RECOMMENDATION ITU-R P.1058-1

DIGITAL TOPOGRAPHIC DATABASES FOR PROPAGATION STUDIES

(Question ITU-R 202/3)

(1994-1997)

The ITU Radiocommunication Assembly,

considering

a) that the application of propagation prediction models requires topographical information;

b) that future propagation prediction models will be able to make use of more detailed topographic information;

c) the need to provide practical engineering advice on the preparation of digital topographic maps for propagation prediction;

d) that data exchange is required between different administrations;

e) that it is desirable to establish a worldwide topographic database,

recommends

1 that topographic database coordinate systems should be determined according to § 2 of Annex 1;

2 that the horizontal spacing of data values in a topographic database should be determined taking into account the information contained in § 5 of Annex 1;

3 that topographic databases should unambiguously identify sea and lake surfaces, including their heights;

4 that topographic databases should contain information about ground cover, either man-made or natural, and include details of the type and height of the ground cover;

5 that the additional information contained in Annex 1 should be taken into account when setting up a topographic database.

ANNEX 1

1 Introduction

Digital topographic databases established for the purpose of propagation predictions need to contain information which is related to the type of prediction being undertaken. For frequencies above about 30 MHz, information about the terrain height and ground cover is currently needed. For detailed propagation predictions for frequencies above about 1 000 MHz, especially in urban areas, information about the location, size and orientation of individual buildings is currently needed in addition to terrain height information.

It is to be expected that increasingly sophisticated prediction models will be developed which will permit more detailed propagation predictions but which will also demand more detailed information and, potentially, a reduced horizontal spacing for the data samples.

The purpose of this Annex is to provide guidance on the type of information which should be contained within topographic databases and on suitable values of horizontal spacing for the data samples.

It must be noted that a very wide range of uses for topographic databases can be foreseen and also that a very wide range of ground cover information can be identified. In any individual geographic region, it is unlikely that all types of ground cover will be found and this has an important implication with regard to the data storage. While a universal set of ground cover information could be developed, many of the categories would be irrelevant in the majority of specific topographic database applications. This implies a requirement for unnecessary storage capacity. Under such circumstances, it does not seem appropriate at present to develop a set of ground cover categories which would be used in the same way in all applications. Guidance can, however, be given on the categories which have been found appropriate and those which seem likely to be worth further investigation.

No universal storage format can be proposed for similar reasons to those given above. However, it is considered to be desirable that propagation prediction computer routines should access the database by means of suitable interface software. In this way, the contents and structure of the database may be modified as more information becomes available and, with suitable changes to the interface software, the propagation prediction routines are unaffected.

In order to effect a satisfactory exchange of a topographic database, for example between administrations or from a supplier to a customer, it is essential either that suitable interface software is supplied with the database or that full information about the database contents and storage scheme are supplied.

2 Coordinate systems

Topographic data can be referenced to any of several coordinate systems. These normally fall into one of two major categories:

– angular coordinates, normally latitude relative to the Equator and longitude relative to a reference meridian, normally Greenwich;

– a rectangular projection applied to a particular area of the Earth's surface according to a defined mathematical projection.

The principal characteristics of these two systems can be summarized as follows:

– latitude-longitude coordinates provide global coverage without discontinuity, but with a non-linear relationship between coordinate values and ground distances. In particular the scale factor between longitude and ground-distance varies with latitude;

– rectangular projections approximate to a linear and scale-invariant relationship between coordinates and ground distances over a defined geographic area, but must be redefined for different areas to avoid significant distortion. Many national mapping agencies adopt a rectangular projection for paper maps, and for this reason the most detailed topographic data for a given area are often indexed at regular intervals of the local projection.

Many national mapping systems are based on the Transverse Mercator projection. The Universal Transverse Mercator (UTM) system is a set of such projections based on uniform definitions for different longitudes, with northings referenced to the Equator. This provides a useful degree of standardization. In some cases there is a preference for projections optimized for accuracy at a specific latitude as well as longitude, in which case individual values for earth elipticity are usually chosen in order to minimize errors. There are also a number of non-Transverse Mercator projections.

The most suitable choice of coordinate system can depend on several factors, including:

– where the highest accuracy is important there is an advantage in retaining the source coordinate system, since conversion to a different system will usually result in a loss of accuracy;

– when extracting short path-profiles data indexed to a rectangular projection provides a useful simplification, since a straight line in the coordinate-space will approximate to a straight line on the ground. The discrepancy when compared with a true great-circle path will depend on the projection system and the path orientation and length. As a general guide, a straight line in a rectangular projection is typically sufficiently accurate for propagation studies up to about 100 km. However, actual discrepancies will vary according to the projection in use, and will tend to be greater for west-east path orientations and at higher latitudes. Users should evaluate worst-case errors when laying-out path profiles as a straight line in a rectangular projection;

– latitude-longitude coordinates are valuable in providing continuous coverage over wide areas. When great-circle geometry is used to avoid excessive non-linearity, the use of latitude-longitude coordinates avoids the need for many coordinate conversions to a rectangular projection.

In view of the above factors it is not practicable to recommend a single coordinate system for all purposes. For international coordination the use of latitude-longitude is recommended in view of its ability to cover the entire surface of the Earth without discontinuities. In cases where a rectangular projection is needed on the basis of practicality, the use of UTM coordinates is preferable on the grounds of uniformity.

The above discussion is summarized in Table 1.

TABLE 1

Coordinate systems

Parameter	Latitude-longitude	UTM	Other
Applicability	Complete Earth	Most of Earth	Usually local
Grid cell shape	Curvilinear trapezoid	Good approximation to square	Usually good approximation to square
Scale-factor variation	Varies with latitude	Good approximation to constant	Usually good approximation to constant
Boundaries	None	According to longitude	Varies

3 Geodetic datum

A geodetic datum is the set of reference values upon which a coordinate system must be based. The WGS 84 datum, which is based on the GRS 80 geoid, is recommended for international coordination.

4 Database compatibility

When combining topographic or mapping data from different sources care must be taken to ensure compatibility. In general misalignments will occur unless all data are based on the same geodetic datum and coordinate system.

5 Horizontal spacing in a macroscopic database

The value of horizontal spacing between data-points which should be used in a topographic database depends upon the use to which the data will be put. It is not practicable to recommend a particular value. In practice horizontal spacings in the approximate range 20 m to 1 km, or the equivalent in latitude-longitude, are typical. Various propagation-prediction models not only have different requirements for horizontal resolution, but differing sensitivity to changes in horizontal resolution. It should not be assumed that increasing horizontal resolution with a given propagation method always improves prediction accuracy.

6 Accuracy of terrain height data

The accuracy of propagation prediction models can be strongly affected by the accuracy of terrain height data in a topographic database. The accuracy of terrain heights is typically expressed as a root-mean-square (r.m.s.) error value. Horizontal resolution, vertical accuracy, and the propagation method in use, will all affect the calculated result. In general, the more detailed deterministic propagation methods require greater resolution and accuracy in topographic data, but details will vary in individual cases. An r.m.s. error of 15 m in terrain height data has been found acceptable for many purposes.

7 General principles of data storage for terrain heights

Most current topographic databases used for propagation prediction and radio planning use 2-dimensional arrays of data at equal intervals in the chosen coordinate system, referred to as “gridded data”. This has the advantage that horizontal coordinates need only be provided for reference points, with most data consisting of self-indexing arrays of height values. For rectangular projections the horizontal data-spacing will typically be the same throughout a complete database. For latitude-longitude coordinates the longitude spacing is sometimes increased in steps as latitude increases in order to keep the longitude scale-factor approximately constant.

Gridded data storage is recommended for topographic databases used for propagation studies on the basis that it is simple and in wide use.

The following information is provided as general guidance on other approaches to storing topographic data which may be found useful.

There is increasing interest in using other storage strategies for topographic data both to reduce storage space and in some cases to provide a more efficient representation of terrain height.

Standard methods can be used to compress any topographic data, although in general greater compression ratios are available using specialized methods, not all of which are error-free. Examples of compression for gridded data are:

– the discrete cosine transform (DCT);

– various forms of Huffman coding, which can be error-free, and which is particularly efficient if the difference between actual heights and a prediction of height from neighbouring points is Huffman encoded for storage;

– the use of variable point-spacing according to terrain irregularity, which can be stored efficiently in linked-list form using quadtree nodes.

Where terrain height data are available at a sufficient horizontal resolution for irregularly-located points, which normally implies a surveying system selecting features such as ridge and valley lines, the Triangulated Irregular Network (TIN) has a number of advantages. The method is based on storing both the horizontal coordinates and height of each point. It is also necessary to define a triangulation linking all points in order to represent terrain as contiguous triangular facets. The triangulation may be stored explicitly, or implicitly for reconstruction during data-retrieval.

It should be noted that the advantage of TIN relies on points linked to terrain features, which in general will be irregular. Two points arise:

– traditional cartography does not always provide such points accurately surveyed to an adequate resolution;

– a TIN system derived from gridded data should employ a system to identify the more topographically-significant points. It should also be noted that ambiguous triangulations can exist for regularly-spaced points.

8 Representation of terrain height data

Gridded terrain height values may represent different aspects of terrain height:

a) the highest, lowest, median, or other characteristic height for a square area of terrain having a side equal to the horizontal data spacing;

b) the height at the single point represented without providing information on heights elsewhere.

The choice of how heights are represented affects both how path profiles of terrain height should be extracted from a database, and how the height information will interact with a propagation prediction method. It is not practicable to provide a general recommendation in this area. Methods of profile extraction are discussed in § 9.

9 Profile extraction

When drawing a profile between two arbitrary locations, few or none of the data points in a grid-based database will coincide exactly with the profile. Various methods are available for extracting terrain height data in such cases. The following are recommended according to circumstances:

– when the height data are in some way representative of a square area of land, as described in § 8 a), data should be placed in the profile for each square through which it passes. Each profile point may be placed on the normal from the profile line to the corresponding data point, although this will not in general produce equally-spaced profile points. If the propagation method requires equally-spaced points, it is acceptable to move profile points to accomplish this;

– when the height data represent only the height at each exact point, as described in § 8 b), the preferred extraction method is to pre-determine equally spaced profile points and obtain the terrain height for each by bilinear interpolation from the immediately-surrounding gridded-data values.

Different principles apply to extracting a profile from a TIN-based database. Strictly the profile is the continuous line following the contiguous triangular facets by which the TIN represents the terrain. In practice, sampling this surface for pre-determined equally-spaced profile points is acceptable.

10 Urban area topographic databases

Special considerations apply in the case of topographic propagation predictions in urban areas, especially at frequencies above about 1 000 MHz where reflections from building surfaces need to be taken into account. In such cases, very detailed information is needed, including the height and shape of the buildings and possibly, the location and width of the streets, although the latter information may, in some cases, be derived as the area not covered by buildings.

Two different approaches have been found useful in such cases. The first approach is an extension of the general concept outlined in § 5 using a horizontal spacing of 5 to 10 m and storing the building height information as part of the ground cover data (see Note 1). In this case, the mean orientation of the buildings may only be derived approximately. In the second approach, a vector database is set up which holds the coordinates, in three dimensional form, of the vertices which define the shape of each building (see also § 12). In both cases, the heights stored may be absolute values or values relative to the local mean ground height. There is currently insufficient evidence to indicate which of these two approaches provides the better basis for propagation calculations.

NOTE 1 – Irregularly shaped buildings may be stored as a combination of sub-buildings with different heights.

11 Macroscopic ground cover information

As noted earlier, the range of possible ground cover categories is very large and the full range is unlikely to be relevant to any individual geographic area. Table 2 gives a set of general categories which are in use by various organizations. However, in many cases, it has been found desirable to subdivide some of the categories to provide a better description of the ground cover involved.

12 Special purpose ground cover information

The considerations in § 10 may be extended to any special situations where detailed propagation predictions are required. Table 3 provides some examples of categories of ground cover together with a possible mechanism for recording their characteristics; this is basically an extension of the first approach described in § 10. Alternatively, the vector method of storing the coordinates of the extremities of the objects may be used.

TABLE 2

Categories and parameters to be listed in macroscopic ground cover database

Ground cover	Parameters
Dense urban (City centre location)	– Mean building height – Maximum building height – Building density(1)
Urban (Areas with commercial developments offices, shops)	– Mean building height – Maximum building height – Building density(1)
Industrial (Areas with factories and warehouses)	– Mean building height – Maximum building height – Building density(1)
Dense suburban (Areas with terraced houses greater than 3 storeys or other high-rise dwellings)	– Mean building height – Maximum building height – Building density(1)
Suburban (Areas with detached and semi-detached dwellings, housing estates)	– Mean building height – Maximum building height – Building density(1)
Village centre (Typically locations with a green area and low density buildings)	– Mean building height – Maximum building height – Building density(1)
Deciduous trees	– Mean tree height – Maximum tree height – Tree density(2)
Coniferous trees	– Mean tree height – Maximum tree height – Tree density(2)
Mixed tree types	– Mean tree height – Maximum tree height – Tree density(2)
Orchard	– Mean tree height – Maximum tree height – Tree density(2)
Sparse (Featureless region such as fields, parkland, sand dunes, etc.)	
Marshland	
Mud flats	
Sea water	
Fresh water	

(1) Building density is defined as fraction of the area under consideration which is covered by buildings.

(2) Tree density is defined as number of trees per 10 000 m^2.

TABLE 3

Additional categories and parameters for database of special structures

Ground cover category	Parameters
Row of buildings (A well defined row of buildings in isolation, typically a row of terraced houses along a road)	– Mean building height – Coordinates at end points of row
Isolated building (Isolated building within a square)	– Building height – Coordinates of building centre – Area covered by the building
Line of trees (Typically a tree-lined road)	– Mean tree height – Coordinates at ends of tree line
Towers (Electricity pylons, wind turbines, etc.)	– Height of feature – Coordinates at centre of feature

13 Population data

For many purposes it is necessary to establish the population coverage for a radiocommunication service. This can be done very conveniently if a population data bank is established and it has been found useful to have the same horizontal spacing for population as for ground cover and terrain heights.