Radar Coverage Calculations Based on Antenna Characteristics and Digital Terrain Elevation Data

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Abstract: - The paper presents radar coverage processing software. Detail radar coverage calculation techniques has been described. Digital Terrain Elevation Data level 1 was applied for the Earth's surface modelling and digital radar model has been used for different antenna spatial characteristic influence. Calculation results on real maps for different target height were presented and discussed.

Key-Words: - radar, antenna, digital map, software

1 Introduction
Present command and control systems dedicated for military applications require advanced planning techniques to provide flexible radar location for best terrain coverage by antenna beams. It needs radar coverage processing software which can calculates limits within which objects can be detected by one or more radar stations. Software library should consider radar antenna characteristics, terrain topology, wave aspect of antenna beam and influence of the Earth’s curve. Visualisation on the map results permits easy estimation of proper radar stations placement.

2 Radar coverage calculations method
Radar coverage estimation is based on Digital Terrain Elevation Data (DTED) which is a uniform matrix of terrain elevation values, which provides basic quantitative data for systems and applications that require terrain elevation.

It allows representation of the Earth's surface for general modelling and assessment activities. DTED level 1 has been applied which is the basic medium resolution elevation data source for all military activities and systems with spacing every 3 arc seconds (approximately 100 meters). The information content is approximately equivalent to the contour information represented on a 250,000 scale map.

Radar coverage calculations applied digital radar model which includes antenna characteristics performed for one or more equivalent cross sections of target. Multi beam antenna characteristic has been presented on figure 1. All calculations are performed with 100m resolution in distance domain and 1° in angle domain (Fig. 2). It generates large number of tested points, eg. for radar nominal range equal 200km over 720,000 points are tested.

3 The Earth's surface model influence
In the first part of work geometric optic approximation has been applied to beam propagation model. The
The blue curve presents radar antenna spatial characteristic, which is described like the table of angle and ray pairs. For better resolution points between defined antenna characteristic points (1, 2) are linear approximated (4). Calculation in this case is based on checking if each point on red curve (3) is inside radar antenna spatial characteristic, by comparison the length of R and Rx vector. If the tested point is placed outside antenna characteristic logic ‘0’ is written to Visibility Table in proper address. Finally series of logic ‘1’ and ‘0’ are results for each azimuth. Next they are filtered to avoid single and double logic ‘0’ or ‘1’, eg. string like ‘..010..’ is changed into ‘..000..’, or string like ‘..110011..’ is changed into ‘..111111..’. Thus calculation results are much more clear.

5 Calculations results
During the test of radar coverage processing software large number of calculations have been done. Typical results of described calculation for single beam radar antenna characteristic for target object flying over ground on 3 different heights are presented in figure 5. This coverage was performed for radar situated close to the centre of the pictures. All patterns are with good agreement to terrain topology. For green coverage rays separation is visible according large distance from radar source, but it still gave good visual estimation of radar coverage for operator.
Another results of calculation for scanning radar with single antenna beam characteristic for target objects flying over ground on 20m, 100m, 500m and 1km altitudes are presented in figure 6. In this case radar was situated in the little valley then for the lower heights (20m and 100m) short visibility limits can be observed. Distortions of main shape of coverage pictures into ellipse is caused by non-linear scale of map in ortogonal directions. (geographic degrees instead of meters).

In the next 2 pictures (figure 7 and figure 8) results of described calculation for multi beam radar antenna characteristic for different heights are presented.

In figure 7 calculation were performed for target flying over ground on 20m, 100m, 5km and 40km while in figure 8 calculation were performed for target flying over mean sea level on the same heights. The bit difference between those two patterns can be observed, according calculation technique and both of they stay in agreement with theory. Double light blue cyinders result from multi beam character of used antenna characteristic. Simply analysing route of target object cross 2 separated antenna characteristic beams.

Results of coverage calculation for the same type of radars with multi beam antenna characteristic for target flying over ground on 20m, 100m, 5m and 40km altitudes are presented in figure 9. In this case radars were separated about 1 degree of latitude and 0.5 and 1 degree in longitude. The large difference of coverage patterns between different radars according they positions can be observed.
Fig. 9. Multi radar coverage calculation for target objects flying over ground on 20m - red, 100m - green, 5km - blue, 40km - yellow for multi beam antenna characteristic.

6 Conclusion

Basic technique of radar coverage calculation based on digital terrain elevation data level 1 and antenna spatial characteristic was proposed. The geometric optic approximation of beam propagation model provides very good quality of radar coverage patterns. Applied methods provide to consider different kind of antenna characteristics.

All software was written under Linux operating system in C++ using gcc compiler. Described function are available as library function, which required radar position in geographic degrees, radar antenna characteristic, DTED source and heights as input parameters and they return string in svg format.

In the next part of work wave aspects of radar beam propagation model and coverage report based on manual basic optical measurements will be considered.

References:


