Radar Clutter Backscattering Simulation for Specific Sites

G. Rode

Microwaves and Radar Institute, German Aerospace Centre (DLR)
Oberpfaffenhofen, 82234 Weßling, Germany
E-mail: gerald.rode@dlr.de

Abstract: The state of development of the surface clutter prediction model DORTE is presented. This simulation program utilizes Digital Elevation Models and land use information to calculate reflectivity maps for specific sites with optional statistical variation using semi-empirical and statistical clutter models. Land use information is provided by the database CORINE of the European Environment Agency. The simulated map is compared to a SAR image.

1. Introduction

In order to determine the detectability of artificial objects embedded in a natural environment it is essential to assess the clutter contribution of the surrounding area. The determination by measurement surely is the most precise method, but sometimes a quick and inexpensive estimation of the clutter level by numerical simulation can be sufficient. In addition, temporal factors (e.g. weather, season, vegetation) may be included as well as the variation of radar parameters (e.g. position, frequency, polarization). To this end the surface clutter prediction model DORTE (Detection of Objects in Realistic TErrain) is being developed.

2. Clutter Models

Clutter return is determined by terrain shape and type. In regard to type, currently two kinds of clutter models are employed in DORTE: (semi)empirical and statistical.

2.1. (Semi)empirical models

(Semi)empirical models are based on measurements often supplemented by theoretical considerations. The radar backscattering cross section (RBS) is given by simple formulas containing several parameters (e.g. frequency, grazing angle, terrain type) and delivering a quick and simple estimation. Based on experimental values one has to keep in mind that the pattern propagation factor is included to the 4^{th} power. Also other influences of the environment may be included which are not given by the model. Some of these models are only valid for a certain range of grazing angles and contain only few terrain type classes. For the estimation of land clutter the models of Billingsley, Currie-Zehner, Hayes-Dyer and Kulemin and the water cloud model of Attema and Ulaby can be applied [1]. For water bodies the Georgia Institute of Technology model, the hybrid model and the TSC [2] model are implemented in DORTE.

2.2. Statistical models

In statistical models, terrain shape is described by statistical parameters, as for example RMS height and coherence length. Terrain type is characterized by complex permittivity and permeability. To allow for soil moisture, a simple mixture model of dielectric constants can be used, or the Dobson model, which also takes into account soil porosity. In DORTE the composite Rice-Peake-Barrick (RPB) model [3] is used. Due to its versatility it is applied in cases for which there are no semi-empirical clutter classes. For water bodies the modified composite sea clutter model according to Guinard, Dailey and Choong [4] can be used.

2.3. Statistical variation

Airborne measurements showed that specific RCS values may differ as much as 10 dB for the same terrain type [5]. To assess the detectability of objects in a natural environment it is therefore essential to take into account the statistical variation of clutter. Some of the above mentioned clutter models (e.g. Currie-Zehner, Billingsley) also deliver estimated probability density functions of the measured clutter distribution. For other models (e.g. Attema-Ulaby) these functions can be generated by deliberately varying the model's parameters (Fig. 1). To simulate statistical variations in DORTE, the l'Ecuyer random number generator is used in connection with a Bays-Durham shuffle to generate the uniform distribution. The clutter distribution (Gauss, Weibull, Lognormal etc.) is achieved via the inverse probability distribution function.

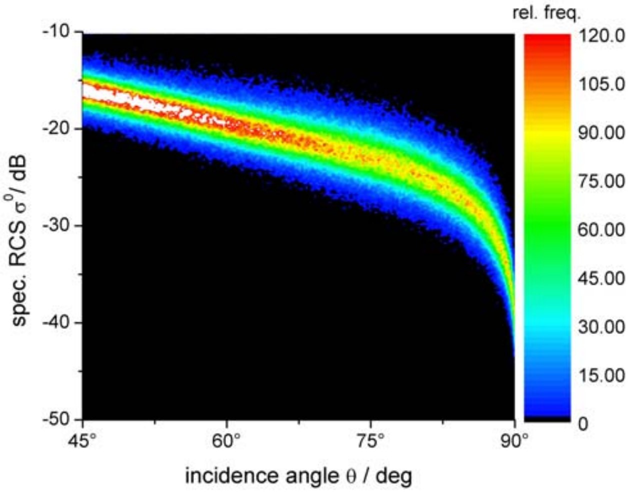

Fig. 1 Attema-Ulaby water cloud model for forest. Colour indicates relative number of frequency

3. Topography

The terrain shape is given by a DEM (Digital Elevation Model). Elevation figures are corrected using the 4/3 effective earth radius approximation. A 2-dimensional Akima spline interpolation is applied to calculate intermediate elevation values and terrain slopes which are used to determine the local grazing angle for use with the above mentioned clutter models. By means of a specialized hidden surface algorithm it is possible to discern areas which would not be accessible for a given radar device position, which is especially important for land-based or airborne radar devices working at low grazing angles. This geometric-optical approach is valid for frequencies above 1 GHz, for which diffraction effects can be neglected.

4. CORINE

To assign clutter models to the visible parts of the terrain, the free land use database CORINE (CoORdinated INformation on the European Environment) of the European Environment Agency EEA is employed. This database is available for most European countries with a resolution down to 100 m × 100 m and consists of 44 land use types. Made for environment purposes, CORINE is not necessarily the first choice for radar applications. For some land use classes (e.g. leisure facilities, mineral extraction sites) appropriate clutter models are difficult to find. In most of these cases statistical models are employed. On the other hand, there are many land use classes to which clutter models can be readily assigned (e.g. coniferous forest, pastures, bare rocks), but additional information is not available as for example average tree height. In such cases typical values are assumed. For several complicated clutter

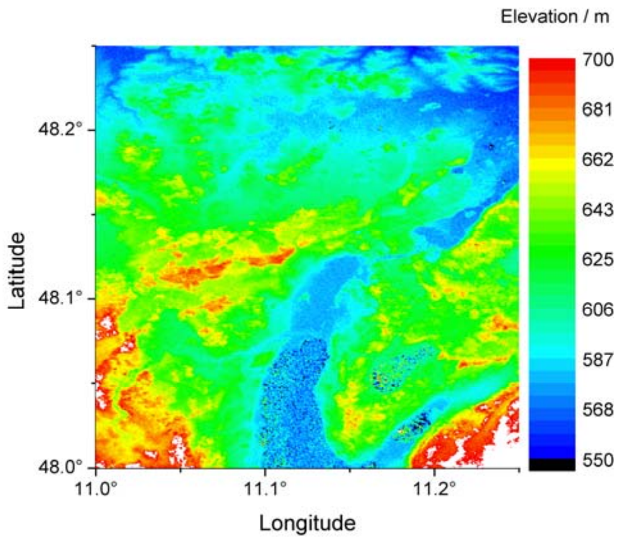

Fig. 2 Digital Elevation Model of the northern Ammersee region.

classes (e.g. complex cultivation patterns) mixtures of different simple clutter models are applied.

5. Simulations

For the simulation of radar clutter return DORTE utilizes a DEM and the corresponding land use information (LUI). Fig. 2 shows the DEM of the northern Ammersee region with a resolution of 376 × 581, derived from the original SRTM DEM by Akima spline interpolation, Fig. 3 shows the fitting CORINE LUI. For this area 16 land use classes are given as described to the right of the figure.

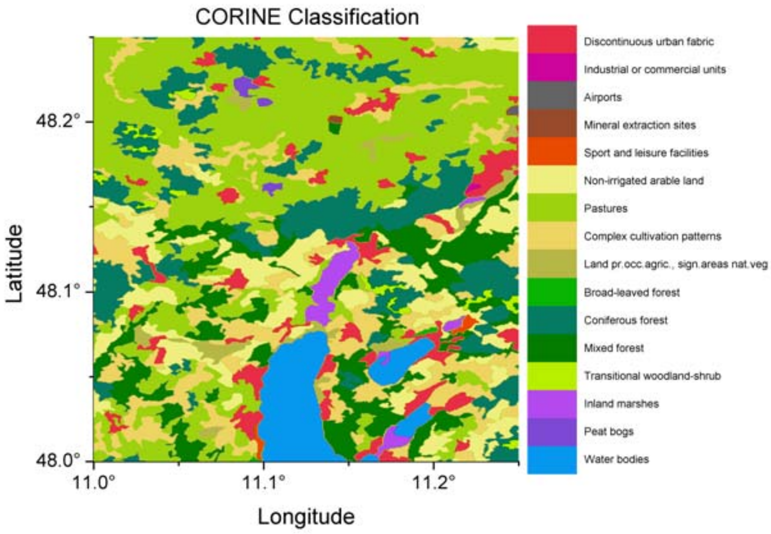

Fig. 3 CORINE LUI, Source: CORINE land cover, Germany, UBA, 2004, European Environment Agency

Fig. 4 shows the resulting DORTE simulation of the radar reflectivity map with statistical variation at 9.6 GHz radar frequency, VV polarisation. The incidence angle at the scene centre is 54°, the true heading to the radar device is 316°. For the calculation of the water return wind strength of 1 Beaufort has been assumed. For the generation of the histogram data have been averaged in 2 × 2 blocks.

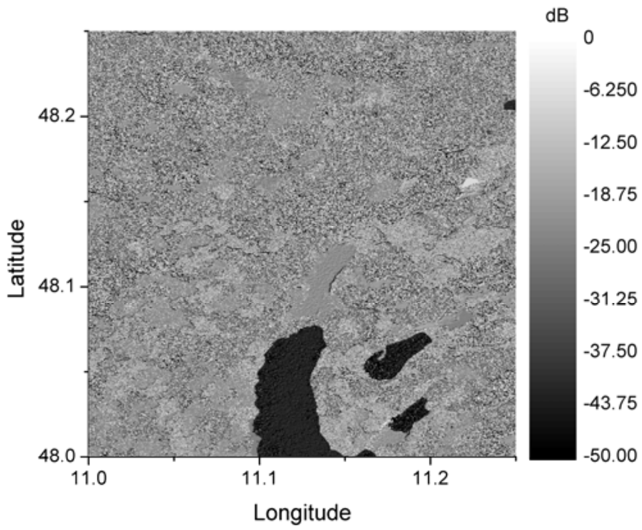

Fig. 4 Radar backscattering simulation by DORTE

Fig. 5 shows a cut-out of the same area of the SRTM / X-SAR GTC (Geocoded Terrain Corrected) product Altomuenster, completely corrected to specific RCS values with data reduction factor and block averaging square size of 2.

To be able to compare these two pictures the histograms of the specific RCS of the measurement and of the simulation are given in Fig. 6. The average RCS of land clutter is around -23 dB in both cases, but the overall variation is much higher for the simulation. This is mainly due to two clutter classes: mixed forest and complex cultivation patterns (CCP). Mixed forest delivers higher values which may be due to the fact that the data was measured in winter and the percentage of deciduous forest is not known (in the simulation 50% was assumed). The return of CCP is generally to low which is to be attributed to the difficulty of assigning appropriate clutter models to this land use class. The water return at lower dB values is strongly dependent of wind strength and direction and would shift to higher values

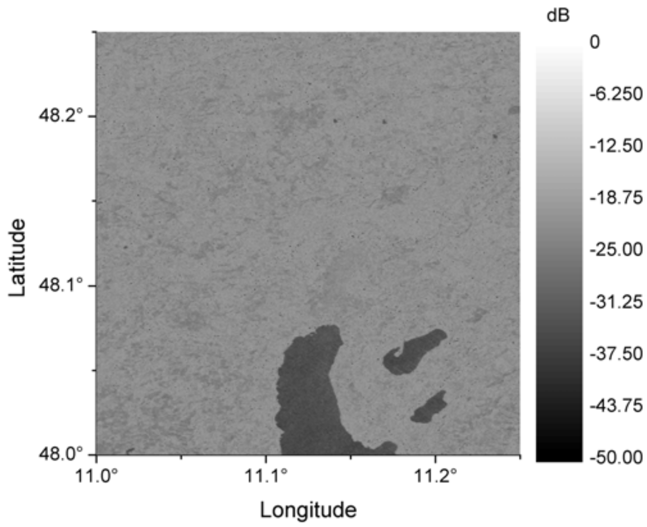

Fig. 5 SRTM/X-SAR GTC Altomuenster cut-out, copyright DLR 2002

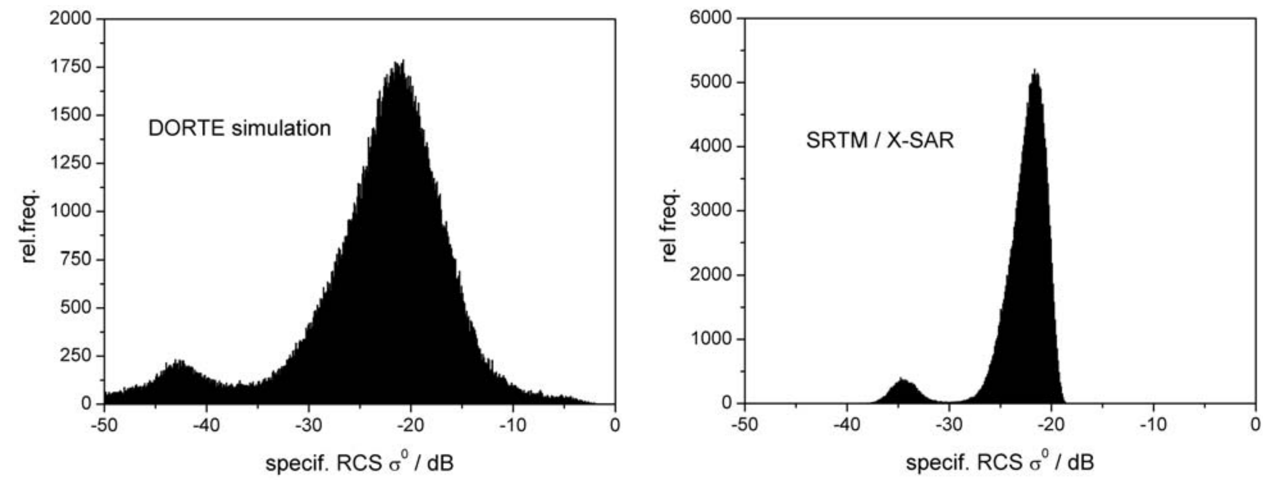

Fig. 6 Histograms of the simulated (left) and measured (right) specific RCS values of the northern Ammersee region

for stronger wind. The abundance of high dB values is due to employing urban clutter models for discontinuous urban fabric.

6. Summary

By using DEMs and land use information reflectivity maps of arbitrary sites can be calculated for a variety of radar, terrain and weather parameters quickly and inexpensively. To this end semi-empirical and statistical clutter models are employed. The predicted average clutter return corresponds to the measured, but the variation for several clutter models is in some cases much higher, the reason of which should be further investigated.

Reference

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