MODELING OF RADAR LAND CLUTTER MAP FOR SMALL GRAZING ANGLES.

Evgeny V.TARNAVSKY, Gennady P. KULEMIN, Professor

12, Ac. Proskura st., 310085 Kharkov, Ukraine Fax 38-0572- 441-105
E-mail: gkulemin@ire.kharkov.ua

Abstract
The technique of radar clutter map elaboration for land backscattering at the frequency band of 3-100 GHz for small grazing angles is proposed taken into consideration the terrain relief and vegetation. The sources and methods for receiving of the initial data for modeling are analyzed and described. A brief description of operation principle and area of application of specially designed neural structure (consolidation tree) in the model is presented.

1. Introduction

The low-altitude target detection and land clutter rejection associate with number of difficulties [1,2]. First of all, the target scattered power, determing by the radar cross-section (RCS), is comparable or less than the clutter intensity. Besides, the backscattering from non-homogeneous terrain leads to the shadowing zones appearance because of relief influence, to the great dynamic range of RCS change, etc. In these conditions the clutter models developed for the homogeneous terrain are very limited and do not give the full picture of clutter distributions both for range and azimuth. To design the model it is a need to plot radar ground visibility maps at a given relief.

The main interest presents the modeling of land clutter for ground radar which is positioned at a height of 100m or less over the surface with operation range of about 5-10 km. There is a great amount of topographic data which are practically not used for the modeling. It can be used some different initial data such as DTED (Digital Terrain Elevation Data), Digital multilayer maps, digital or regular topographic maps and so on.

To realize this model authors developed a package of “Radar Map” programs which permits to modeling the normalized RCS s^0 map of the land surface. It determines the radar signal characteristics at given surface point and has a number of additional functions which make the modeling and data processing a lot easier.

2. The features of clutter map development

The clutter signal on the entrance of ground radar is determined, first of all, by scattering of electromagnetic field from the land surface. The most important characteristic for clutter signal intensity determination is the normalized RCS of land surface. On the base of analysis of experimental data at the frequency band of 3-100 GHz and grazing angles less than 45 degrees in [1] an empirical model for normalized RCS determination was obtained in the form

$$s^{o} = A_1 + A_2 \lg \frac{y}{20} + A_3 \lg \frac{f}{10}, \qquad (1)$$

where f is the frequency in GHz, and y is the grazing angle in degrees. The A_1 – A_3 coefficients for various types of terrain are presented in Table 1.

Table.1 The A_1 – A_3 coefficients in land clutter model

Terrain type	**A_1**	**A_2**	**A_3**
Concrete	-49	32	20
Arable land	-37	18	15
Snow	-34	25	15
Deciduous and coniferous forests, summer	-20	10	6
Deciduous forest, winter	-40	10	6
Crass with height more than 0.5 m	-21	10	6
Crass with height less than 0.5 m	-(25-30)	10	6
Urban territories (town and country buildings)	-8.5	5	3

It is enough to classify the surfaces by types which are presented in Table 1 for the most practical tasks.

Each type of data is presented in the model as a layer which is tied to geographical coordinates and it allows to use the different scale of data. The structure of the layer allows to present any initial data (weather and atmosphere conditions, vegetation, rivers and lakes, etc) as a layer. The general view of the layer structure is shown in the Fig.1.

There is a considerable number of vectoral maps (isograms and topographic maps). Description of the relief is worthwhile for vectoral maps and topographic maps can be used only for general cases because of their accuracy and quick changes caused by human activity.

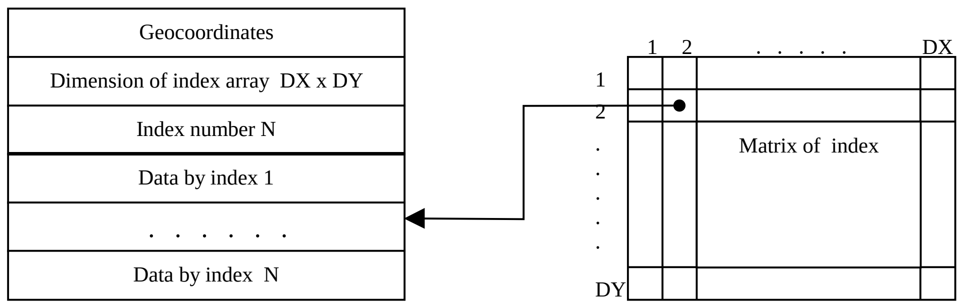


Figure.1. Structure of the layer

For the exact correlation between the model and real data we combine the terrain relief known from certain sources (large-scale vectoral maps) and received from other sources (space or aerial photos). The layer structure allows the combination of initial data with coordinates without regard to scale only. For separation of land surface objects (area texture) to 9 standard surface types it was developed a special neural structure - consolidation tree which is adaptable to the wide class of problems [3]. The use of this structure reduces to minimum values the dependence of model errors on initial data and the cost of data processing. Also it raises the speed of model designing and it does not require the classification of image characteristics and setting off the significant ones.

Some features of this method may be listed:

1. the image characteristics are the isomorphous ones;
2. the characteristics number is arbitary and it increases with advancing into the structure (the images of one level specify the previous one);
3. images may have signs of certain classes (the classification can be performed at the same time) or they can do some activities;
4. the structure of tree is described in topologicaly by the use of ρ, Δ, Δ_{lm} functions, here ρ is the Euclidean distance between any two image characteristics (for example, the distance between points on plane), Δ is the difference degree between two images and it takes value 0 (image is compared with itself) and not over 1 (the maximum image difference), Δ can be considered as a distance in space of objects features (characteristics) and depending on it the probability of proper image identification can be valued, Δ_{lm} is an internal function of the structure and it determines the maximum coefficient of branching and tree sensitivity;
5. the interaction of few structures is described also.

The tree structure and efficiency of its use depend on sequence of its training. Usually, the operations number over tree images is log K where K is a number of images in training sample. Properties 1 and 2 define the ability of structure to classify images at the lack of initial data.

If it is not possible to design the dividing surface for image classes immediately we can use property 5 and to design a few interrelated structures. It allows to analyze the images not only with different physical characteristics (color and pixel coordinates) but also by complicated characteristics (for example, sections of lines, regions, subsidiary objects, etc.). The bigger the number of interrelated structures, the higher abstraction level of image analysis we receive and correspondingly the higher classification quality.

The tree is much like neural net and it reacts on a set of initial data, receiving an output set of probable image classes. Its general view is presented in Fig. 2. The division on levels is logical, one consolidation tree can perform

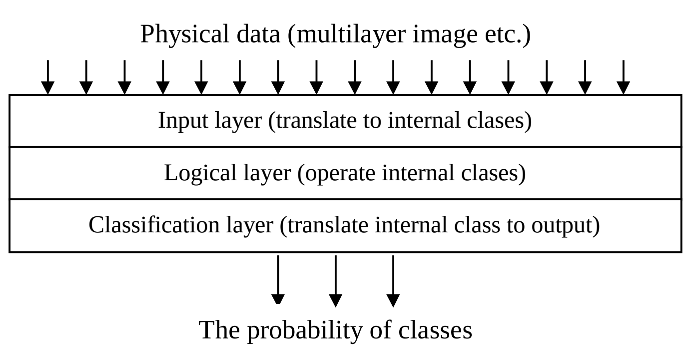


Figure 2. The neural structure level

functions of all levels and each level consists of several trees.

The main feature of this model is a strong dependence of model on earth surface grazing angles and small model sizes (about 5-10 km). For the surface restoration we used different types of initial data: earth surface stereophotography , data from GPS, digital vectoral maps. The analysis showed that method of surface restoration by stereophotography is not always possible or it gives unacceptable modeling error (about 20 m). The primary method for surface restoration by base points or vectoral maps (isograms) is a method of Delaunay's triangulation. This method of surface restoration gives an acceptable error at heights but in joints of triangles we receive an error in grazing angles. This error and absence of "peaks" will change the model significantly. So we need a method, which would have errors of height restoration as Delaunay 's triangulation and be superior to errors of surface gazing angles. We can receive these characteristics by smooth functions – splines for relief restoration. The performance of relief recombination by separate basic points (GPS) does not cause any problems, but the use of isograms brings the difficulties in the choice of points for designing 3D – spline. The solution of this problem is the use of weighted mean of several 2D splines for certain neighborhood of point. This method allows the choosing basic points accurately and calculation error does not exceed 10% from 3D spline. As we determine the point height using this method we receive heterogeneous surface (Fig. 3).

a) the restored relief in tone view b) the restored relief without smoothing c) the fully restored relief

Figure 3. The features of relief restoration (for the RCS model)

The heterogeneity grows along with increase of distance from isogram, that's why it was used heterogeneous Gauss filtering. It means that at the range from isogram the depth of smoothing increases [4]. For elimination of possible errors of relief recombination with splines some auxiliary operation were added. The described method was performed by package of programs Radar Map and it gives error of 6-10% order from quantification of basic points (Delanunay's triangulation gives error of 12-20% order), independent of relief characteristics.

If we have test data for areas of earth surface of specified radar, the model (for this radar parameters) can be corrected using the consolidation tree. The use of consolidation tree gives the following advantages:

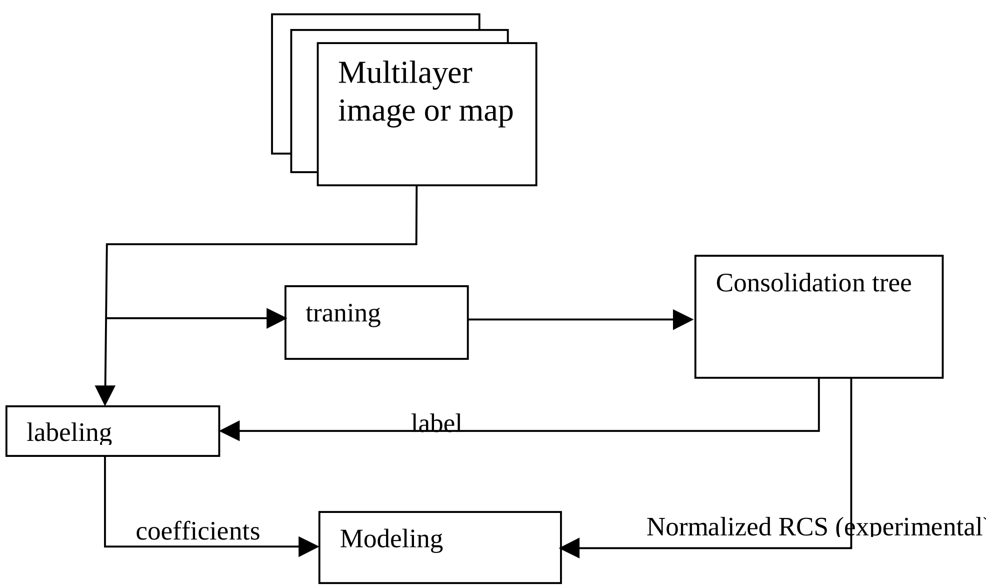


Figure 4. The modeling scheme

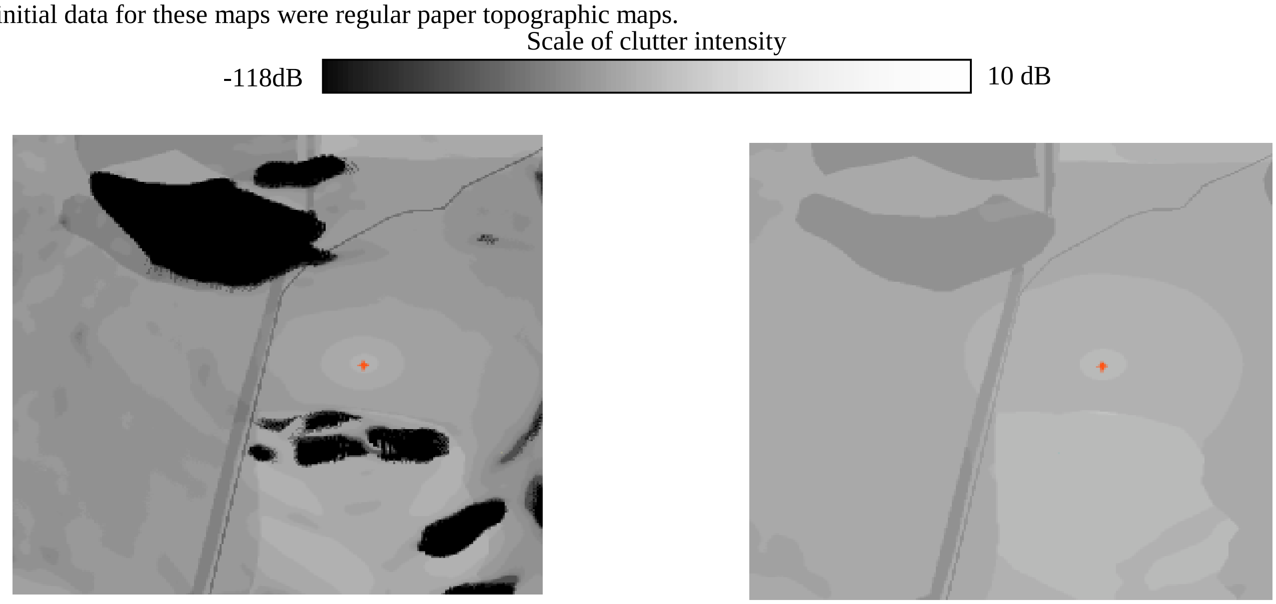
- determination of normalized RCS of point by its neighborhood;
- makes possible to design exact model of space-expanded objects (power lines, railways, motor roads);
- determination of normalized RCS to a high precision;
- possibility to receive a big amount of test data.

A weakness of this method is that structure functions only within the limits of test data, on which it was trained. So it is worthwhile to design model by formula (1) and perform the correction using the consolidation tree. The steps of modeling with the use of consolidation tree are shown in Fig.4

3. The results of modeling

The results of modeling for two radar heights 20 and 200 m are presented on figure 5. The analysis of these results showed, that positioning of radar closer to earth than 50 m is not worthwhile because of low radar ground visibility. The quality of the model depends a lot on the quality of initial data. At the use of pictures for underlying, the error of model decreases in few times and approaches mathematical expectation of real normalized RCS of earth surface. The use of exact topographical maps allows designing and evaluating clutter maps of earth surface.

The modeling allows determination of the best radar location at given task, determination of best height of radar location for certain earth surface area . Also it allows optimization of target trajectory for lowering efficiency of its detection. The clutter maps which were received with the use of program package Radar Map are presented in Fig. 5. The initial data for these maps were regular paper topographic maps.



a) the radar heights 20 m

a) the radar heights 200 m

Figure 5. The results of modeling of clutter map

3. Conclusions

The modeling of radar land clutter map for small grazing angles was considered in which the clutter intensity depends on the grazing angle, frequency, terrain relief and vegetation. Features of different input data for model are illustrated and methods of their obtaining and errors are considered. The neural structure (consolidation tree) are used for improvement the model input data quality. The model development on the example of RadarMap software package is illustrated.

References

1. G.P. Kulemin," Sea backscattering model for millimeter band of radiowaves", *URSI Com. F Symp.* (Aviero, Portugal, Sept. 1998), Proc., pp. 128-131.

2. G.P. Kulemin, V.B. Razskazovsky, *The scattering of the millimeter radiowaves by Earth's surface for small grazing angles*, Naukova Dumka, Kiev, Ukraine, 1987 (in Russian).

3. E.V. Tarnavsky, "Consolidation tree for the object classification with big dimension of the characteristics vectors", KhAI, Kharkov, Ukraine 1998, Proc.

4. R.A. Schowengerdt, *Remote sensing. Models and methods for image processing*, Academic Press, Tucson, Arizona 1997