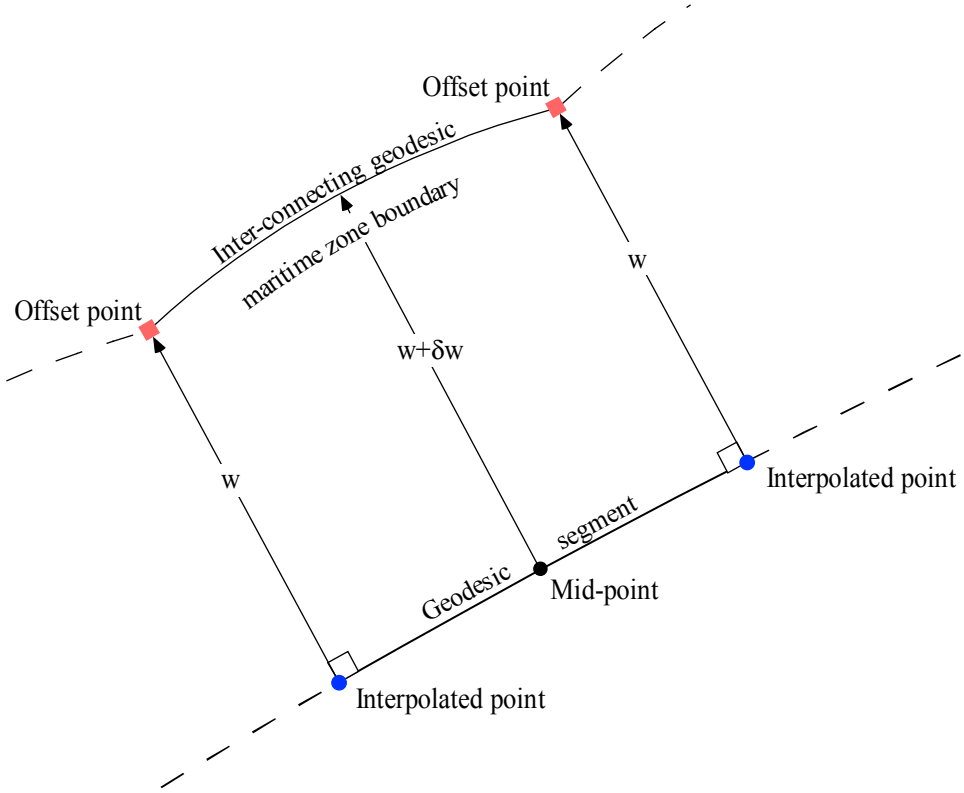

Figure 3 – The error (δw) in the maritime zone width at the mid-point of a geodesic segment

A computer algorithm has been developed to implement the proposed baseline segmentation procedure on the surface of the reference ellipsoid.

Table 2 shows, for maritime zone widths of 12, 24, 200 and 350 M, the approximate baseline segmentation length corresponding with a user-defined maximum offset error of δw = 0.25 metre.

Baseline Origin: 45° North or South Latitude **Baseline Azimuth: 360°, 45°, 90°** **Ellipsoid: GRS80**		
Maritime Zone Width (M/m)	Maximum Separation Between Mid-points of Baseline Geodesic Segments and Zone Boundary Geodesics (m)	Baseline Segmentation Length (approx.) M/m
12/22224	22224.25	32.40/60000
24/44448	44448.25	23.06/42710
200/370400	370400.25	8.10/15000
350/648200	648200.25	6.04/11195

Table 2 – Baseline segmentation lengths that give a mid-point separation of $\delta w = 0.25$ m for various maritime zone widths

6. A Note on Precision

A potential criticism of the approach proposed above for the practical implementation of the method of *tracés parallèles* is that it does not rigorously satisfy the criterion that every point on the zone boundary should be exactly the zone width from the straight baseline. It has been pointed out that the variation in the offset distance can be minimised by choosing a very small segment length for the computation of interpolated points on the baseline geodesic, however, reducing the segment length imposes a greater computational load.

When choosing the maximum tolerable variation in the zone width, realistic precision limits need to be considered. Generally, terminal point coordinates will be quoted to no better than ±0.1", equating to approximately 3 m at the equator on the surface of the reference ellipsoid. Because of the one-to-one correspondence between the precision of the terminal point coordinates and the precision of the generated zone boundary, it is meaningless to require that the maximum tolerable mid-point separation error should be significantly smaller than the precision of the generating coordinates. It is suggested that if the mid-point separation error is set to be an order of magnitude smaller than the intended precision of the coordinates, the algorithm described above will provide a rigorous implementation of the method of *tracés parallèles* within the precision limits of the data supplied. For coordinates quoted to ±0.1", the maximum allowable error would therefore be approximately 0.3 m.

7. Straight Baselines, Article 76 and the Scientific and Technical Guidelines of the Commission on the Limits of the Continental Shelf

Where coastal States are able to claim an extended continental shelf, UNCLOS Article 76 (5) provides that:

> *"The fixed points comprising the line of the outer limits of the continental shelf on the seabed, drawn in accordance with paragraph 4 (a)(i) and (ii), either*

shall not exceed 350 nautical miles from the baselines from which the territorial sea is measured…"

Furthermore, Article 76 (6) provides that:

"Notwithstanding the provisions of paragraph 5, on submarine ridges, the outer limit of the continental shelf shall not exceed 350 nautical miles from the baselines from which the territorial sea is measured."

However, Article 76 (7) states that:

"The coastal State shall delineate the outer limits of its continental shelf, where that shelf extends beyond 200 nautical miles from the baselines from which the breadth of the territorial sea is measured, by straight lines not exceeding 60 nautical miles in length "

Coastal States that have proclaimed straight, closing and archipelagic baselines and intend to claim an extended continental shelf *may* be able to define the outer limits at a distance of 350 M from those baselines. The constraint imposed by Article 76 (7), whereby "*straight lines not more than 60 nautical miles in length*" must be used to define the outer limits, raises the problems associated with the delimitation of boundary lines offset from straight, closing or archipelagic baselines which have already been discussed.

At this point, it is important to note that the recently published *"Scientific and Technical Guidelines of the Commission on the Limits of the Continental Shelf",* Section 3.3, Geodetic Definition of Baselines, stipulates that *"…the Commission shall accept the definition of straight, closing and archipelagic baselines as either geodesics or loxodromes."* Furthermore, in relation to the use of straight lines not exceeding 60 M in length as specified in Article 76 (7), *"… the Commission will employ geodesics on the surface of the official geodetic reference ellipsoid used by a State in each submission to define the path and distances of these specific straight lines."* (Section 2.3, Delineation of the Outer Limits of the Continental Shelf).

Where a coastal State, in its submission to the Commission on the Limits of the Continental Shelf, chooses to use the maximum constraint line length of 60 M in the definition of the outer limits in accordance with the provisions of Article 76 (7), it may need to define some or all of those lines as geodesics offset 350 M from geodesic straight, closing and archipelagic baselines. In this case, the separation between the midpoints of the offset geodesics and the midpoints of the corresponding segments of the baseline geodesics will exceed the zone width by approximately 24.4 metres (computed on the GRS80 ellipsoid using baseline azimuths of 360°, 45° and 90°, with starting coordinates at 45° north or south latitude).

Finally, the requirement to define straight, closing and archipelagic baselines as either geodesics or loxodromes as set out in Section 3.3, Geodetic Definition of Baselines, of the *"Scientific and Technical Guidelines of the Commission on the Limits of the Continental Shelf"* applies only to those coastal States intending to proceed with the submission of a claim for extended continental shelf under the provisions of Article 76. Coastal States unable or unwilling to claim an extended continental shelf can

continue to define the geometric properties of straight baselines by whatever method they choose.

8. Summary

The promulgation of straight, closing or archipelagic baselines in national maritime legislation without an explicit definition of the technical properties of these lines continues to pose problems for all disciplines associated with maritime boundary delimitation. These problems are only exacerbated when such lines need to be used in international maritime delimitation.

The offsetting of maritime zone boundaries from straight, closing and archipelagic baselines defined as geodesics presents geodesists and cartographers with a number of complex technical issues. Unless these are fully understood, significant errors will arise in the definition of those boundaries.

This paper has proposed a method for implementing a practical and workable solution to the method of *tracés parallèles* when offsetting maritime zone boundaries from a geodesic straight baseline. Whilst the solution is approximate, the degree of approximation can be controlled by specifying the allowable discrepancy between the nominal zone width and the actual zone width. This error limit is then used to determine an appropriate segment length for the subdivision of the baseline geodesic prior to computing the offset zone boundary. The method proposed also has application in the computational definition of the legal limit of the extended continental shelf boundary under the provisions of UNCLOS Article 76.

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