



An Optimal Approach to Reflected Signal Model in Airborne Radar Systems

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ABSTRACT

This work focuses on the optimal approach for implementing the reflected signal model in airborne radar systems. It primarily emphasises integrating various established and improved mathematical models for radar signals, terrains, and objects of different sizes, among others, to create an effective radar scene. Additionally, the unique features of the proposed models are briefly outlined. Furthermore, the algorithm for computing radar echoes within the radar scene is examined. To wrap up, the necessary criteria for the models and recommendations are outlined.

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1. Introduction

Technique progress in digital signal processing and computer simulation technologies goes with the rapidly increasing requirements to complex various on-board radar systems and reflected(backscattered) signal simulators for them [1].

This paper concentrated on the radar scene modeling, which is useful for creating multipurpose simulators of radar echoes. It allows researchers to test an influence of the following main parameters: flight parameters (altitude, trajectory, evolutions of the airborne vehicle, etc.), terrain types (forest, ice or water with different salty and wavy), signal distortions (fading, multi-path), type of emitted signal, and radar parameters (antenna pattern, carrier frequency, bandwidth, duration, repetition frequency, etc.).

The proposed digital model is useful in cases of creating the algorithms of analog and digital signal processing and hardware design of radar scene simulators, which are broadly used to check a radar system operation in real-time [6].

The quality of hardware-in-the-loop (HIL) simulators depends on their signal processing capabilities and possibilities to represent all essential aspects of

the real flight [6], [13]. So, the develop of models of reflected signals for variety of different flight circumstances is worthwhile.

The first question is what programming environment is best for mathematical model design. It is obvious, that every well-known universal program, which is devoted to a signal computation, can be used for creation of radar signal processing models. It is necessary to decide, which is the best one for the radar scene model.

2. Mathematical Model of Reflected Signals

2.1. Programming Environment

At this point, a brief characteristic of different numerical computing environments will be presented.

The first package is application pure C/C++ environment, but despite the universality of this package and ability of using various libraries freely available through the Internet, it is a very long process to create and debug the model.

So, we turned to the more specialized packages. One of them is the SimInTech environment [2]. This program package contains a lot of libraries for creating various systems from power supply stations to airborne vehicles. This system supplies the visual mode for blocks combinations and signals plotting in the scheme, which is similar to Simulink and Vissim. Moreover, libraries are written in many languages and could be imported in the dll-mode. Other advantage is that many blocks have open-source code and can be modified during the model experiment. So, the producers of this program provide customers support in design and evaluating models for any purposes. On the other hand this program product is the proprietary software.

Another candidate is the GNU Radio [3]. This package is provided only for the Linux OS. So, typical Windows user would feel uncomfortable to use this product. This product provides also the visual mode of design and a lot of libraries for various radar blocks, all libraries are provided with source code and could be modified. But compatibility of libraries causes many questions, because of the conception "as is". Only enthusiasts use and improve this project. The next candidate is the SystemVue program [4]. This product contains libraries for radar's signal multi-path propagation, multiple channels, jammer, interference, etc. It is also compatible with the MATLAB system. The price of this product is equally high.

The next product is the SciLAB, it is an analog of the MATLAB system with free-ware license and open-source code. Most of packages have similar functionality, for example, the Signal Processing and Communication toolbox, Simulink, SAR simulator, import from MATLAB libraries, etc. So, it can be used as the cheap and effective model system for creating the radar scene. This program has a problem with compatibility of different libraries, some of them are unstable and could crash the system. But it is improved every year by European airspace industry.

The last and the most popular program product is the MATLAB, it contains a huge number of libraries, but most of them are unavailable for modification. But the MATLAB has many advantages, some of them are technical support, very effective improvements with each release, ability to build own libraries and import of the third-party modules, and well-designed user interface. Also, it is available in some universities for staff and students. So, we have chosen the last one.

2.2. Model Structure

It is necessary to divide model in some blocks and describe them separately. Analysis of known sources showed that the most common way is to use the following blocks: underlying surface (terrain) properties, channel of propagation, reflected signal, and evolutions of the airborne vehicle. As it was shown in [1, 5, 6, 7], for radar signals the phenomenological model provides ideas that the superposition of partial signals can be used for radar echoes, the reflection could be presented in terms of geometrical optics, and underlying surface could be split into facets, i.e., tiny pieces of terrain. Because of difficulty and impossi-

bility of implementing other electromagnetic methods for description of big areas of real relief terrain we, have chosen the phenomenological facet model.

So, representation of terrain could be implemented by square or triangle facets, each of them has its own parameters: a square, orientation, backscatter-ing diagram, radar cross section (RCS), and position. All these parameters are sufficient to compute an amplitude and phase of partial signals. This way allows us to model various types of terrains, such as "meadow", "ground", "asphalt", "concrete" and so on.

The rough terrains usually could be presented in the two-scale model, which combines low roughnesses and relief (terrain, such as rocks and hills). The rough-nesses could be presented by their mean statistical characteristics. We chose an effective backscattering diagram, which (as it was shown in number of sources [1, 5, 10, 11]) is the most useful statistical characteristic for radar echo signals. The relief could be modeled by position and orientation of the tiny facets [6, 12]. Also, it is possible to model a wavy water surface and forest by this way. But in this paper, other more complicated way is suggested to evaluate reflected signals from these complicated types of terrains.

Forest Modeling. Nowadays it is possible to model a reflected signal from each tree and, also, we can change its geometry and its reflection characteristics [1, 7]. For example, we can create the model of pine, aspen, or a birch. For obvious simplification, we have divided the reflected signal in three parts or layers: Canopy, Trunks and Ground. The forest model in Figure 1 depicts additional (for the Direct beam backscattering) the multi-path signal reflections [7].

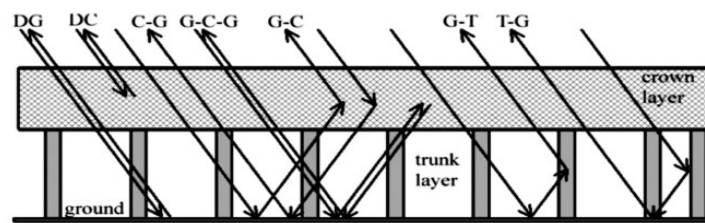


Figure 1. The multi-path signal reflection from forest layers

For different incidence angles and wavelengths of an emitted signal, the weight of each part would be different. For example, if we talk about the 3 cm-wavelength with about vertical illumination the most weighty component of the reflected signal will be from the crown (if it about leafy trees), a bit less signal will come from a ground, and very few reflected signal returns from trunks. For the millimeters-wavelength, the most strong component is the signal from the canopy, otherwise the meters-wavelength signal is reflected mostly from the ground. So, the reflection depends on wavelength, and we have to get information from real flight experiments to reveal the reflection dependencies.

So it is necessary to design a geometric model for each tree, which will be the base for computing the multi-path signal reflections with precious values of amplitudes and phases of all facets partial addends [6].

After this, it is preferable to model the signal from forest, which can be presented by a number of trees. As soon as we have the geometric model for one tree, we can apply it to many similar trees (clones, which orientation is random) and obtain signal from all the forest. So, we do not need to evaluate signal all the time from each tree, but we can compute it from the geometric model according to proper angles.

There we face to other problem how to evaluate the signal, which is weakened by the leaves of other trees or re-reflected from the lower part of canopy or trunks. There is no common decision, but in some sources [6, 7] it is mentioned that it is possible to neglect the re-reflected signal at all for typical trees because of the weakness their relative magnitudes.

The examples of triangular facet models of the single tree (imported from the 3Ds Max library), woods (reconstructed in the MATLAB system), and the accordingly evaluated received pulse (there about 1.2 million facets in the scene for the radar altitude 50 m with the vertical illumination by a short pulse radar) are presented in Figure 2.

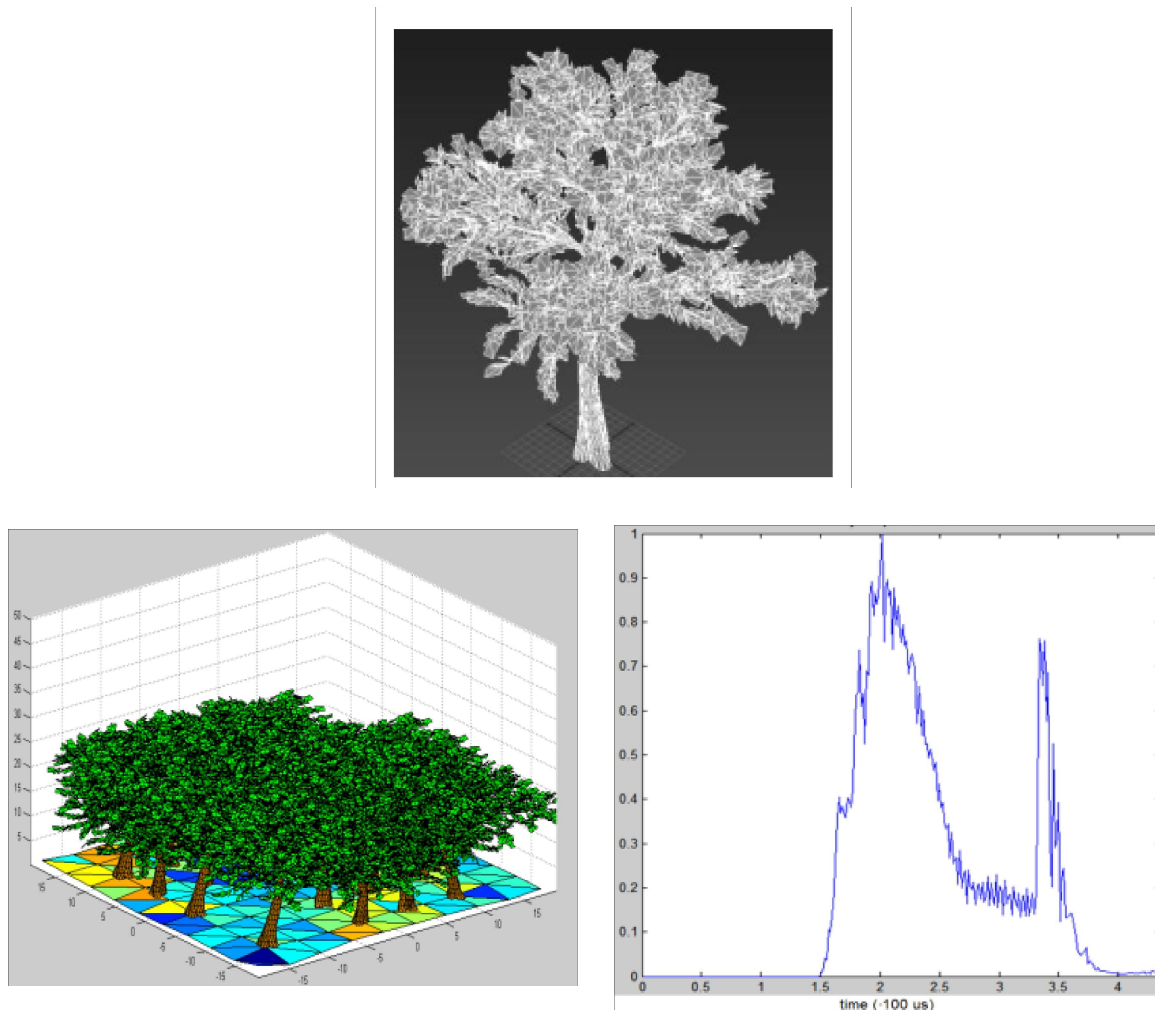


Figure 2. Examples of models of the tree, woods and a received pulse

The signal shadowing by canopy can be resolved by implementing the backward raytracing method. The ability of model simplification instead of accurate model of trees is to implement a cloud of randomly spread reflectors. It is mostly useful for the crown model.

But the question is how many reflectors is necessary to use in the model. On the one hand, it can be revealed by the comparison of results of natural experiments and model results. On the other hand, we can take into account the real accuracy of the example of radar system and fill every distance-angle volume or bin (resolved by the common or imaging radar, SAR, etc.) by sufficient number of facets: up to 10–50 facets inside each interesting bin. As the result, we can create an appropriate model for such a complicated terrain type and radar system.

Wavy Water Modeling. The next point is the model of a wavy surface. As soon as this topic was highlighted in many researches, we have big amount of carefully debugged models and experimental results of water surface explorations.

At first, it is necessary to mention that the agitation of water surface depends on the wind speed; so, the reflected signal will be different for variety of wind speeds. But not only wind causes surface agitation, it can be caused by ships, water flows, or by the attraction of the moon; and also by a change of water depth, especially, for small depths and steep slope of water bottom. The last one is the most challenging process in modeling the wavy surface. Other feature is that not all emitted signal backscatters on the water surface; it can be reflected from the ground under water, especially, for small depths, unsalted water, and low carrier frequencies.

So, the next thing to deal with is salty of water. The magnitude of the reflected signal depends on salty, as it was shown in [10, 11]. Sequentially, it is necessary to design a wavy water model, which can accurately takes into account the foregoing effects.

Revision of existing models revealed that the most suitable models are the Pierson-Moskowitz (PM) model, Texel, Marson and Arsole (TMA) model, and their enhanced methods [8, 9, 12], which allow us to take into account most of the mentioned effects including the depth dependence of water waving. One approach on the basis of the Joint North Sea Wave Project (JONSWAP) and TMA models can be described by calculating an energy spectrum of waves [9]

$$E_{\text{TMA}}(f) = E_{\text{JONSWAP}}(f) \cdot \Phi(f^*, h), \quad (1)$$

$$E_{\text{JONSWAP}}(f) = \frac{\alpha \cdot g^2}{(2\pi)^4 \cdot f^5} e^{-\frac{5}{4} \left(\frac{f_p}{f}\right)^4} \cdot \gamma e^{-\frac{f_p - f}{2 \cdot \sigma^2}}. \quad (2)$$

Here, f is the wave frequency, $\Phi(f^*, h)$ is the Kitaigorodskii depth function for the depth of water h ; $\Phi(f^*, h) = \frac{1}{s(f^*)} \cdot \left[1 + \frac{K}{\sinh(K)}\right]$; $f^* = f \cdot \sqrt{\frac{h}{g}}$; $K = 2(f^*)^2 \cdot s(f^*)$; $s(f^*) = \tanh^{-1} \left[\left(2\pi \cdot f^*\right)^2 \right]$; α is the scaling coefficient; g is the gravity constant; γ is the peak enhancement factor; $\sigma = 0.07$ for $f \leq f_p$; $\sigma = 0.09$ for $f > f_p$; [9]

f_p is the maximum spectrum frequency given by $f_p = 3.5 \cdot \left(\frac{g^2 \cdot F}{U_{10}^3}\right)^{-0.33}$, where F is the fetch length; U_{10} is the wind speed at a height of 10m.

According to this spectrum, the parameters for each elementary wave of water surface are defined (height and wavelength, direction of propagation, wave phase, etc.). These data, together with the aircraft speed vector, current time, and the antenna direction are inserted into the analytical formula [12] Nf-1

$$\xi(x, y, t) = \sum_{n=0}^{N_f-1} \sigma_n \cdot \sin(K_{0n} \cdot [(x + (V_x - U_{nx}) \cdot t) \cdot \cos \beta_n + \dots (y + (V_y - U_{ny}) \cdot t) \cdot \sin \beta_n] - \Omega_n \cdot t + \alpha_n) \quad (3)$$

where x, y is the actual facet location at time t ;

n is the number of wave trains;

V_x, V_y is the aircraft speed projection;

U_{nx}, U_{ny} is the waves speed projection;

$z + (VU_{nx})t, y + (V_yU_{ny})t$ is the offsets in the Oxy plane;

α_n is the wave phase;

β_n is the direction of wave propagation;

Ω_n is the pulsation;

K_{0n} is the wave number;

$N_f \gg 1$ is the number of waves;

σ is the standard deviation of sea wave heights.

Examples of model results of wavy water surface according to the model with the wind speed 10 m/s is presented in Figure 3. The results of model experiments correspond to information from open sources [1, 5, 11]. The salty of water can be taken into account by results of salty measurements. Nowadays we can base on researches provided by many organizations and researcher teams [12].

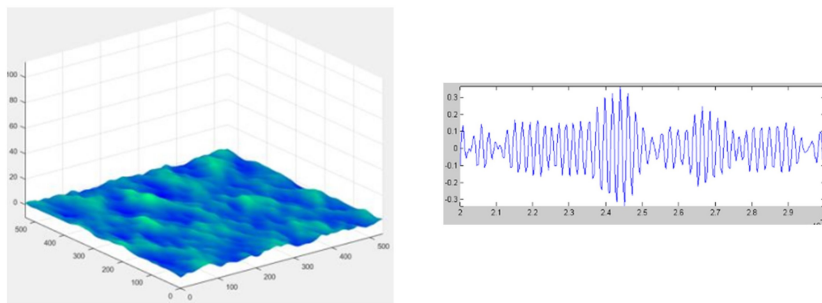


Figure 3. Examples of the wavy surface and computed beat signal of the radio altimeter

Other complex terrain types and objects. Another type of terrain, which currently has no implementation in designed model, is an urban development. This is extremely complicated type of terrain, which can be modeled by implementation of 3D models of buildings, bridges, roads, power lines, and huge amount of other different objects. Some their geometric models are ready and accessible in graphic programs, such as the AutoCAD and 3Ds Max. Their surface forms can be imported, for example, in the MATLAB system, and presented as facets. So, the next step is to accurately set the reflection characteristics for all facet materials. Usually, just a lot of experiments can be helpful for that challenge. Therefore, this type of terrain with some simplifications also can be added into the designed facet model. For many special local objects, such as vans, tanks, or cars the geometric models exist, which are freely accessible (for examples, see [6]). So, we can implement them to fulfill a radar scene.

The next and last point is combination of terrain types in one radar scene.

It can be easily presented by brushing (specifying) facets by different reflecting characteristics. So, if one facet presents water, it can be brushed as water-terrain; if other presents the grass, it is brushed with the grass-terrain type. This idea allows us to create lengthened and other usual objects of any form and size.

As the result, we discussed the conceptions for terrain modeling process that allows us to model various terrains and their combinations.

2.3. Signal Representation

The next point is how to represent the signal. It was nothing told about it earlier. For definiteness, we talk about the pulse radar signal, but the very similar operation (as it is written in [6]) can be done for a chirp signal with linear frequency modulation. The emitted signal can be modeled at the carrier frequency. So, it is necessary to have more than two points per a period of signal, but the amount of computations becomes unacceptable. Thus, the usual way is to implement low frequency as the source of information with addition of in-phase and quadrature components, which include the phase information. It is especially necessary in evolution of the evaluate Doppler phase shifts and computation of radar images. The in-phase component could be presented by the sinusoidal signal, the same could be told about the quadrature component, but between components there exists the phase shift of 90 degrees.

The next point is how to sum signals reflected from partial facets. We applied the method, where partial signals can be added to the result signal with their delays, according to the optical geometry theory. For an illuminated spot, we collect the partial signals from all facets in the circle (or ellipse) bounding the half-power level of the antenna pattern. We neglect other partial signals. But the result signal presents only one pulse or repetition interval, so, it is necessary to present the train of pulses. It depends on parameters of pulses: a pause between pulses, duration, envelope, and magnitude. The only envelope should be discussed in detail, others are intuitive parameters. In terms of modeling process, the pulse form could be presented by a number of plots, each of them presents a count of the amplitude (or the power, it is the matter of convenience). For each count with its delay, we accumulate the result signal. Therefore, we have the reflected power (or amplitude). After that it is obvious to evaluate in-phase and quadrature components by multiplication of the sinusoidal signal with counts of reflected amplitude. At the end, we have the train of reflected pulses, which can be processed, for example, by methods of synthesis the radar image.

3. The Digital Model Implementation

At this moment we described the distinctions of the designed model, and now it is the time to describe exactly the implementation of the designed model.

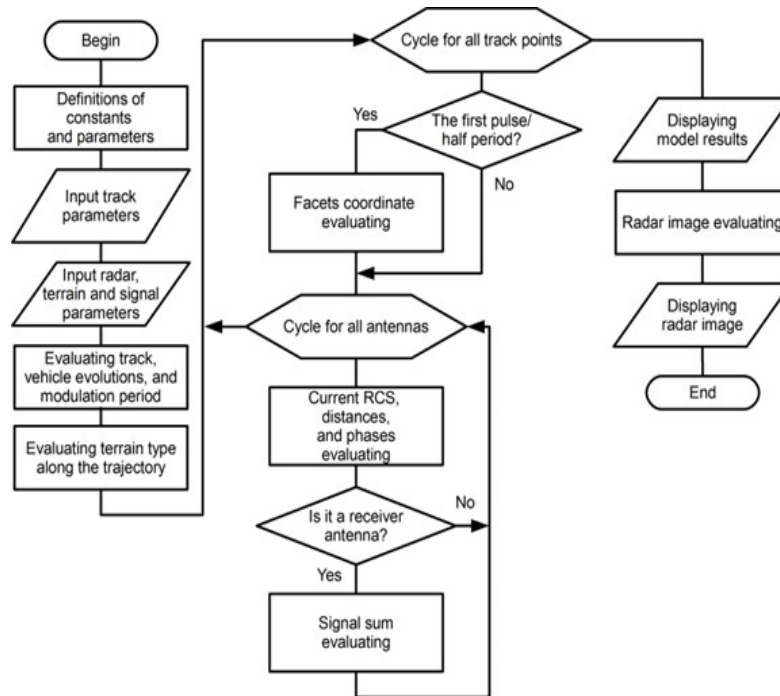


Figure 4. The algorithm of the model of radar echo signal

In Figure 4, the scheme of the radar scene model is shown, which implements all foregoing ideas in one scheme. Here, following sequence of computation is implemented: constants definition and model parameters; input the track, signal and terrain parameters; track, vehicle, and illuminated spot evaluating; cycles for all antennas and for all points of trajectory where the reflected signal is evaluated; displaying the model results and radar image preparation.

This model allows us to change separately each part of the model without changing others; also, it suits as well for pulse radar as chirp radar. Also, as it was mentioned above, we can add local objects, such as trees or cars, combinations of terrains, change signal, vehicle and terrain parameters. Therefore, this model is flexible and powerful enough to build the simulator of the radar scene.

Therefore, it is possible to extend this model by adding more complex signal forms, extending database of terrains and local objects or connecting this model to the real-time services of vector maps, which are freely available through the Internet, for example, Google-maps.

As soon as we have the model, it is necessary in brief to describe the module structure of the radar scene model. In Fig. 5 the modules are highlighted in bold names. For example, in the MATLAB system, modules are presented in separate files. Also, nearby the names of modules, the brief descriptions are given.

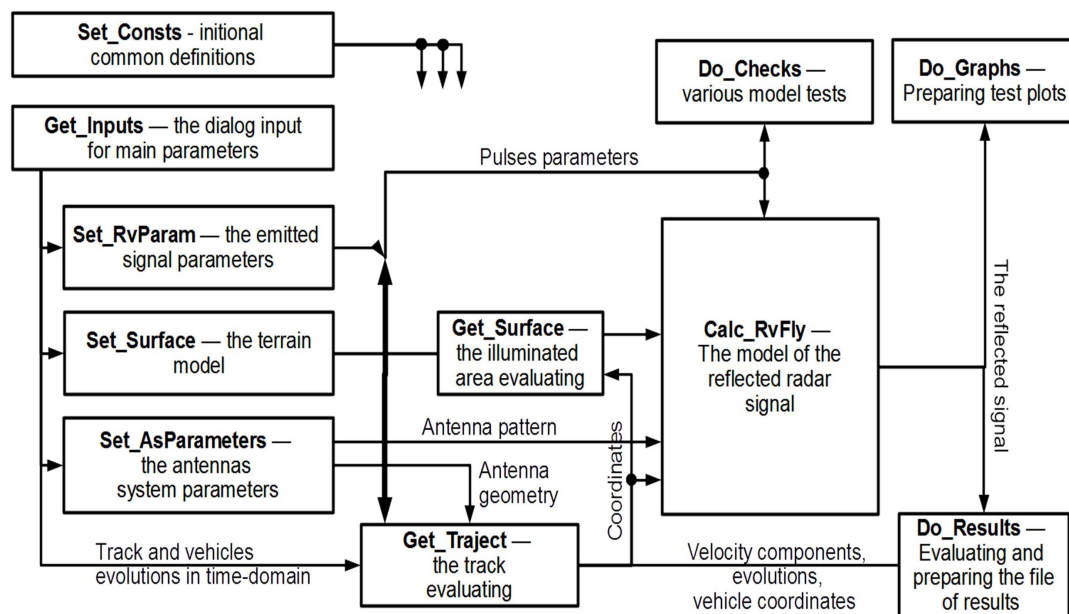


Figure 5. Module structure of the radar scene model

The module **Get Trajectory** is the clock module, which synchronize all modeling process; so, the parameters of emitted signal and trajectory at first are passed to this block. Also, this model has the following distinctions: the parameters of the transmitter can be passed in the **Set RvParam** module; the receiver parameters (if it is necessary) could be implemented afterward.

4. Conclusions

In this paper, the radar scene model is described; it can be implemented and helpful for various explorations from radar image algorithm verification up to simulator design [6, 13]. The designed digital model operates with facets, which can represent difficult shapes and

layers of natural surfaces. Additional facet radar properties, such as an orientation, RCS, and backscattering diagram are used to compute the multi-path reflections and overall reflected signal. Also, the radar system carrier motion is taken into account.

Now the model works in the MATLAB environment; so, it allows us to change parameters of signal processing, edit blocks and redesign the model according to specifications of existing and prospective radar systems. Furthermore, the model is sufficiently flexible, in other words, each block can be improved and transformed separately by a researcher for different radar and navigation systems. The next step is the following: weakening relations between modules, terrain database fulfillment, and addition various algorithms for digital signal processing.

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Designing A Clutter Suppression Algorithm for Synthetic Aperture Radar

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ABSTRACT

Modeling the clutter reflection suppression algorithm in synthetic-aperture radar is considered in the article. The proposed algorithm allows one to increase the signal detection efficiency with closely located sources of clutter due to the use of a priori data of static objects of the infrastructure.

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1. Introduction

The forming problem of the optimal algorithm for signal detection in the radar with synthesized aperture (SAR) under the presence of the clutter reflections from the local objects and the design of the efficiency estimation method of such detection are the main problems in the development air and satellite observational platforms for remote earth and water surfaces sensing system.

2. Algorithm Development

Devoted to the problems of signal processing within the SAR papers [1-3] pay great attention to research of the detection algorithms under clutter impact caused by the reflection from the underlying surface and noises. A SAR antenna pattern in some practical situations (along with the valid signal reflected from the multiple-unit target) has powerful clutter signals produced by the reflections from the clutter objects. Therefore, in these cases the processing algorithm should be formed accounting both the distribution target character and the clutter presence. Determination of the main principles of algorithm construction and the analysis methods present the content of this paper. Suppose the side-looking radar moves along the linear path. The range resolution cell has the target and clutter signals formed by the separate reflectors, which are distant at $d_t^i (i = \overline{1, n})$ and $d_c^i (i = \overline{1, N})$ from the coordinate origin with the Δt step, and n and N are the numbers of the target and clutter reflectors respectively (Figure 1). Under the discrete time processing, the vector of the observed data is presented in the following form:

$$Y = \beta_T A_T + \beta_C A_C + N_N \quad (1)$$

$$\beta_T = \begin{bmatrix} X(d_{1,1}^t), X(d_{2,1}^t), \dots, X(d_{n,1}^t) \\ X(d_{1,2}^t), X(d_{2,2}^t), \dots, X(d_{n,2}^t) \\ \dots \\ X(d_{1,M}^t), X(d_{2,M}^t), \dots, X(d_{n,M}^t) \end{bmatrix} \quad (2)$$

where

$$X(d_{n,k}^t) = \left\| \exp(-j \frac{4\pi}{\lambda R_0} d_n^t r_k) \right\| \quad (3)$$

is the phase signal distribution reflected from i -target element on the points of synthesized aperture with the coordinates $r_k, k = \overline{1, M}$ (λ is the wavelength); A_T and A_C are $(n \times 1)$ and $(N \times 1)$ vectors of complex target and clutter amplitudes which are normal random variables with zero mean and dispersions $\sigma_{T_i}^2$ and $\sigma_{C_i}^2$ respectively; matrix β_C is determined similarly to (2) and (3), N_N is the complex amplitude vector of gaussian noise.

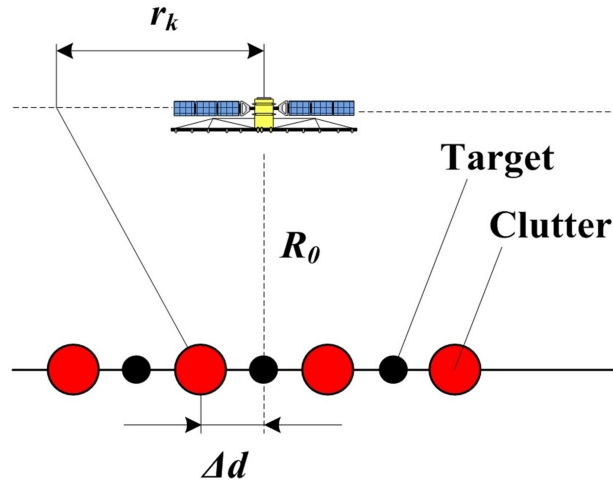


Figure 1. Task geometry

Recording the observed data in the form (1), the quadric form of sufficient statistics for the detection of the target signal is

$$\alpha = Y^{*T} \theta Y, \quad (4)$$

where $\theta = R_C^{-1} - R_{TC}^{-1}$ is the processing weight function,

$$R_{TC} = \beta_T Q_T \beta_T^{*T} + R_C^{-1}, \quad (5)$$

$$R_C = \beta_C Q_C \beta_C^{*T} + R_N, \quad (6)$$

are the correlation matrices of vector (1) with and without the target signal respectively

$$Q_T = \text{diag}(\sigma_{T_1}^2, \dots, \sigma_{T_n}^2), \quad (7)$$

$$Q_C = \text{diag}(\sigma_{C_1}^2, \dots, \sigma_{C_N}^2), \quad (8)$$

$$R_N = \sigma_N^2 E \quad (9)$$

where $*$ is a complex conjugation, T is a transpose sign, E is the identity matrix with the noise dispersion $\sigma_N^2 = 1$. Using Woodbury formula for the determination of the optimal weight function the equation of the sufficient statistics derives as

$$\alpha = Z P Z^{*T}, \quad (10)$$

where

$$P = (E + Q_T \beta_T^{*T} R_C^{-1} \beta_T)^{-1} Q_T, \quad (11)$$

$$R_C^{-1} = R_N^{-1} - R_N^{-1} \beta_C (E + Q_C \beta_C^{*T} R_N^{-1} \beta_C)^{-1} Q_C \beta_C^{*T} R_N^{-1}, \quad (12)$$

$$Z = Y^T R_C^{-1} \beta_T^* = Y^T X^* (d_i^t) - \sum_{l=1}^N \chi_{li} Y^T X^* (d_i^c), \quad (13)$$

$$\chi_{li} = \sum_{t=1}^n \rho_{lt} X^T (d_t^c) X^* (d_i^c) \quad (14)$$

where ρ_{lt} It is the matrix (11) element.

The schematic structure with the optimal algorithm (10) is shown on Figure 2.

The main functional operation in (13) is

$$Y^T X^* (d_i) = \sum_{k=1}^M \exp(-j \frac{4\pi}{\lambda R_0} d_i^t r_k) \quad (15)$$

that presents the chirp demodulation and the discrete Fourier transform (DFT) estimated for the spatial frequencies $2d_i/\lambda R_0$ that corresponding to all elements of target (clutters).

3. Algorithm Analysis

The relative gain of the optimal processing in comparison with the traditional one in SAR does not allow one to estimate the absolute values of the detection characteristics with multiple-unit sources of signals and clutters. On the other hand, the exact calculation of these characteristics is connected with the significant calculation difficulties caused in the determination and integration of distributed statistics (10). Therefore, the efficiency estimation of the considered algorithm uses the method based on the Chernoff bound [3], according to which the detection and false alarm probabilities are counted the formulas

$$P_D = -\exp[\gamma(\nu(s) + (1-s)(\dot{\nu}(s) + 0.5(1-s)^2\ddot{\nu}(s)))] \times \text{erfc}[(1-s)\sqrt{\gamma\ddot{\nu}(s)}], \quad (16)$$

$$P_F = \exp[\gamma(\nu(s) + s\dot{\nu}(s) + 0.5s^2\ddot{\nu}(s))] \times \text{erfc}[s\sqrt{\gamma\ddot{\nu}(s)}], \quad (17)$$

where

$$\nu(s) = \ln \int_{-\infty}^{\infty} \dots \int_{-\infty}^{\infty} P\left[\left(\frac{Y}{T+C}\right)\right]^2 [P(Y/C)]^{1-s} dY, \quad (18)$$

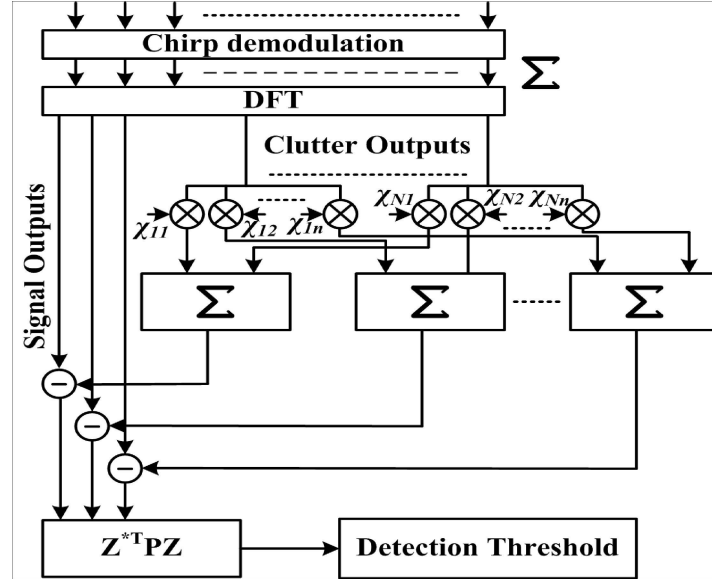


Figure 2. Optimal algorithm flowchart

and $\dot{\nu}(s)$ and $\ddot{\nu}(s)$ are the first and second derivatives of (18), $s = 0 \dots 1$ is the dummy argument, γ is the number of independent tests (for SAR γ is the nlook, e.g. the number of used frequencies with multi frequency probing or the number of non-coherent summed synthesized images for partly coherent SAR working mode), $P(Y=(T+C))$; $P(Y=C)$ are the probability densities of the observed vector under presence or absence of the target signal.

According to the case presented in the paper, formula (18) has the following form:

$$\begin{aligned} \nu(s) = & -0.5 \times \ln(\det(R_T) \times s + \det(R_C) \times (1-s)) \\ & + 0.5s \times \ln(R_T) + 0.5(1-s) \ln(\det(R_C)). \end{aligned} \quad (19)$$

Using formulas (16)-(19), the performance and detection characteristics are calculated. The performance curves shown in Figure 3-5 are calculated for the case when there is only one target and one clutter, $\sigma_T^2 = \sigma_C^2 = \sigma_N^2 = 1$, and the number of observation periods is $M = 1300$.

In the graphs, the performance curves are also shown for the no-clutter case and for processing that does not use the algorithm presented in the article.

Figure 3 shows curves for different values of target-clutter space and Δd at $\gamma = 1$. The graph shows that processing using the algorithm described in the article improves the detection characteristics even at $\gamma = 1$. With increasing target-clutter space, starting from 10 m, the performance curve approaches to the case when the clutter is completely absent.

Figure 4 shows the curves for different values of γ at $\Delta d = 20m$. Figure 5 is the zoomed part of Figure 4. With increasing γ , detection characteristics have a significant gain in comparison with processing without clutter compensation.

Detection characteristics of a multi-element target ($n = 5$) against a background of multiple-element clutter ($N = 5$) for $(N = 5)$ for $\sigma_N^2 = 1, \sigma_C^2 = \{0.1; 1; 0.1; 0.7; 0.5\}$, $M = 100$; $\gamma = 2$ for different target-clutter location cases (Figure 6) are shown in Figure 7.

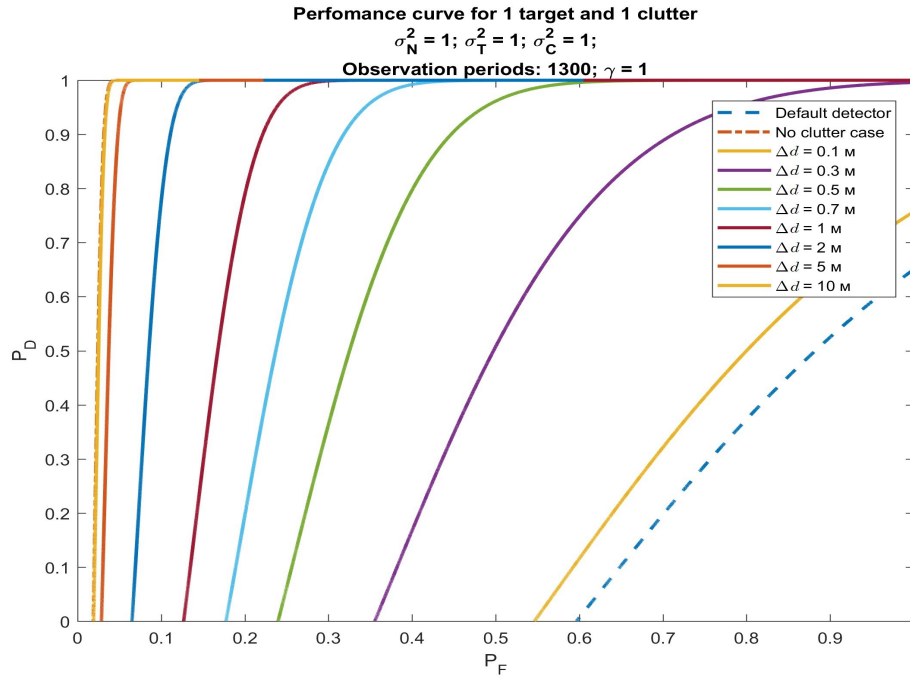


Figure 3. Performance curves for 1 target and 1 clutter

From the presented curves it follows that with a greater spatial separation of the target and clutters the algorithm significantly increases the detection probability of the target.

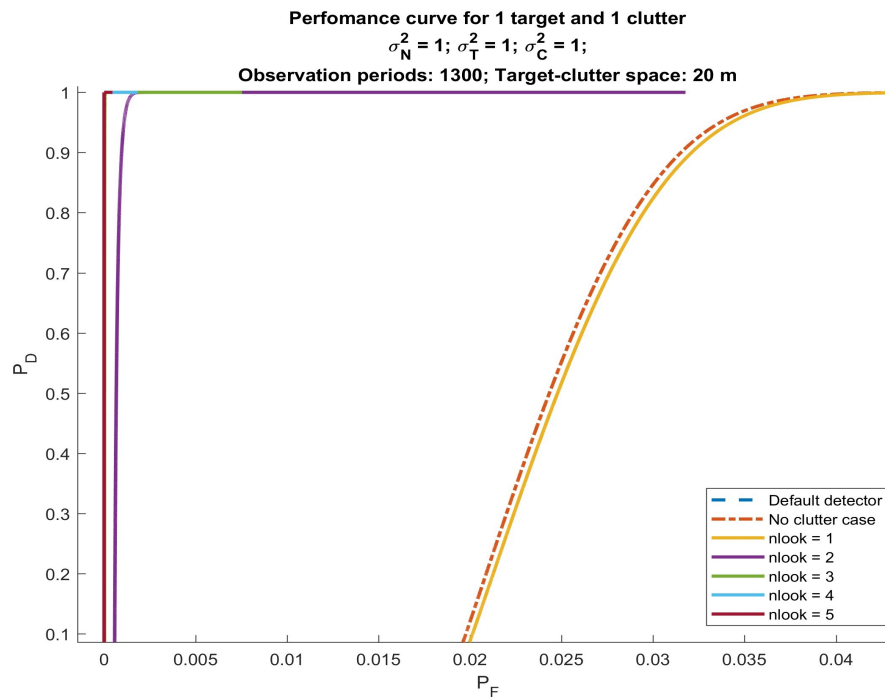


Figure 4. Performance curves for 1 target and 1 clutter

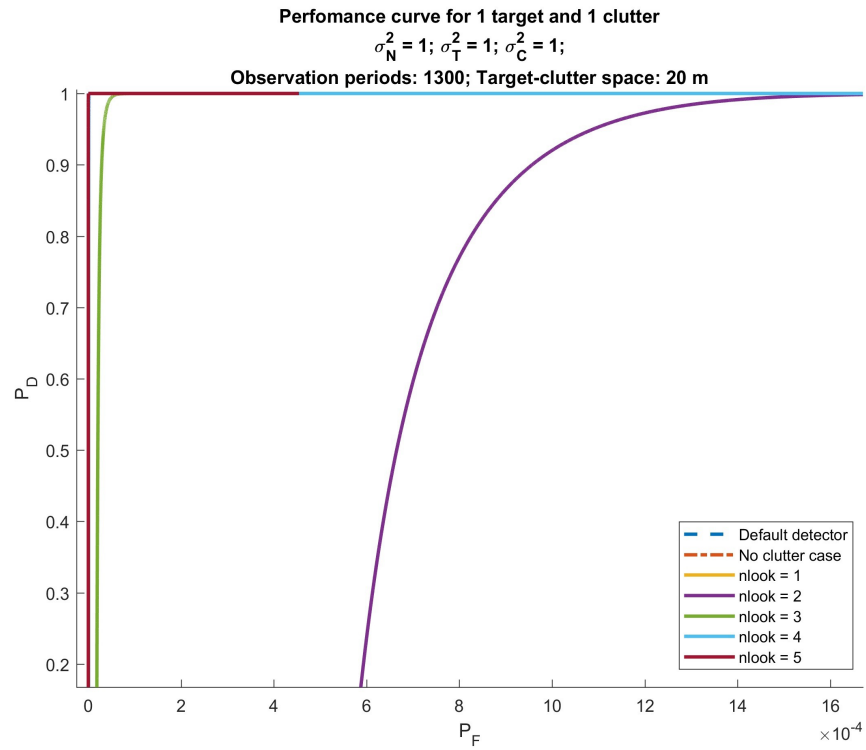
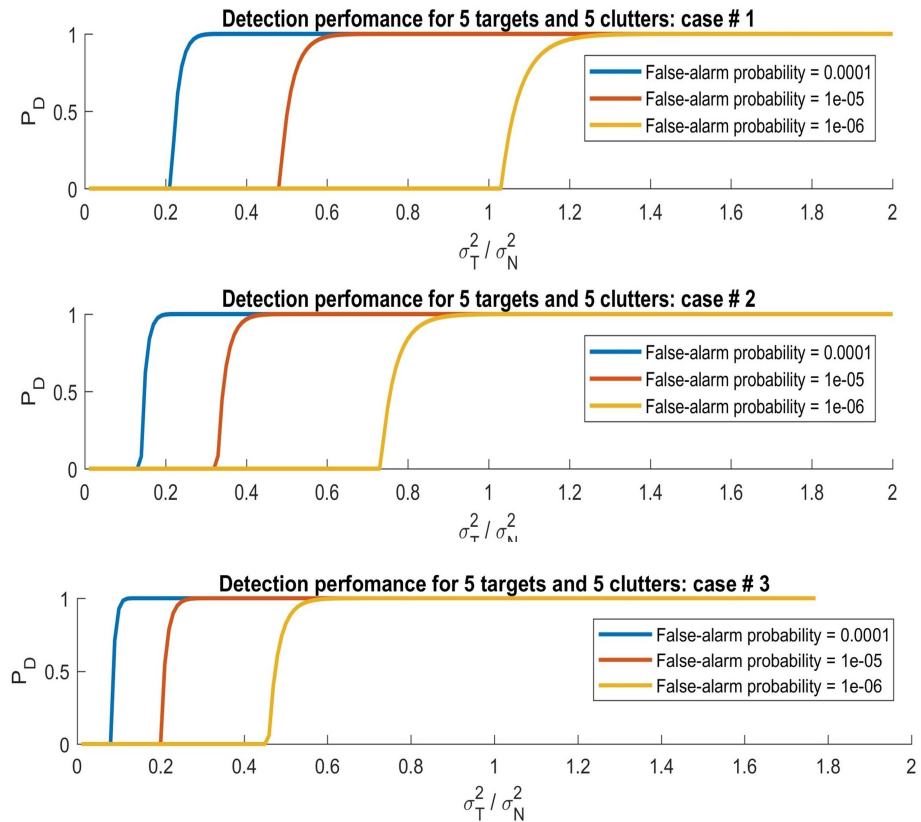


Figure 5. Performance curves for 1 target and 1 clutter (zoomed)



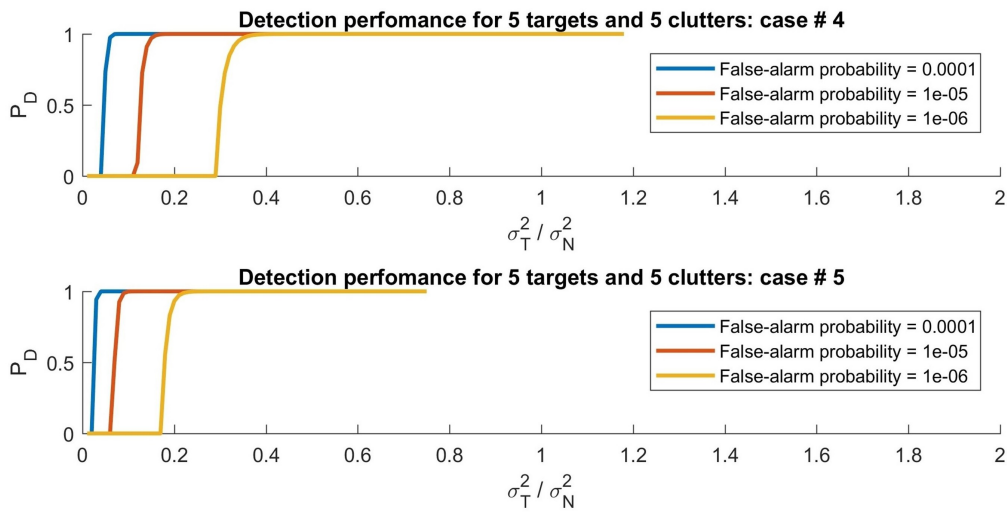


Figure 6. Detection performance for 5 targets and 5 clutters

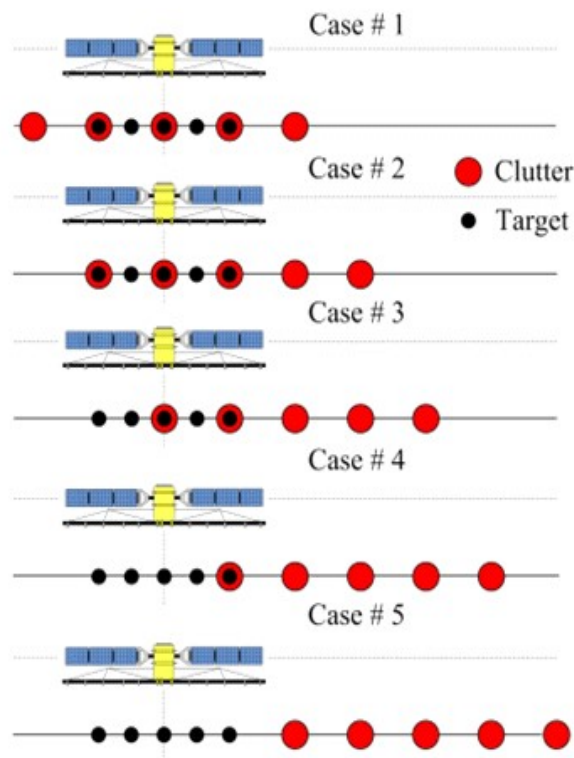


Figure 7. Target-clutter location cases

4. Conclusion

Clutter reflection suppression algorithm in SAR presented in the article significantly improves the detection efficiency of the signals reflected from targets, which are located closely with clutter objects, even in cases where the clutters overlap targets.

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Close-range Radiation Region Surrounding A Ferrite Antenna Using HFSS Model

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ABSTRACT

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The research outlines the findings from a simulation of the close-range radiation region surrounding a ferrite antenna. It explains the HFSS model of the ferrite antenna, which includes a ferrite core, multiple wire coils, and a port for excitation. Additionally, the document displays the outcomes of estimating the antenna's far-field boundary and visualizing the near-field elements. Conclusions were drawn regarding the suitability of this setup of the ferrite magnetic antenna for ground-penetrating radar applications.

Keywords: Ground Penetrating Radar, Near-eld Estimation, Ferrite Antenna

1. Introduction

The ground penetrating radar is aimed at finding and visualizing the objects in concealment environments. The process of finding objects is often complicated due to the nature of the underlying surface (snow, ice, asphalt). A powerful masking reflection from the top edge of the underlying surface layer can completely suppress the reflection signal from the searched object because of the limited receiver dynamic range.

The authors hypothesis is that with specific restrictions on the ground penetrating radar, namely, the search and visualization of objects with high magnetic permeability, such as iron products, the following solution of the raised problem is possible. Due to the highly expressed magnetic properties of the searched objects made of iron, it is appropriate to use magnetic antennas, characterized by predominance of the magnetic field over electrical in the near-field zone. Thus, the hypothesis is that the use of magnetic antennas will allow one to receive the magnetic component of the field, reflected from the searched object undermining the influence of concealing effect reflect from the top layer of the concealment environment with high dielectric permeability [1].

The purpose of this work is to examine the characteristics of the electromagnetic field in the near zone of the magnetic antenna as a result of the ANSYS HFSS simulation. It is proposed to develop and use the ferrite antenna model as a magnetic antenna. The article is organized as follows. Chapter 2 examines the ferrite antenna model created in the ANSYS HFSS program. It also analyzes the input impedance of antenna. Chapter 3 shows the results of the field modeling in the near-field zone of the ferrite antenna. It also evaluates the long-range boundary of the radiation on the basis of the wave resistance approximation to the value of 120 ohm. Analysis of the influence of the amount of the wire turns on the antenna parameters is also given. Chapter 4 provides a brief discussion of the results.

2. Model of the Ferrite Antenna

The basis of the ferrite antenna is a ferrite core in the form of a solid rod or set of rings. Taking into account the frequency range used, the ferrite material must meet the broadband requirements. It also should have low losses. Therefore, on the basis of the minimum loss requirement in the specified frequency range (up to 100 MHz), we have chosen the ferrite ring Amidon FT-50-68. The size of each ring is 12.7 x 7.14 x 4.78 mm. The admissible frequency range is from 1 MHz to 150MHz.

On the basis of known equations, the equivalent diameter of the ferrite rod is defined

$$d = \sqrt{d_{\text{outer}}^2 - d_{\text{inner}}^2} = \sqrt{12.7^2 - 7.14^2} = 10.5(\text{mm}). \quad (1)$$

Now the condition that the maximum efficiency of the ferrite antenna on the rod is achieved with a ratio of its length to the diameter being about 25{30, the required rod length can be calculated

$$L = d \cdot (25...30) = 10.5 \cdot 25 = 263(\text{mm}). \quad (2)$$

The specified ferrite rod has a wire winding with the following parameters: the number of coil turns (turns), the diameter of the wire in millimeters (wire d), and the pitch of the coil winding in times (pitch). Ferrite rod with wire winding represents an inductor with ferrite core, or a ferrite antenna from another point of view.

The widely used design of a ferrite antenna in the form of a simple winding of the wire on the rod has a number of disadvantages. In particular, the power supply terminals of the coil are spaced apart from each other, causing a loop forming when connected. There is irregularity in the phase distribution of the field strengths because the coil is asymmetrical. Turning to the problem of suppressing a direct coupling signal by constructing a differential circuit of two or more receiving antennas [2], it is important to ensure the uniformity of wave

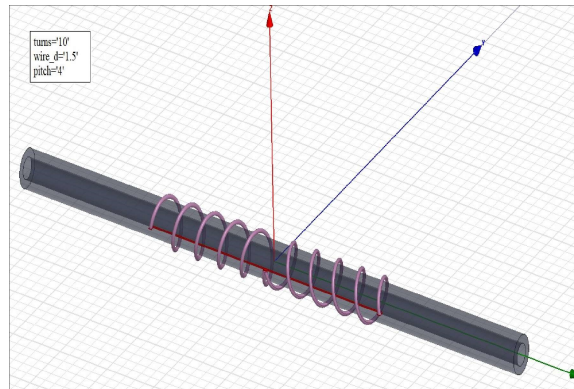


Figure 1. 3D-view of a ferrite antenna model

propagation in the direction of each receiving antenna. Such a task might be solved by a modified model of a ferrite antenna with two in-phase coils connected at a common point. The 3D-view of the ferrite antenna with in-phase coils is shown in Figure 1. It is seen that two coils are symmetric relative to the center of the rod. They are connected at a common point, and the coil ends are connected by an earth conductor (red line) and contact the power port at the center. Also, the coil has the mentioned parameters turns, wire_d and pitch.

Firstly, let us consider the input impedance of the antenna in the range 50- 100 MHz (Figure 2). In this case antenna parameters are the following: the number of wire turns is eight, the wire diameter is 1.5 mm, and the winding step is four wire diameters.

It can be seen that the real part of the input impedance is from 1.8 to 6.3 Ohm, and the imaginary part is from 142 to 406 Ohm. Positive reactance indicates the "inductive" nature of the input impedance in a given frequency range. It is seen that the graph of the reactance at the upper frequency becomes hyperbolic instead of the linear. It indicates that there is undesirable parallel resonance at an excess of 100 MHz.

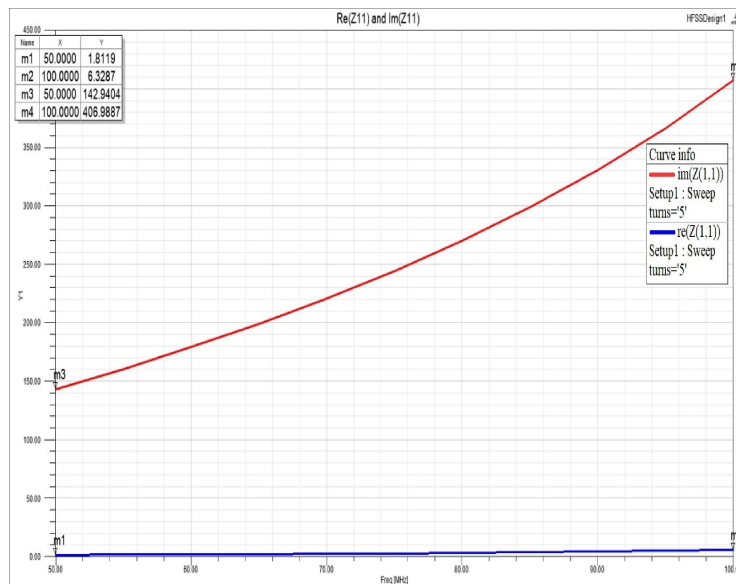


Figure 2. Antenna input impedance: imaginary (red line) and real (blue line) parts

The cross-sections of the 3D-body of the radiation pattern by the azimuth plane at zero elevation and the angle plane at zero azimuth are shown in Fig. 3. In this case, the axis of the ferrite rod is directed along the X axis. The zero directional diagram in this direction is observed. It is seen that the greatest directionality of the antenna is 2.5 dB in the direction perpendicular to the direction of the axis of the ferrite rod. The directional pattern in this case has the form of a torus.

3. Near-field estimation

It is known that any induction coil has a parasitic intercoil capacity, which results in a parasitic parallel resonance. Let us analyze the antenna input impedance at 75 MHz when the number of coils is changed from 3 to 20. As it is seen in Fig. 4, with the number of coils between 7 and 8, a vivid resonance occurs. A more precise resonance level can be achieved by tuning the frequency.

We will consider the influence of the number of coil turns on the characteristics of the field in the near zone. For this purpose, we analyze the graphs of intensity of the electric and magnetic fields along a five-meter-long line emanating from the geometric center of the

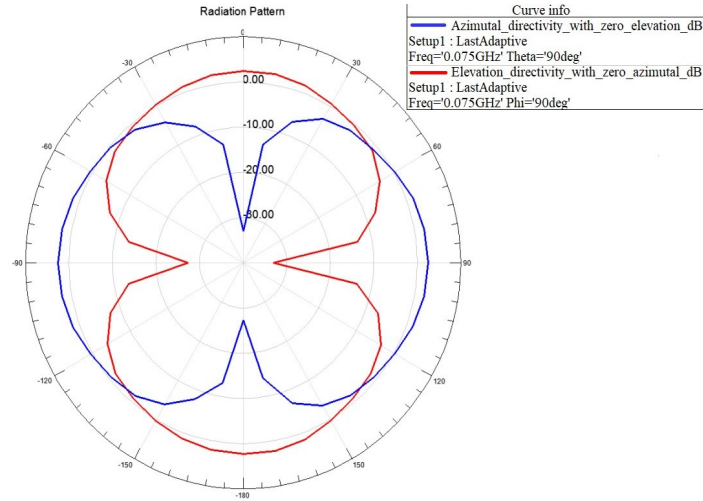


Figure 3. Azimuth plane (blue line) and elevation plane (red line) radiation patterns

antenna. The number of turns in each half of the coil is two turns, five turns, or ten turns. Figure 5 shows that the curves practically coincide. It can be concluded that within a single design in a fixed frequency range, varying the number of turns of the coil significantly affects only the input impedance of the antenna. Wherein, it should not be forgotten about the different frequencies of a coil self-resonance.

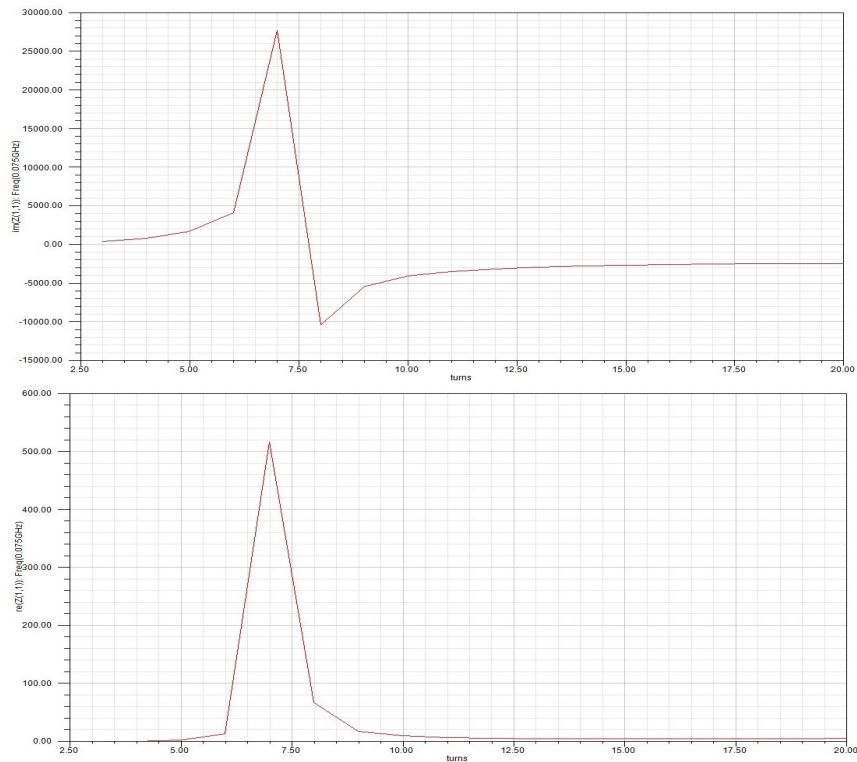


Figure 4. Parasite resonance, depending on the number of wire turns at xed frequency 75MHz: imaginary (above) and real (bottom) components of the antenna input impedance

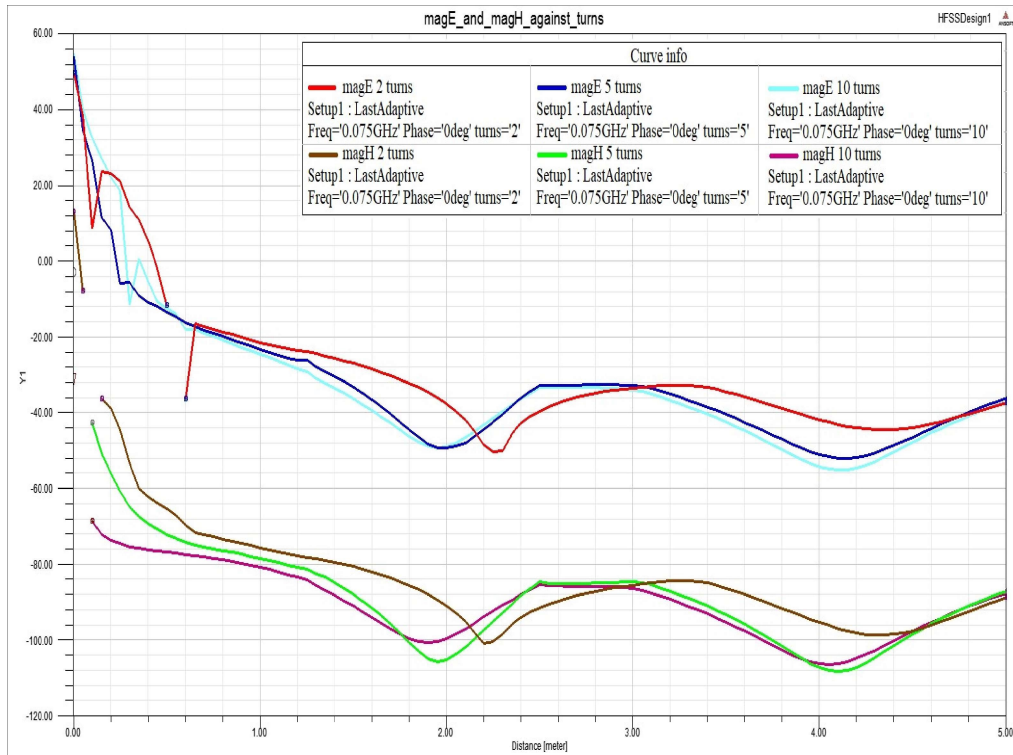


Figure 5. Intensities of the electric (upper curves) and magnetic (lower curves) fields depending on the number of wire turns, dB

There are different approaches to divide the radiation field of the antenna into the near-field and far-field radiation zones, as well as there are different criteria for determining the boundary of far-field radiation. One of criteria is to consider the wave impedance, namely, the ratio between the intensities of electric and magnetic components of the electromagnetic field. When an exact ratio is established, then the intensity of an electric field is 120 times more than the magnetic field intensity. On one may say that the electromagnetic wave front has formed, which propagates in the environment. Let us consider the character of the wave impedance of a ferrite antenna in the near-field zone (Figure 6). It can be seen that the wave impedance in the near-field zone has an inductive character, i.e. the magnetic field prevails over the electric one. As the oscillations of this curve settle around 377 Ohm, the presence of the far-field radiation boundary at this distance can be predicted. It can be said that this boundary is located at the 1{meter distance in case of the frequency equals to 75 MHz (wavelength equals to 4 meters). This result, with an error, corresponds to a theoretical estimate of the far-field radiation boundary for a full-size antennas

$$d_f = \frac{\lambda}{2 \cdot \pi} = 0.63(m). \quad (3)$$

Finally, the iso surfaces of intensities of the electric field (Figure 7) and magnetic field (Figure 8) in the azimuth plane of the antenna are shown, while the position of the antenna is displayed with a red dot at the center. The visible area of the field mapping is five by five meters, which is 1.25λ at an average wavelength equals to 4 meters. The maximum linear size of the antenna is 263 mm, or 0.066λ . The structure of the electric and magnetic fields forming in the near-field zone is clearly visible. We can say that the structure of the magnetic field in the near zone is more uniform and distinctly formed. This is one of the distinguishing features of magnetic antennas in comparison with electrical ones.

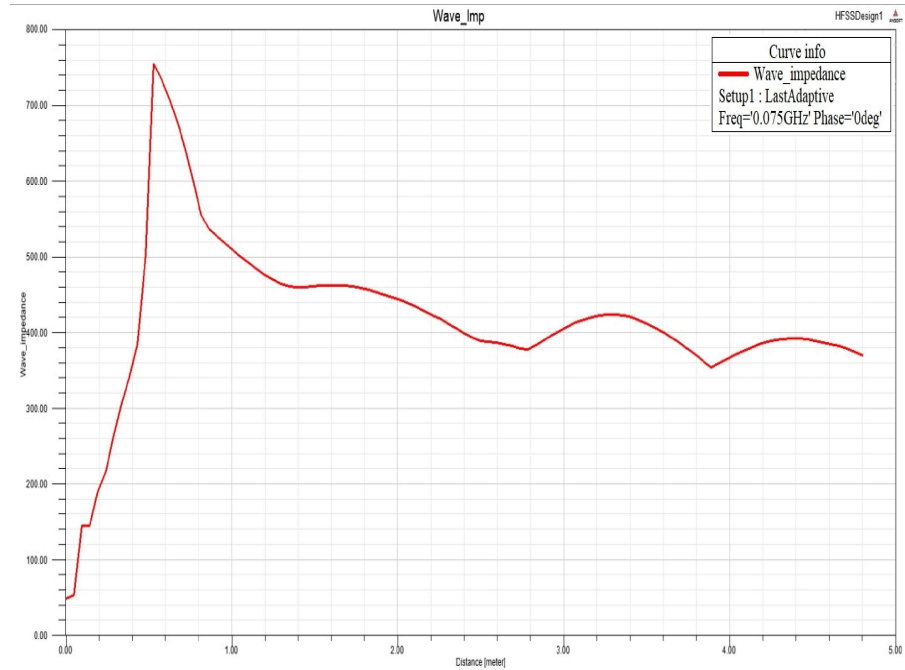


Figure 6. Estimation of the far-eld radiation boundary by wave impedance, Ohm

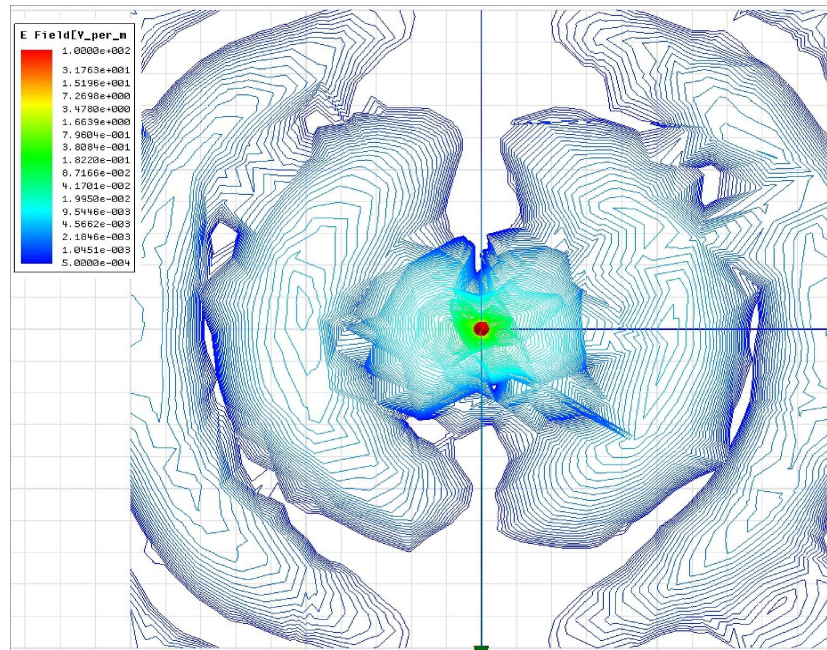


Figure 7. Electric field intensity in the near-eld zone, V/m

4. Conclusion

The modeling results show that it is reasonable to design short-range VHF antenna systems based on ferrite antennas. This will allow one to implement the discussed advantages that are impossible to radio-vision systems with shorter wavelength [3]. A small

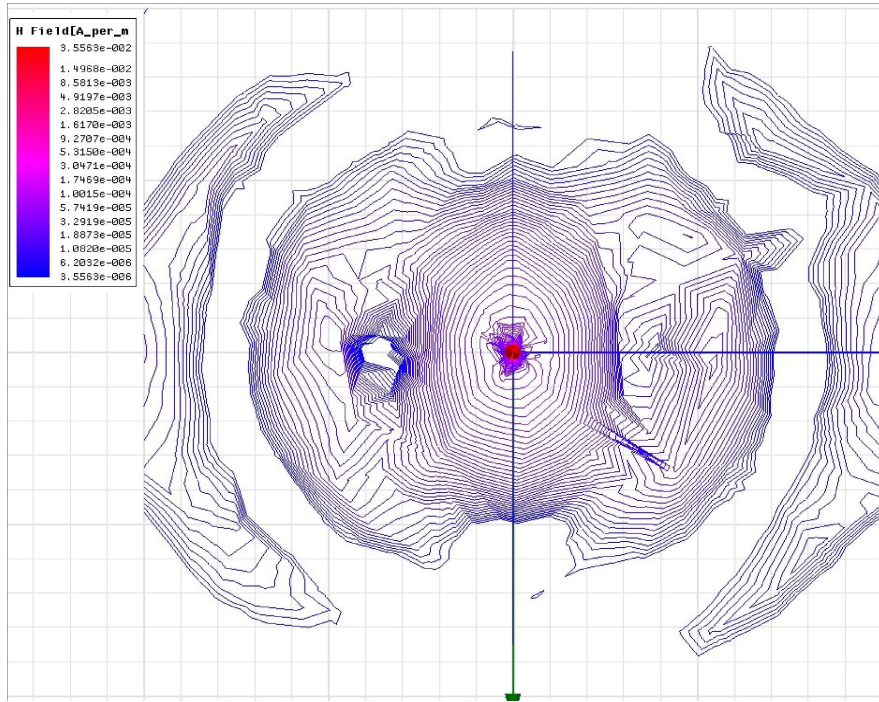


Figure 8. Magnetic field intensity in the near-field zone, A/m

directivity and complicated impedance is a compromise with an extremely large reduction in the size of the antenna (up to 0.09). The boundary of the far-field radiation zone is at a range of about 1 meter according to the simulation results. Thus, at ranges up to 1 meter, the magnetic field emitted from the antenna dominates. In other words, surrounding objects and the underlying surface differently affect on the GPR antenna in the cases of using the magnetic or electric antennas.

Thus, the results of the research confirm the hypothesis of the authors that the use of magnetic antennas can allow one to receive the magnetic component of the field reflected from the searched object undermining the influence of concealing effect reflecting from the top layer of the concealment environment with high dielectric permeability. This results could be used for further research on evaluating the possibility of designing the GPR with a reduced influence of the underlying surface.

It should be noted that the ferrite antenna is an electrically small antenna with all the inherent disadvantages [4]. It is necessary to carefully design the matching circuits, since the impedance of the ferrite antenna has a large imaginary part and must be accurately matched [5]

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Book Review

Data Analytics for Discourse Analysis with Python

Dennis Tay
Routledge
Taylor & Francis Group
ISBN 9781032419015; 978103360292

Data Analysis is related to data and information extraction and processing to derive decision-making. Data has grown voluminous in the last decade, and data processing and analysis are required with enhanced models. Dennis Tay, realizing this fact, has written this book.

With its six comprehensive chapters, this book leaves no aspect of data analysis unexplored. The author's emphasis on Objectivity, Scalability, Data richness, Novelty, Flexibility, and Interdisciplinarity as key focus areas ensures a thorough understanding of the subject. This comprehensive coverage ensures that all your needs and interests in data analytics and discourse analysis are met, making this book a valuable resource for professionals and students.

The Monte Carlo system is used to deal with uncertainty issues. Data simulations are handled in different environments in Monte Carlo. This chapter is supported by extensive program codes and numerous examples. The data analytics assign objects into groups for practical interpretation and analysis. Clustering techniques are extensively used in data analytics. The third chapter provides illustrations of all cluster method techniques. Finally, clustering solutions are explained in this unit. Classification of objects and group prediction is an important component in data analytics addressed in chapter 4. Object properties are used to model the relationship, which is crucial in classification. The classification techniques with some model test results are presented in this unit.

Time series represent sequential measures of variables at regular intervals of time. The fifth chapter provides time series regression models with data projections. Using time series analysis, this unit comprehensively explains model selection, guidelines, and data representations. The last chapter is the conclusion, summarizing the work presented in the earlier chapters. All the chapters are supported by a good reference list. This book presents an unambiguous description of data analytics with several practical models and illustrations.

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Sixth International Conference on Real-Time Intelligent Systems (RTIS 2024)

Tien Giang University
My Tho (near Ho-chi-Minh) -Vietnam
October 17-19, 2024
www.socio.org.uk/rtis

Springer Lecture Notes in Networks and Systems (LNNS)

The International Conference on Real-time Intelligent Systems (RTIS) has traveled from Beijing, China (2016), to Ho-Chi-Min, Vietnam. The sixth edition will take place at Tien Giang University.

Over the last few years, real-time intelligent computing has radically transformed the human lifestyle. Research on real-time intelligent systems is multi-disciplinary, exploiting concepts from diverse areas such as big data processing, computational intelligence, location-based services, recommendation systems, and multimedia processing. In today's highly dynamic environment, analysing data in real-time is necessary to understand how systems process data, reason the outputs, and anticipate trends in intelligent computing. To this end, this conference will serve as a platform to manifest the ongoing research in the field. Thus, RTIS welcomes theoretically grounded, methodologically sound papers that address aspects related to topics, such as:

Artificial Intelligence and Data mining
Streaming data, streaming engines
Trace-based intelligent real-time services
Adaptive vision algorithms
Location-based services
Intelligent Robotic Systems
Collaborative Intelligence

Data capture in real-time
Data quality and cleansing
Intelligent Data Analysis
Intelligent Database Systems
Knowledge representation and reasoning
Intelligent information fusion
Large Language Models, cognitive methods, sequential inference, data mining, pattern/behavioral analysis,
Big Data systems and applications for high-velocity data
Intelligent Information Systems
Privacy and security in Intelligence
Software Engineering Solutions

Intelligent Soft Computing
Real-time multiprocessor systems
Internet of Things
Architectures for Intelligence
Real-time distributed coding
Smart services and platforms
Real-time modelling user information needs
Wireless Communication

Real-time intelligent communication
Real-time intelligent network solutions
Mobile Smart Systems

Broadband Intelligence
Cloud Computing and Intelligence
Collaborative Intelligence
Analysis in domains such as energy, sensors

Decision support systems in real-time
Multi-agent Intelligent Systems
Multilingual information access
Recommendation systems
Real-time intelligent alert systems
Real-time remote access systems
Intelligent Transportation Systems

Autonomous systems (incl. autonomous vehicles and drones)
Distributed systems
Cloud/edge computing/fusion
Defence/security, robotics, aerospace, intelligent transportation
Mining/Manufacturing
Environmental monitoring

Critical Real-time Applications
Real-time noise removal systems
Event-driven analytics
Intelligent Fuzzy Systems
Machine translation in real-time
OLAP for real-time decision support
Crowdsourcing and crowd intelligence

Submission, proceedings

Papers must be submitted online through OpenConf. Author instructions and LaTeX2e (preferred) and Word macro files are available on the submission page. Submitted papers should be at most 14 pages (long papers) and 8 pages (short ones), including figures, tables and references (in the Springer template). Authors of accepted papers are required to transfer their copyrights. For a paper to appear in the proceedings, at least one of the authors MUST register for the conference by the camera-ready submission deadline with a full registration.

Springer's Lecture Notes in Networks and Systems (LNNS) (<https://www.springer.com/series/15179>) will publish the accepted papers and be indexed in SCOPUS, EI Compendex, INSPEC, WTI Frankfurt eG, zbMATH, and SCImago.

All the papers published in the series are submitted for consideration in the Web of Science.

Important Dates

Submission of papers:	August 05, 2024
Notification:	September 01, 2024
Camera-ready:	October 01, 2024
Registration:	October 01, 2024
Conference Dates:	October 17-19, 2024

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CALL FOR PAPERS

Fourth International Conference on Digital Data Processing (DDP 2024)

Yeshiva University, New York, US

September 25-27, 2024

IEEE Xplore

(www.socio.org.uk/ddp)

Data grows voluminously and exponentially with heterogeneity and complexity. A single organization or industry processes over a few million transactions hourly and stores several petabytes of data. We live in a world of tremendous pressure to analyze and process data more efficiently where the Data analytics can reflect hidden patterns, incomprehensible relationships, intrinsic information relations, and segmentation. The data applications have introduced cutting-edge possibilities in every activity in our lives. Thus, studying data and its underlying structure, dynamics of data relations, and newer data technologies is a never-ending process. The literature and research on data management are enormous; they do not sufficiently solve the data processing requirements.

Currently, the use of technology and interrelations among information pieces generate enormous amounts of data. Many studies tend to develop models and systems to analyze voluminous datasets. Analyzing the impact of data leads to application domains on decisions that have a systematic influence. Knowledge generated from the data analysis can enable the production of critical information for several domains.

Hence, this conference reviews and discusses the recent trends, opportunities, and pitfalls of data management and how it has impacted organizations to create successful business and technology strategies and remain updated in data technology. This conference also highlights the current open research directions of data analytics that require further consideration.

The proposed conference will discuss topics not limited to

- Data applications in various domains and activities
- Data in cloud
- Real-world data processing
- Data inaccuracy and reliability issues
- Data Ecosystem
- Business Analytics
- New data analytics techniques
- Physical and management challenges
- Privacy and Security
- Crowdsourcing and Sensing
- Data modelling
- Deep learning techniques
- Data fusion
- Descriptive analytics, Diagnostic analytics, Predictive Analytics, and Prescriptive analytics
- Machine learning
- Network optimization

- Data in Biomedical Engineering
- Data in Materials science and mechanics
- Data handling and applications in domains
- Wireless Networking Data Management
- Data of Electronic & Embedded Systems
- Multi-media Systems Data
- Artificial intelligence Models and Systems Data
- E-Computing Data
- Renewable Energies Data

Publications

Besides, modified versions of the papers will appear in the following journals.

1. Journal on Data Semantics
2. Technologies
3. Data Technologies and Applications
4. Webology
5. Journal of Digital Information Management
6. International Journal of Computational Linguistics
7. Journal of Optimization
8. International Journal of Distributed Systems and Technologies¹

Important Dates

Submission of Workshop Proposals:	March 31, 2024
Submission of Papers:	June 15, 2024
Notification of Acceptance/Rejection:	July 20, 2024
Camera-ready:	September 01, 2024
Registration:	September 01, 2024
Conference Dates:	September 25-27, 2024

Paper Submission

Contact: stm@socio.org.uk

**Fifth International Conference on Science & Technology Metrics
(STMet 2024)
October 17-19, 2024**

***Tien Giang University, My Tho (Near Ho-Chi-Minh)
Vietnam
www.socio.org.uk/stm***

Building metrics is the key to science and technology measurement and translating the measures to work better. The metric is not confined to drawing numbers and analysing. Selecting a metric depends on synthesizing multiple directions and evidence-based data. Producing benchmarks and standards in science and technology evaluation and implementing them with real data mark the full-fledged system. Quite recently, we have witnessed the emergence of new metrics-based models aiming to reflect the growth of science and technology. The proposed Science and Technology Metrics (STMet 2024) conference concerns how many metrics may involve assessing different aspects of science and technology, which are best expressed using different approaches. Besides the standard conference track and the Doctoral Symposium, STMetrics will host several workshops and tutorials related to the conference's theme. The workshops provide participants with a friendly, interactive atmosphere for presenting novel ideas and discussing their application of metrics in Science and Technology Systems. The tutorials aim to enable the participants to familiarise themselves with theoretical and practical aspects and the application of metrics.

The proposed conference includes invited talks, presentations, tutorials, workshops, and discussions. The STMet has tracks on specialized topics. The STMet addresses the themes below but is not limited to them.

The proposed conference includes invited talks, presentations, tutorials, workshops, and discussions. The STMet has tracks on specialized topics. The STMet addresses the themes below but is not limited to them.

Citation-based metrics

Ranking of Journals, Institutions, and Countries

Discipline and Domain Analysis

Economic factors

Databases and datasets for evaluation

Evaluation Tools and Indicators

Web-based metrics

Visibility and impact

Internationalisation

Text-based Metrics

Innovation indicators

Wearable Devices

Open data

Download Scientific Collaboration and cooperation analysis

National Evaluation Systems
Open access and open publishing
New indices for evaluation
Altmetrics
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Scientific Visualization
e-Science in the Cloud
Scientific Journalism
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Research Data Access
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Science, Innovation and Economic Performance
Public Research Systems
Future S & T Policies
Translating Metrics to Science Policy
Evaluation beyond Metrics.

All submitted papers will be reviewed by a double-blind (at least three reviewers) and participative peer review. The review process will enable the selection process of those who will be accepted for their presentation at the international conference. Authors of accepted papers who registered in the conference can access the evaluations and possible feedback provided by the reviewers who recommended the acceptance of their papers so they can improve the final version of their papers accordingly.

Mentoring support is available to young researchers and authors from developing countries.

Please note that all submitted papers undergo review and editing by senior editors. We will take care of content enhancement and language editing. There is no fee for editing and language correction services.

Selected post-conference modified versions of the papers will be published in the following journals.

1. Journal of Digital Information Management
2. Research in Production and Development
3. International Journal of Computational Linguistics Research
4. Frontiers in Research Metrics and Analytics

There is no further publication fee for the above journals.

A Workshop on Text-based Metrics will be organized as a part of STMet 2024

Previous proceedings

The past STM proceedings are available with ISBN and DOI at <https://dline.info/new1/STMPceedings>

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Contact: stm@socio.org.uk

Important Dates

Submission of papers-	August 05, 2024
Notification-	September 01, 2024
Camera-ready (post-conference version)-	October 10, 2024
Registration-	October 01, 2024
Conference Dates-	October 17-19, 2024

