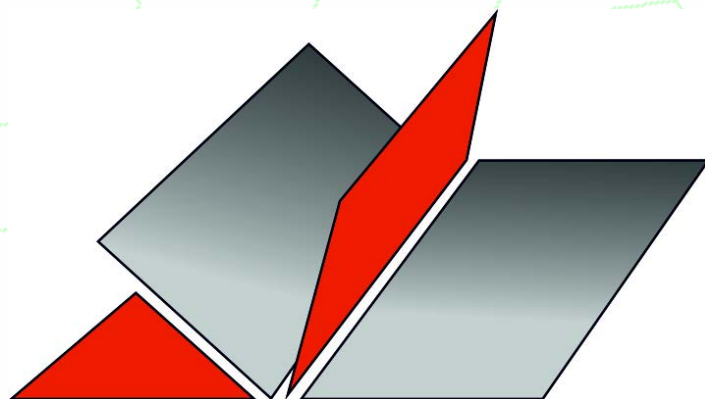


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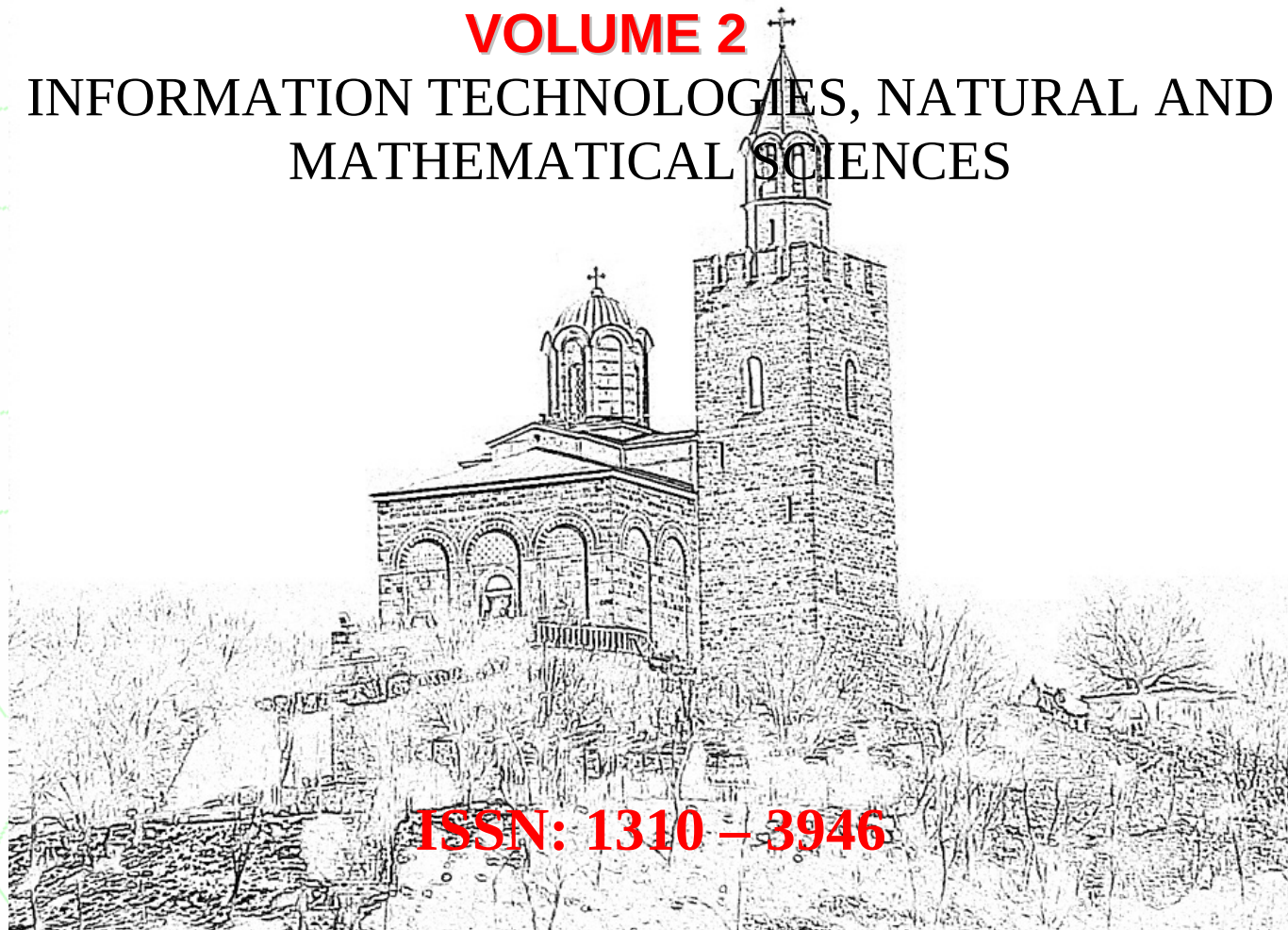
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«MOMENT» REPRESENTATION OF «FAST DECREASING» GENERALIZED FUNCTIONS AND THEIR APPLICATION TO SEVERAL APPLIED STOCHASTIC PROBLEMS

“МОМЕНТНОЕ” ПРЕДСТАВЛЕНИЕ “БЫСТРО УБЫВАЮЩИХ” ОБОБЩЁННЫХ ФУНКЦИЙ И ИХ ПРИЛОЖЕНИЕ К НЕКОТОРЫМ ПРИКЛАДНЫМ СТОХАСТИЧЕСКИМ ЗАДАЧАМ

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Abstract: This paper describes the process of building special space of generalized functions, its properties and applications. Presented applications are: constructive solution of Kolmogorov-Feller type equation with polynomial drift coefficient; proof of exponential nature of equilibrium establishment in rarefied gas, described by Boltzmann equation of kinetic theory of gases.

Keywords: GENERALIZED FUNCTIONS, MOMENT REPRESENTATION, KOLMOGOROV-FELLER EQUATION, BOLTZMANN EQUATION

1. Introduction

This paper describes the construction, properties and application of special space of generalized functions (see terminology in [1]), proposed by A.N. Firsov in [2, 3] and developed in cooperation with A.V. Koval [4]. The following examples of application are presented: the constructive solution of the Kolmogorov-Feller type equation with the polynomial drift coefficient, and the proof of the exponential nature of the time equilibrium establishment in a rarified gas, described by the Boltzmann kinetic equation.

Kolmogorov-Feller type equations are found in control theory, communication theory and stellar dynamics. In literature on analytical methods for solving such equations the case of drift coefficient linear dependence on coordinate is usually considered. In this case it is possible to use the Fourier transformation. This paper considers the solution of the Kolmogorov-Feller equation with quadratic and cubic drift coefficient – the cases, in which the use of the Fourier transformation is ineffective.

In addition in this paper the asymptotic properties (for the large values of time) of the linearized Boltzmann equation solution are considered.

Boltzmann kinetic equation is the basis of research and analysis of mathematical models of (mass, energy, momentum) transport processes in gases, as derivation of the equation is based on the more natural idea of gas as a set of interacting molecules, rather than a continuous medium. This approach is particularly advantageous in the research of the body motion in the upper atmosphere, where the idea of gas as a continuous medium is inadequate. The main problem, that arises here, is the complexity of the Boltzmann equation, which consists in the structure of the collision integral operator, associated with the microstructure of the medium and the nature of the interaction between the matter molecules. Therein lies one of the reasons for the comparatively small number of studies on the analytically rigorous formulation of the solvability conditions and the analysis of the solutions of the Boltzmann equation. The latter refers not only to the full nonlinear version of the Boltzmann equation, but its linear approximation.

2. The theory of “fast decreasing” generalized functions [2,3]

Definition 1. Let $s > 0$. Through E_s we denote the space of (complex) functions $\varphi \in C^\infty(R^v)$ such, that for any $\rho > 0$

$$|D^q \varphi(x)| \leq C(s + \rho)^{|q|} e^{-(s+\rho)|x|}, x \in R^v.$$

Here C is a constant, depending, generally speaking, on φ , s and ρ , but not on $q \in \mathbb{Z}_0^v$.

Note, that the polynomials $P(x_1, x_2, \dots, x_v)$ and functions $e^{s_1 x_1 + \dots + s_v x_v}$, $e^{i(s_1 x_1 + \dots + s_v x_v)}$ belong to the E_s , the latter at $s \geq \max(|s_1|, \dots, |s_v|)$.

We introduce a countable system of norms in E_s

$$(1) \quad \|\varphi\|_s^{(\rho)} = \sup_{q,x} \left[\frac{|D^q \varphi(x)|}{(s + \rho)^{|q|}} e^{-(s+\rho)|x|} \right], \rho = 1, \frac{1}{2}, \frac{1}{3}, \dots$$

Theorem 1. Space E_s , equipped with the system of norms (1), is a complete countably-normed space.

Since $E_{s+1} \supset E_s$ and convergence of the sequence $\{\varphi_n\}$ in E_{s+1} results from its convergence in E_s , it is possible to introduce a countable union $E = \bigcup_{s=1}^\infty E_s$; convergence in E is determined in a conventional manner (see [3]). Obviously, space E is complete in terms of the corresponding convergence. The following property of spaces E_s is the basis for further derivations.

Theorem 2. Let $\varphi \in E_s$, $a = (a_1, a_2, \dots, a_v) \in R^v$. Then:

1) Taylor series for the φ

$$\varphi(x) = \sum_{l=0}^\infty \sum_{|q|=l} \frac{\varphi^{(q)}(a)}{q!} (x-a)^q$$

converges for all $x \in R^v$;

2) partial sums

$$S_m(x) = \sum_{l=0}^m \sum_{|q|=l} \frac{\varphi^{(q)}(a)}{q!} (x-a)^q$$

converge to φ in the terms of convergence in E_s .

The following lemmas indicate a number of other properties of space E (details see in. [2, 3]).

Lemma 1. If $\varphi, \psi \in E$, then the product $\varphi\psi \in E$.

Lemma 2. Let $\varphi_n \rightarrow \varphi$, $\psi_n \rightarrow \psi$ in space E , then $\varphi_n \psi_n \rightarrow \varphi\psi$ in E .

Lemma 3. If $\varphi \in E_s$, then $D^q \varphi \in E_s$.

Lemma 4. If $\varphi_n \rightarrow \varphi$ in E_s , then $D^q \varphi_n \rightarrow D^q \varphi$ in E_s .

Space E' is introduced in conventional manner as a conjugate to E . In the usual manner it determines linear operations, the operation of multiplication by functions of E and differentiation. These operations, as follows from the previous results, are continuous in terms of convergence in E' (i.e. weak convergence). By the theorem on completeness of space conjugated to complete countably normed space, this space will be complete (with respect to weak convergence) – see [1].

It should be noted here, that the stock of the regular functionals in E' is large enough. So every summable in R^v function $f(x)$, satisfying the condition

$$f(x) = O(e^{-\alpha|x|^{1+\varepsilon}}), |x| \rightarrow \infty, \alpha > 0, \varepsilon > 0,$$

generates in E' the functional $\hat{f}$ by the formula

$$(\hat{f}, \varphi) = \int_{R^v} f(x) \varphi(x) dx, \varphi \in E.$$

The following lemma takes place:

Lemma 5. If $f \in L_1(R^v)$, $\varphi \in E$ and for every $\int_{R^v} f(x) \varphi(x) dx = 0$, then $f(x) = 0$ almost everywhere.

Also we note, that if the “normal” function $f(x)$ is differentiable in the usual sense, and f and $f^{(q)}$ generate the regular functionals $\hat{f}$ and $\hat{f}^{(q)}$, then $\hat{f}^{(q)} = \hat{f}^{(q)}$, where the right is the functional $\hat{f}$ derivative in terms of differentiation in space E' . Finally, the delta-function $\delta_a = \delta(x-a)$, defined in the usual way, i.e. $(\delta_a, \varphi) = \varphi(a)$, $\varphi \in E$, is also belong to E' and is a singular functional.

Now we formulate the main properties of the generalized functions of E' (details – in [2,3]):

Theorem 3.

1) Every generalized function $f \in E'$ at a random point $a \in \mathbb{R}^n$ can be presented in the form

$$f = \sum_{k=0}^{\infty} \sum_{|q|=k} C_a^{(q)} \delta_a^{(q)},$$

where coefficients $C_a^{(q)} = (-1)^{|q|} \frac{(f, (x-a)^q)}{q!}$.

2) The generalized function f belongs to E' if and only if the series

$$(2) \quad \sum_{k=0}^{\infty} s^k \sum_{|q|=k} |C_a^{(q)}|$$

converges for every $s > 0$.

3) Let $f, g \in E'$ и $C_a^{(q)}, d_a^{(q)}$ be “moment” decomposition coefficients. Then the following statements are valid:

1. $\alpha f + \beta g = \sum_{k=0}^{\infty} \sum_{|q|=k} (\alpha C_a^{(q)} + \beta d_a^{(q)}) \delta_a^{(q)}$, where $\alpha, \beta \in \mathbb{C}$;

2. $D^k f = \sum_{k=0}^{\infty} \sum_{|q|=k} C_a^{(q)} \delta_a^{(q)}$;

3. if $\psi \in E$, then $\psi f = \sum_{k=0}^{\infty} \sum_{|q|=k} h_a^{(q)} \delta_a^{(q)}$, where

$$h_a^{(q)} = \sum_{r=0}^{\infty} (-1)^r \sum_{\substack{|n|=r+|q| \\ n \geq q}} \binom{n}{n-q} C_a^{(q)} \psi^{(a)}(a).$$

In the space E' it is possible to use the usual procedure to determine the convolution of two generalized functions. Such convolution always exists (unlike other spaces of generalized functions), has the usual properties and satisfies the following

Theorem 4. Let $f, g \in E'$ and $C_a^{(q)}, d_a^{(q)}$ are corresponding “moment” decomposition coefficients. Then

$$f * g = \sum_{k=0}^{\infty} \sum_{|q|=k} h_a^{(q)} \delta_a^{(q)}, \text{ where } h_a^{(q)} = \sum_{i+j \leq q} (-1)^{|q-i-j|} \frac{\alpha^{q-i-j}}{(q-i-j)!} C_a^{(i)} d_a^{(j)}.$$

In particular, for $a = 0$ “moment” decomposition coefficients

$$h_0^{(q)} = \sum_{i+j=q} C_0^{(i)} d_0^{(j)}.$$

3. Solution of the Kolmogorov-Feller equation with the quadratic drift coefficient [4]

One-dimensional stationary Kolmogorov-Feller equation with the quadratic drift coefficient is given by:

$$(3) \quad \frac{d}{dx} [\alpha(x)W(x)] + \nu \int_{-\infty}^{+\infty} p(A)W(x-A)dA - \nu W(x) = 0.$$

Let the unknown function $W(x)$ and the given function $p(A)$ be the generalized functions of E' . Then, according to the first paragraph of theorem 3, function $W(x)$ can be presented as $W(x) = \sum_{q=0}^{\infty} C_0^{(q)} \delta_0^{(q)}$. Similarly $p(A) = \sum_{q=0}^{\infty} d_0^{(q)} \delta_0^{(q)}$, where $d_0^{(q)} = (-1)^q \frac{(p, A^q)}{q!}$. Since the meaning of the function $p(A)$ is probability density, we should assume that $(p, 1) = 1$.

We consider separately each of the terms in the left side of equation (3). With obvious transformations, using the statements of the third paragraph of theorem 3, we obtain

$$\frac{d}{dx} [(\alpha x + \beta x^2)W(x)] = \sum_{q=0}^{\infty} k_0^{(q)} \delta_0^{(q)} + \sum_{q=0}^{\infty} l_0^{(q)} \delta_0^{(q)},$$

where $k_0^{(q)} = \alpha C_0^{(q)} - 2\beta(q+1)C_0^{(q)}$,
 $l_0^{(q)} = \beta(q+1)(q+2)C_0^{(q)} - \alpha(q+1)C_0^{(q)}.$

According to the theorem 2 we transform the convolution in the equation (3) to the form

$$p * W = \sum_{q=0}^{\infty} \left(\sum_{i=0}^q d_0^{(i)} C_0^{(q-i)} \right) \delta_0^{(q)}.$$

Thus, equation (3) reduces to

$$\sum_{q=0}^{\infty} k_0^{(q)} \delta_0^{(q)} + \sum_{q=0}^{\infty} l_0^{(q)} \delta_0^{(q)} + \nu \sum_{q=0}^{\infty} \left(\sum_{i=0}^q d_0^{(q-i)} C_0^{(i)} \right) \delta_0^{(q)} - \nu \sum_{q=0}^{\infty} C_0^{(q)} \delta_0^{(q)} = 0,$$

which is equivalent to

$$\sum_{q=0}^{\infty} \left[k_0^{(q)} + l_0^{(q)} + \nu \sum_{i=0}^q d_0^{(q-i)} C_0^{(i)} - \nu C_0^{(q)} \right] \delta_0^{(q)} = 0.$$

Using paragraph 1 of theorem 3, we find, that

$$k_0^{(q)} + l_0^{(q)} + \nu \sum_{i=0}^q d_0^{(q-i)} C_0^{(i)} - \nu C_0^{(q)} = 0 \quad \forall q \in \mathbb{Z}_0.$$

As a result, after appropriate transformations, taking into account the property $(p, 1) = 1$, we obtain a recurrence relation, from which one can sequentially find all the coefficients $C_0^{(q)}$:

$$(4) \quad C_0^{(q+1)} = \frac{\alpha}{\beta(q+1)} C_0^{(q)} - \frac{\nu}{\beta q(q+1)} \sum_{i=0}^{q-1} d_0^{(q-i)} C_0^{(i)}.$$

To obtain a unique solution of the chain of equations (4), apparently, it is necessary to set the coefficients $C_0^{(0)}$ and $C_0^{(1)}$. Thus, to settle the issue of the existence of the equation (3) solution in the space E' , one must verify the point 2 of theorem 3.

Theorem 5. To satisfy point 2 of theorem 3 it suffices that the sequence $\{C_0^{(q)}\}_{q=0}^{+\infty}$ of (4) is bounded.

The proof of theorem 5 is based on the following lemma.

Lemma 6. Suppose that there exists $Q > 0$ such that for any $0 \leq q \leq Q$ the requirement $|C_0^{(q)}| \leq |C_0^{(Q)}|$ is fulfilled. Suppose, moreover, that $\left| \frac{\alpha}{\beta} \right| + \left| \frac{\nu}{\beta} \right| D \leq Q + 1$, where $D = \max_{q \geq 0} |d_0^{(q)}|$. In this case $|C_0^{(q)}| \leq |C_0^{(Q)}|$ for any $q \geq Q$.

To prove this lemma the principle of mathematical induction is used.

Here is an example solution of equation (3) with (4). Suppose $p(A)$ is a regular functional, which is a normal distribution with the mean 0 and variance σ . In this case “moment” decomposition coefficients are

$$d_0^{(q)} = (-1)^q \frac{(p, A^q)}{q!} = \begin{cases} 0, q = 2i + 1, i \in \mathbb{Z}_0, \\ \frac{\sigma^q}{i!}, q = 2i, i \in \mathbb{Z}_0. \end{cases}$$

Then the moments of the unknown function $W(x)$ can be found, using the relation

$$C_0^{(q+1)} = \frac{\alpha}{\beta(q+1)} C_0^{(q)} - \frac{\nu}{\beta q(q+1)} \sum_{i=0}^{q-1} \frac{\sigma^q}{2 \cdot 4 \cdot \dots \cdot q} C_0^{(i)},$$

$q = 2j, j \in \mathbb{Z}_0$

4. Solution of the Kolmogorov-Feller equation with the cubic drift coefficient

One-dimensional stationary Kolmogorov-Feller equation with the cubic drift coefficient has the form

$$(5) \quad \frac{d}{dx} [(\alpha x + \beta x^2 + \gamma x^3)W(x)] + \nu \int_{-\infty}^{+\infty} p(A)W(x-A)dA - \nu W(x) = 0.$$

The chain of equations (4) is replaced with relations:

$$(6) \quad C_0^{(q+2)} = -\frac{\alpha}{\gamma(q+1)(q+2)} C_0^{(q)} + \frac{\beta}{\gamma(q+2)} C_0^{(q+1)} + \frac{\nu}{\gamma q(q+1)(q+2)} \sum_{i=0}^{q-1} d_0^{(q-i)} C_0^{(i)}$$

There is a theorem analogous to theorem 5:

Theorem 6. Suppose the sequence of coefficients (6) $\{C_0^{(q)}\}_{q=0}^{+\infty}$ is bounded, then the condition 2 of theorem 3 is satisfied.

The proof of this theorem is based on a lemma analogous to lemma 6.

5. The analysis of the asymptotic behavior of the linearized Boltzmann equation solutions for large values of time [3]

Consider the Cauchy problem for the linearized Boltzmann kinetic equation [5]:

$$(7) \quad \begin{aligned} \frac{\partial f}{\partial t} + \bar{u} \frac{\partial f}{\partial \bar{x}} &= L[f], L[f] = K[f] - \nu f \\ f &= f(\bar{x}, \bar{u}, t), \bar{x} \in \mathbb{R}^3, \bar{u} \in \mathbb{R}^3, t \geq 0 \\ f|_{t=0} &= f_0(\bar{x}, \bar{u}) \end{aligned}$$

Here $f(\bar{x}, \bar{u}, t)$ is linearized distribution function of the molecules in the coordinates $\bar{x}$ and velocities $\bar{u}$ at time t . $K[f]$ is a bounded linear operator, acting on f as a function $\bar{u}$; $\nu = \nu(u) = O(u^\beta)$ for $u \rightarrow \infty$, $0 < \beta \leq 1$, $u = |\bar{u}|$. Properties of the function $\nu(u)$ depend on the specific intermolecular interaction model, accepted during the derivation of the kinetic equations. For details see [5].

It is known [6] that the solution of (7) in the case of “hard” intermolecular interaction potentials $U = C_k r^{-k}$, $k > 5$ at $t \rightarrow \infty$ has, in general, the power asymptotics of the form $O\left(\frac{1}{1+t^\mu}\right)$, $\mu > 0$. This result is obtained under assumption that $f(\bar{x}, \bar{u}, t)$ at $x = |\bar{x}| \rightarrow \infty$ behaves as a function of the $L_p(\mathbb{R}_x^3)$, $p > 1$.

It turns out, that if we impose more rigid conditions on $f(\bar{x}, \bar{u}, t)$ behavior, for example, require that $f(\bar{x}, \bar{u}, t)$ satisfies for $\bar{x}$ and uniformly for $\bar{u}, t$:

$f(\bar{x}, \bar{u}, t) = O(\exp(-\alpha|\bar{x}|^{1+\varepsilon}))$, $|\bar{x}| \rightarrow \infty$, $\alpha > 0$, $\varepsilon > 0$, then the establishment of equilibrium (i.e. function f convergence to zero at $t \rightarrow \infty$) is exponentially fast.

The idea of the proof is as follows. We seek a $f(\bar{x}, \bar{u}, t)$ in the class of functions such that almost for every $\bar{u} \in \mathbb{R}^3$ and every $\varepsilon > 0$ $f(\bar{x}, \bar{u}, t) \in E'_\varepsilon$, i.e. the function f can be written as

$$(8) \quad f(\bar{x}, \bar{u}, t) = \sum_{l=0}^{\infty} \sum_{|q|=l} C_a^{(q)}(\bar{u}, t) \delta_a^{(q)}(\bar{x}).$$

Substituting this expression in (7) and taking into account the results of paragraph 2 of this paper, we obtain the infinite “looping” system of equations for coefficients $C_a^{(q)}(\bar{u}, t)$

$$(9) \quad \begin{aligned} \frac{\partial C_a^{(0)}}{\partial t} &= L[C_a^{(0)}] \\ \vdots \\ \frac{\partial C_a^{(q)}}{\partial t} &= L[C_a^{(q)}] - [u_1 C_a^{(q-I_1)} + u_2 C_a^{(q-I_2)} + u_3 C_a^{(q-I_3)}], \\ |q| &\neq 0 \end{aligned}$$

where in terms of I_1, I_2, I_3 multi-indices (1, 0, 0), (0, 1, 0) and (0, 0, 1) are expressed respectively.

Equations (9) are heterogeneous equations of the form

$$\frac{\partial C_a^{(q)}}{\partial t} = L[C_a^{(q)}] - g_q(\bar{u}, t), |q| \neq 0,$$

where $g_q(\bar{u}, t)$ is a known function (at each step – its own known function). Thus, the properties of the functions $C_a^{(q)}(\bar{u}, t)$ depend on the operator L properties. The latter have been studied sufficiently (see [3,5-9]). In particular, on the subspace of functions $w(\bar{u}, t)$, orthogonal in terms of $L_2(\mathbb{R}_u^3)$ to the subspace of additive invariants (which is actually equivalent to the classical conservation laws for gas), the operator L generates a semigroup $T(t)$, $t > 0$ of bounded operators, which solves an abstract Cauchy problem for equation (7); in addition, it turns out, that $\|T(t)\| \leq \text{const} \cdot e^{-\mu t}$, $\mu > 0$. With the method, similar to the one used in [6,7], by induction we obtain an estimate for the solutions of equations (9) of the form (the norm is meant in terms of $L_2(\mathbb{R}_u^3)$): $\|C_a^{(q)}(t)\| \leq \text{const} \cdot e^{-\gamma t}$, $\gamma > 0$, where const depends on the initial distribution function $f_0(\bar{x}, \bar{u})$ and parameters of the operator L .

The latter estimate, taking into account (8), leads to the conclusion of an exponentially fast (in time) equilibrium establishment in the system, described by the problem (7).

6. Results

This paper describes the construction, properties and applications of a special space of the generalized functions, proposed by A.N. Firsov [2,3] and developed jointly with A.V. Koval [4]. The following applications are presented: a constructive solution of the Kolmogorov-Feller equation with the quadratic drift coefficient and a proof of the exponential in time nature of equilibrium establishment in rarified gas, described with the kinetic Boltzmann equation.

The proposed method of “moment” representation of generalized functions can be effectively used for solving differential equations with polynomial coefficients and convolution equations.

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EMP 13 – EFFECTIVE MANAGERIAL COMBINATION OF EMERGENCY MEDICINE AND INFORMATICS

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Abstract: *The fields of emergency medicine and medical informatics were both in their infancy 30 years ago. Since then both have dramatically matured and established themselves as critical components of the nation's health care system. Both disciplines today seek to improve health care quality, while simultaneously improving cost effectiveness of the care delivery system.*

Emergency medicine is described as information intensive specialty, where the immediate access to accurate information is crucial for patient care and reduction of costs.

The article presents an author's software solution, successfully integrated two years ago in Center for emergency medical help (CEMH) and its 13 branches, proving its usability through specialized online survey conducted for a month.

Keywords: INFORMATION SYSTEM, E-HEALTH, EMERGENCY HELP

1. Introduction

In 1997, after reforms in the system of emergency help, is developed structure of administrative and business sector, emergency department and 12 subsidiaries, and after the changes in 2007, emergency department is transferred to University Hospital "St. Anna", and the emergency units to subsidiaries are closed. At the beginning of 2008 is established Regional Coordination Station which receives the emergency calls in the region and aims to improve the coordination between teams, as well as accelerating the time for reaction. Connections between Regional Coordination Station and the subsidiaries is double secured – by a mobile operator, landline phones and voice module. In September, the same year, was established a subsidiary in Dragoman. Today, the center is actively working with medical institutions in the region, with other various institutions and has established itself as an indispensable part of the health care system in the region, serving 250,000 residents in 284 settlements in 22 municipalities, covering an area of over 7000 square kilometers.

Generally for the period of its existence, the teams have provided assistance to over 950 thousand patients. Each year the sanitary cars of the center travel almost one million kilometers.

In this context, health is the basis of human life and needs to be supported by effective policies and actions in the countries – members of the European Community and globally.

Under article 152 of the Contract for European Community "the development and implementation of all policies and actions in the community must ensure a high level of protection of human health".

From January 2007, for Bulgaria are already directly applicable the provisions of the European regulations, governing the issues of social and health insurance – in the context of the right for free movement of people within united Europe.

Bulgarian citizens who have continuous health insurance rights under Bulgarian legislation, can use medical care in the countries of the European Community, when residing in a different basis in other countries of the European Union (EU) and European Economic Area (EEA).

E-Health is a key point in developing an action plan and achievement of a European e-Health Area. e-Health challenges include developing common standards and interoperability of health products, systems and services at European level.

Having in mind the recent accession of Bulgaria to the EU, is advisable timely development and investment in e-health in the country.

According to the National Strategy for the Development of Health 2008-2013 [36], the following priorities are displayed:

- ✓ Providing online health services;
- ✓ Implementation of electronic health cards.
- ✓ Implementation of personal electronic health records.
- ✓ Implementation of software applications for complex processing and exchange of information in real time, including

electronic recipes, expert opinions, laboratory and diagnostic data etc.

✓ Development of complex hospital information systems, which are integrated with each other, as well as with external applications. Implementation of electronic medical records.

✓ Building the necessary infrastructure for the normal functioning of the healthcare system – networks, linking devices, etc.

✓ Establishment of appropriate infrastructure for the deployment of telemedicine applications.

E-Health, by definition, is a rapidly growing area in which interact medical informatics, public health, offering of health services and information through the use of modern information and communication technologies. It characterizes technological development to improve health services at local, regional and global levels.

Paper-based documents have existed for centuries and their gradual replacement of computer-based documents is a slow and complex process, which is a fact for twenty years in the Western health systems. Computerized information systems do not have the same level of input in health as in other sectors (finance, transport, specialized industries). The introduction of EHR at national level reaches over 90% of primary medical practice in Norway, Sweden and Denmark (2003), but is limited to only 17% in medical practices in the United States (2001-2003) [HHS, 2005].

2. Material and method

According to European standards for electronic health record, the record cannot and should not be removed from the system, regardless of whether it is wrong or not. The presented software satisfies these requirements by an author's solution, and in this way each record always remains in the system, and in need of inspection can always be viewed and displayed.

The system is successfully integrated in all the 13 branches: Elin Pelin, Pirdop, Ihtiman, Samokov, Kostenetz, Svoge, Kostinbrod, Godech, Slivnitsa, Dragoman, Etropole, Botevgrad, and Pravetz, the staff is trained and has a developed "User Manual".

The system consists of different menus depending on the level of the user:

Administrator – has full rights of access, located in regional Coordination Station - Sofia Operators – local officers in the subsidiaries, who have the right to edit the information in the system, which is already entered.

• Team – physicians and their teams who enter the current, routine information from each new examination of patient

The provided inquiries are extensive and detailed, allowing a choice to dates and to subsidiaries:

- o Inquiry for supplies
- o Inquiry for drugs
- o Inquiry for patients (by ICD groups)
- o Information about the activity

- o Inquiry for trauma and poisonings
- o Inquiry for acute poisonings
- o Annual inquiry Ambulatory/Calls
- o Inquiry for patients who died
- o Information card for children who died
- o Inquiry for ambulatory examinations
- o Inquiry for calls
- o Teams on duty
- o Information about accepted and processed calls
- o Report for sanitary cars

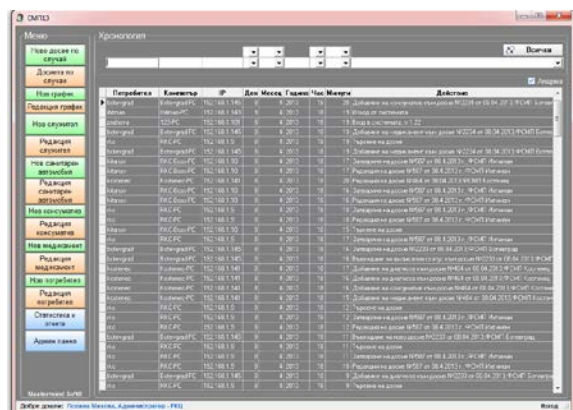


Fig.1. System log archive in EMP 13

There are also copyright developed journals according to the standards – Ambulatory one and Calls journal that eliminate the necessity for any hand writing on paper.

The system has a number of forms for prevention and protection from unauthorized access or opportunity for editing, tracing every single step of each user in the corresponding location to date and time.

The new patient entrance of data uses only initials, age and sex of the patient, by the Law for protection of the personal data, and the listed personal data for physical identity, the patient and his or her personal information are fully protected.

3.Results

Since the launch of vnedrenyavaneto your system are reflected: Ambulatory: Botevgrad - 17056, Godech - 2803, Dragoman - 3922, Elin Pelin - 7812, Etropole - 8400, Ihtiman - 10,509, Kostenets - 4812, Kostinbrod - 4115, Pirdop - 10423, Pravets, 3551, Samokov - 15318, Svoge - 5797, Slivnitsa - 5186. Calls Botevgrad - 5631, Godech - 1928, Dragoman - 2079, Elin Pelin - 5321, Etropole - 2712, -4734 Ihtiman, Kostenets - 3722, Kostinbrod - 4077, Pirdop - 3792, Pravets, 2379, Samokov - 5773, Svoge - 3983, Slivnitsa - 2876. Predstavayame and Our copyright SOWT analysis explores the challenges facing the implementation of a software product in hospital / health facility.

We present an authors SWOT analysis, exploring the challenges for the implementation of a software product in hospital/health facility.

4.Conclusion

As a number of authors noted the Emergency Medicine has special information needs. One relates to the fast pace and sharp nature of the medical emergency. Emergency physicians should assimilate information quickly and distill essential data objects of the entire presentation. In terms of medical informatics, the authors of "as well as with any other innovation, the proof is in the data. It is not enough just to build smart systems, we also need to assess them and test their ability to achieve the targets in well-designed experiments. To confirm the value of a new idea in the field of information science, we need to measure its effectiveness not only in terms of use of the system, but in terms of improved care processes, reduce morbidity, greater patient satisfaction and better recovery. After completion of the probationary period of the system in real conditions shown satisfaction by specialists in office was made more than high, which speaks to the quality of software and the need for its development. The computerization of information in medicine and healthcare is gaining in offices in the country, as this would certainly improve the quality of service, and thus the entire medical work.

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Strengths	Weakness
Part of health care reform	Fear of the new and the unknown
Building a modern technological infrastructure and information systems in all units of the health care system	Lack of the necessary skills and attitudes for working with information systems
Possibility of multiple statistics and cuts directly generated by the system	Time required for training, as well as for establishing habits and routine for work with the information system
Dynamically controlling of schedules, teams, diagnoses with medicines and supplies at any time of Regional Coordination Station	Necessity for system maintenance
Opportunity for controlling and monitoring the actions of the users – the system detects any movement	It is always problematic the implementation of different systems
Reducing the cost for materials – instead of 10 000 lv. yearly for special paper, 2600 lv. for all supplies total	
Reducing omissions and technical errors in data entry	
Opportunities	Threats
Improving the quality of management of medical records and data	The will and motivation of professionals to work with one more system
Better organization and management of the subsidiaries	Data which is not entered and will reflect to the annual reporting
Opportunity for online communication between the units in health care	
Facilitates researches	
Facilitates the economic evaluation of care	
Fast processing of the data	
Easy for shortcuts and data recovery	
Standardization of the information and formats	

Fig.2. SWOT analysis

ЗАДАЧА О ДВИЖЕНИИ ВЯЗКОЙ НЕСЖИМАЕМОЙ ЖИДКОСТИ ПО ЦИЛИНДРИЧЕСКОЙ ТРУБЕ КРУГЛОГО СЕЧЕНИЯ С НЕСТАЦИОНАРНЫМИ КРАЕВЫМИ УСЛОВИЯМИ

THE PROBLEM OF VISCOUS INCOMPRESSIBLE FLUID MOTION THROUGH CYLLINDRICAL ROUND PIPES WITH NON-STATIONARY BOUNDARY CONDITIONS

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Abstract: In this work the model of a viscous incompressible liquid flow through a cylindrical round pipe with non-stationary boundary conditions is considered without usual simplifying assumptions. An exact solution of the corresponding boundary problem was obtained by the authors in a series form of Bessel functions. This solution is compared with the solution of a similar problem with stationary boundary conditions.

KEYWORDS: NON-STATIONARITY, VISCOUS INCOMPRESSIBLE FLUID, NAVIER-STOKES EQUATIONS, LAMINAR FLOW, GROMEKA'S PROBLEM

1. Введение

Рассматриваемая в настоящей работе задача имеет большое значение при проектировании магистральных трубопроводов, связанных, в частности, с транспортировкой углеводородов. Магистральные нефтепроводы – это сложные инженерно-технические сооружения, и их правильной работе и надёжности уделяется много внимания. Для эффективного управления потоками транспортируемой жидкости при различных режимах эксплуатации необходимо иметь удобные аналитические методы расчёта неустановившегося движения, позволяющие получить требуемые для наладки всех задействованных систем данные.

2. Постановка задачи

Применительно к магистральным нефте- и газопроводам большой протяжённости в литературе рассматриваются задачи стационарного движения вязкой жидкости по трубам, основанных на упрощённых уравнениях гидродинамики вязкой жидкости [1,2]. Тем более интересным представляется анализ нестационарного режима движения потока вязкой жидкости по трубам с использованием полноценного уравнения Навье-Стокса с нестационарными краевыми условиями.

Жидкость будем считать несжимаемой: $\rho = \text{const}$. Для вязкой несжимаемой жидкости уравнение движения имеет вид [5,6,7]:

$$\frac{\partial v}{\partial t} = \nu \left(\frac{\partial^2 v}{\partial r^2} + \frac{1}{r} \frac{\partial v}{\partial r} \right) - \frac{1}{\rho} f(t), \quad (1)$$

где v – скорость жидкости вдоль оси трубопровода, ν – кинематическая вязкость жидкости, ρ – её плотность,

$f(t) = \frac{\partial p}{\partial z}$ – градиент давления в трубе. Уравнение (1)

получено из уравнений Навье-Стокса с учётом пренебрежения массовыми силами, одномерности движения и осесимметричности течения. Так же считаем, что характер течения ламинарный, т.е. числа Рейнольдса $Re < 2300$ [5]. Нестационарность диктуется функцией $f(t)$, описывающей граничные условия, т.е. изменение давления на концах участка трубопровода.

2.1. Решение нестационарной задачи

Решение смешанной задачи для уравнения (1) с начальным условием $v(0, r) = \varphi(r)$ и краевым условием $v(t, R) = 0$, полученное авторами методом Фурье, имеет вид [3,4]:

$$u(\tau, \eta) = \int_0^N G(\eta, \xi, \tau) \varphi(\xi) d\xi + \int_0^\tau \int_0^N G(\eta, \xi, \tau - \sigma) (-\gamma(\tau)) d\xi d\sigma, \quad (2)$$

$$G(\eta, \xi, \tau) = \sum_{n=1}^{\infty} \frac{2\xi}{N^2 (J_1(\mu_n))^2} \cdot J_0\left(\frac{\mu_n}{N} \xi\right) \cdot J_0\left(\frac{\mu_n}{N} \eta\right) \cdot e^{-\frac{\mu_n^2}{N^2} \tau},$$

$$G(\eta, \xi, \tau - \sigma) = \sum_{n=1}^{\infty} \frac{2\xi}{N^2 (J_1(\mu_n))^2} \cdot J_0\left(\frac{\mu_n}{N} \xi\right) \cdot J_0\left(\frac{\mu_n}{N} \eta\right) \cdot e^{-\frac{\mu_n^2}{N^2} (\tau - \sigma)},$$

где $u(\tau, \eta)$ – безразмерная скорость; τ – безразмерное время;

$$\eta - \text{безразмерный радиус, } 0 \leq \eta \leq N; \quad \gamma(\tau) = \frac{f\left(t \cdot \frac{\nu}{d^2}\right) d^3}{\rho \nu^2}.$$

Задав начальное распределение $\varphi(r)$ и функцию $f(t)$ можно вычислить распределение скоростей по сечению трубы в любой момент времени. Пересчёт полученных значений $u(\tau, \eta)$

в $v(t, r)$ осуществляется умножением на коэффициент $\frac{\nu}{d}$.

2.2. Стационарный случай

В своей книге [6] Н.А. Слёзкин приводит решение уравнения (1) для случая $f(t) = \text{const}$. Оно было получено через преобразование Лапласа исходного уравнения в предположении, что начальная скорость равна нулю. Условие прилипания к стенкам трубы сохранялось. То есть задача ставилась следующим образом: найти функцию $v(t, r)$, удовлетворяющую уравнению (1), начальному условию $v(0, r) = 0$ и граничному условию $v(t, R) = 0$. Он получил решение в следующем виде:

$$u(t, r) = P \frac{R^2}{4\nu} \left[1 - \frac{r^2}{R^2} - 8 \sum_{k=1}^{\infty} \exp\left(-\nu \frac{\lambda_k^2}{R^2} t\right) \frac{J_0\left(\frac{\lambda_k}{R} r\right)}{\lambda_k^3 J_1(\lambda_k)} \right], \quad (3)$$

где $P = \frac{f(t)}{\rho} = \text{const}$, λ_k – корни функции Бесселя J_0 .

Любопытно посмотреть, описывает ли уравнение (2) стационарное течение жидкости при задании соответствующих условий. Построим решения (2) и (3) для наглядности. Для этого воспользуемся средой Matlab.

3. Результаты

В обоих случаях зададим одинаковое значение $f(t)$; для уравнения (2) возьмём начальное распределение, равное нулю. Параметры жидкости соответствуют параметрам нефти:

плотность $\rho = 830 \frac{\text{кг}}{\text{м}^3}$, кинематическая вязкость $\nu = 2.65 \cdot 10^{-4}$

$\frac{\text{м}^2}{\text{с}}$, диаметр трубопровода $d = 1 \text{ м}$. График на рис.1 показывает зависимость скорости жидкости на оси трубопровода ($r = 0$) от времени.

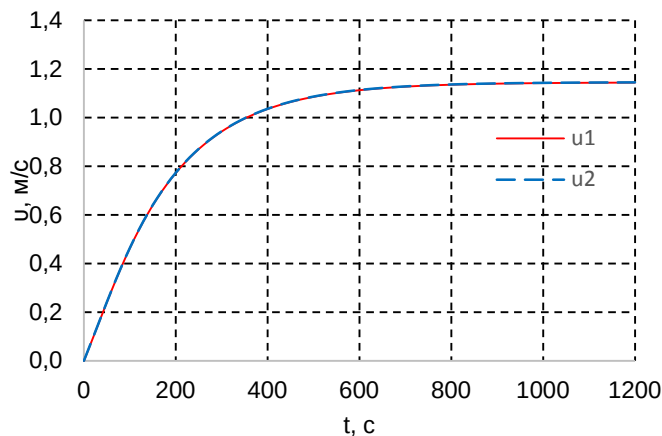


Рис. 1. Зависимость скорости потока на оси трубы от времени

На рис.1 u_1 задаётся уравнением (2), u_2 – уравнением (3). Видно, что решения, полученные двумя разными путями, хорошо совпадают. Масштаб не позволяет оценить разницу между u_1 и u_2 . Ниже представлен график изменения отклонения $\delta = u_1 - u_2$ с течением времени (рис.2).

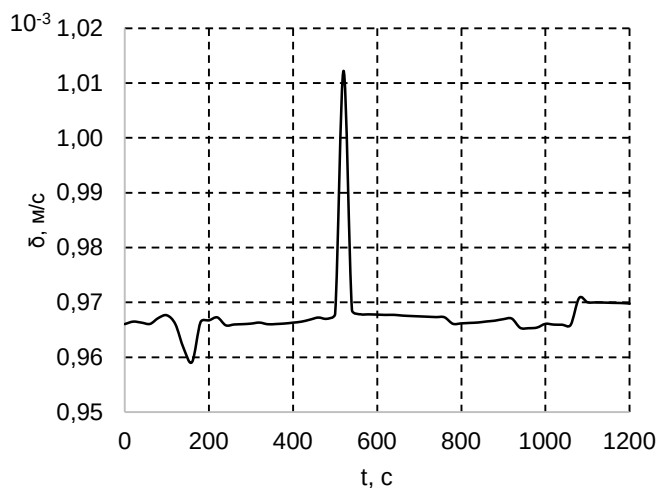


Рис. 2. Зависимость отклонения δ от времени для $r = 0$

На рис.3 представлен график $\delta(t)$ для значения $r = 0.3$.

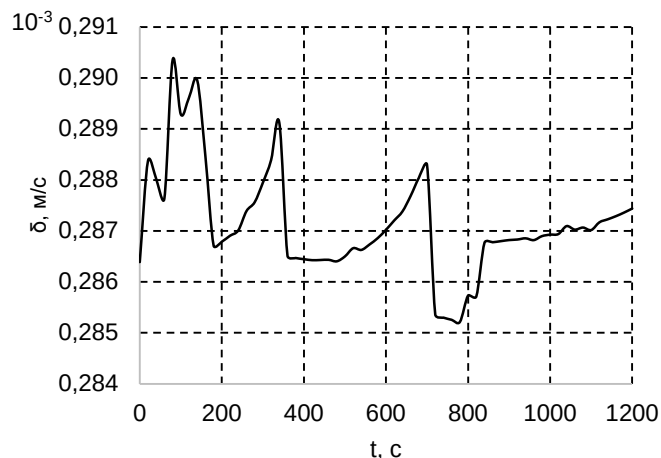


Рис. 3. Зависимость отклонения δ от времени для $r = 0.3$

Видно, что разница между u_1 и u_2 на три порядка меньше их значений, что даёт возможность говорить о хорошем совпадении.

4. Заключение

В работе представлено решение уравнения Навье-Стокса, описывающего движения вязкой несжимаемой жидкости по цилиндрической трубе с нестационарными краевыми условиями на её концах.

Полученное решение в стационарном случае показывает хорошее совпадение с известным решением аналогичной стационарной задачи.

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CHARACTERIZATION AND PHOTOCATALYTIC INVESTIGATION ON COPPER OXIDE CONTAINING CATALYST

ОХАРАКТЕРИЗИРАНЕ И ФОТОКАТАЛИТИЧНО ИЗСЛЕДВАНЕ НА КАТАЛИЗАТОР СЪДЪРЖАЩ МЕДЕН ОКСИД

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Abstract: New type of photocatalyst containing copper oxide hydrate crystalline phase and additional amount of copper sulfate hydroxide was prepared by thermal decomposition of copper sulfate. The EPR detected presence of Cu^{2+} ions. Photocatalytic degradation of two different model pollutants Reactive Black 5 (RB5) and Malachite Green (MG) in aqueous solution under UV illumination was investigated. The copper oxide containing catalyst showed four times higher photocatalytic activity with respect to RB5 than that to MG dye. The catalyst exhibited much higher adsorption capacity to RB5 than to MG dye. The degree of degradation of MG dye is 18%, rate constant is $1.7 \times 10^{-3} \text{ min}^{-1}$ while the degree of degradation of RB5 dye is 90%, rate constant is $8 \times 10^{-3} \text{ min}^{-1}$ after 2 hours of illumination.

Keywords: COPPER OXIDE, REACTIVE BLACK 5, MALACHITE GREEN, PHOTOCATALYSIS, WASTEWATERS

1. Introduction

CuO is p-type semiconductor with a narrow band gap of 1.21–1.51 eV and monoclinic structure [1]. It is an interesting multifunctional material due to its promising applications in gas sensors [2, 3], magnetic storage media [4], lithium ion batteries [5], and solar cells [6] due to its photoconductive and photochemical properties. In most reports composite photocatalyst for dye degradation such as: CuO/SnO_2 , CuO/ZnO , CuO/BiVO_4 , CuO/SiO_2 , $\text{CuO}/\text{zeolite}$ [7], $\text{CuO}/\text{graphene}$ [8], chitosan anchored copper oxide [9] were used but in recent years also pure CuO was studied [10]. CuO was tested as an adsorbent in the Methylene Blue dye decolorization process [11]. Cu-core/ CuSO_4 -shell nanoparticles exhibited higher photocatalytic efficiency than Cu nanoparticles and these results proved that CuSO_4 -shell has significant effect on the degradation of Methylene Blue [12]. Enormous amounts of environmental pollutants, effluents of colored dyes having carcinogenic effect are discharged by the textile and paper industries [13]. These dye pollutants are chemically stable, so technologies relating to direct UV photolysis and hydrogen peroxide oxidation are not effective in removing the color dyes. At present, the photocatalytic method attracts considerable attention due to its effective decolorization of dyes [14]. Malachite Green (MG) has now become a highly controversial compound due to the risks it poses to the consumers of treated fish, including its effects on the immune system and reproductive system and its genotoxic and carcinogenic properties [15]. The photocatalytic efficiencies of cerium-cadmium oxide [16], ZnS-CdS [17], bismuth oxide [18], TiO_2 [15], CuO supported on HY zeolite [19] and other catalysts were tested by using them in the photocatalytic degradation of Malachite Green dye. Sonophotolytic degradation of azo dye Reactive Black 5 (RB5) in an ultrasound/UV/ferric system was examined [20] as well as the efficiency of the $\text{Fe}_3\text{O}_4/\text{FeC}_2\text{O}_4$ magnetic catalyst in the catalytic wet peroxide oxidation of reactive azo dye RB5 [21]. Our previous research has shown high photocatalytic activity of TiO_2 films in the degradation of RB5 dye under UV light [22].

The aim of this article is to characterize by PXRD, XPS and EPR analysis copper oxide containing catalyst synthesized by thermal decomposition of copper sulfate. Because of its recent application in photocatalysis we set ourselves the task to examine its photocatalytic properties in regard to oxidative degradation of two hazardous textile dyes- Reactive Black 5 and Malachite Green.

2. Experimental

2.1. Synthesis of the samples

For preparation of CuO containing sample we used $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ as starting reagent. The suspension of copper sulfate and water was magnetically stirred upon heating for about 1 h. After that the obtained sample was dried at 100°C for 12 h. The finally obtained powder was annealed for 3 h at 500°C in air.

2.2. Powder X-ray diffraction analysis (PXRD)

The PXRD of the obtained photocatalyst was carried out using a TUR M62 apparatus, Germany with PC control and data acquisition, using HZG-4 goniometer and $\text{CoK}\alpha$ radiation. The presence of the phases registered in PXRD pattern was established by using of JCPDS database (Powder Diffraction Files, Joint Committee on Powder Diffraction Standards, Philadelphia PA, USA, 1997).

2.3. Electron paramagnetic resonance (EPR)

The EPR spectrum was recorded on JEOL JES-FA 100 EPR spectrometer operating in the X-band with standard TE011 cylindrical resonator. Spectra were recorded at room temperature.

2.4. X-ray photoelectron spectroscopy (XPS)

The X-ray photoelectron spectroscopy (XPS) studies were performed in a VG Escalab II electron spectrometer using $\text{AlK}\alpha$ radiation with energy of 1486.6 eV under base pressure 10^{-7} Pa and a total instrumental resolution of 1 eV. The binding energies (BE) were determined utilizing the C 1s line (from an adventitious carbon) as a reference with energy of 285.0 eV. The accuracy of measuring the binding energy was 0.2 eV. The O 1s, Cu 2p and S 2p, photoelectron lines were recorded and corrected by subtraction of a Shirley's-type of background and quantified using the peak area and Scofield's photoionization cross-sections.

2.5. Catalytic activity tests

The photocatalytic activities of the prepared samples were measured in oxidative degradation of both Reactive Black 5 (RB5) dye and Malachite Green (MG) under UV light. The photocatalytic

studies were performed using UV-Vis absorbance spectrophotometer in the wavelength range from 200 to 800 nm and a polychromatic UV-A lamp illumination (18W) with maximum emission at 365 nm. The initial concentration of the used RB5 and Malachite Green dye solutions was 20 ppm and 5 ppm respectively. The photocatalytic tests were carried out under slightly acidic pH=6. Before switching on illumination, the catalyst and dye solution were stirred for 30 min in dark to achieve adsorption equilibrium. The degree of degradation of the dyes is calculated using equation (1), where C_0 is the initial concentration (based on absorbance) of the dye, C is the residual concentration of the dye after 120 min of illumination.

$$\text{Degradation}[\%] = \left[\frac{C_0 - C}{C_0} \right] \times 100 \quad (1)$$

3. Results and discussions

Figure 1 represents powder X-ray diffraction spectrum of the obtained copper oxide containing photocatalyst. The PXRD results established the presence of copper oxide hydrate phase ($\text{CuO} \cdot 3\text{H}_2\text{O}$) (PDF-36-0545) and additional amount of copper sulfate hydroxide ($\text{Cu}_3(\text{SO}_4)(\text{OH})_4$) (PDF-76-1621). The incomplete thermal decomposition of the starting material copper sulfate is the possible reason for existence of intermediate precursor phase copper sulfate hydroxide registered in the PXRD pattern of prepared copper oxide containing catalyst.

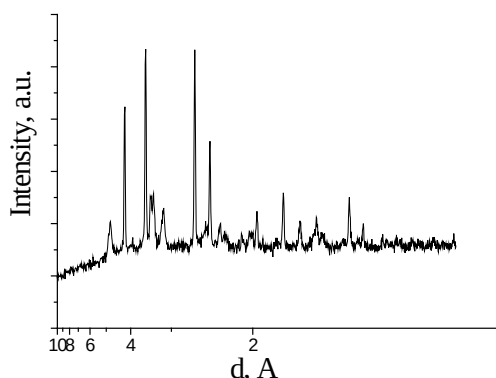


Fig. 1 PXRD pattern of synthesized copper oxide containing photocatalyst.

Figure 2 illustrates the results of electron paramagnetic resonance method. EPR spectrum of CuO containing catalyst at room temperature is consisting of an asymmetric line with g factor 2.24 most probably due to interacting Cu^{2+} ions in clusters [23, 24]. The effect of dipolar interaction between Cu^{2+} ions leads to broadening of individual lines. For this reason the hyperfine structure due to $I=3/2$ of Cu^{2+} ion cannot be seen.

The XPS Cu 2p spectrum of the catalyst sample is shown in Figure 3. The “shake-up” satellite located at 944 eV position and a peak at 935.5 eV are clearly visible. The “shake-up” satellite is an evidence of Cu (II) ions [25], while the peak at 935.5 eV coincides with the known CuSO_4 peak position at 935.4 eV [26]. A low intensity peak at 933.6 eV is typical of the CuO peak [26]. The results indicate incomplete transformation of CuSO_4 into CuO, most probably due to the low temperature of treatment.

Figure 4 represents the course of the photocatalytic reaction as dye concentration decrease with the time of illumination of both investigated model pollutants on the CuO containing photocatalyst. The prepared photocatalyst showed four times higher photocatalytic activity to RB5 than MG dye. It has to be noted that the catalyst exhibited much higher adsorption capacity with respect to RB5 than

to MG for 30 min in dark. The degree of discoloration after 2 hours irradiation for MG is 18%, while for RB5 dye is 90% (Figure 5).

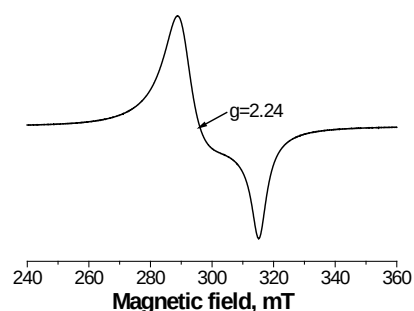


Fig. 2 EPR spectrum of copper oxide containing photocatalyst.

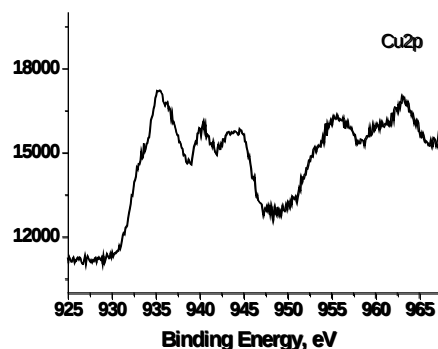


Fig. 3 XPS spectrum of copper oxide containing photocatalyst.

Figure 6 show the dependences of $-\ln(C/C_0)$ as a function of time t under UV light illumination. The dependence shows that the copper containing catalysts exhibit higher photoreactivity to Reactive Black 5 than MG dye in the first 15 minutes of illumination. The photocatalyst has very low activity in degradation of Malachite Green probably due to the difference in the size of conjugated system of C=C and C-C bonds in the molecular structure of the both dyes and different bond scission energies. The rate constants and degree of degradation for the dyes over CuO containing photocatalyst after 120 minutes of UV irradiation are represented in Table 1. The rate constants k after 2 hours for MG and RB5 are $1.7 \times 10^{-3} \text{ min}^{-1}$ and $8 \times 10^{-3} \text{ min}^{-1}$, respectively. Rate constants were calculated using the equation $-\ln(C/C_0) = kt$ on the basis of the slope of the linear logarithmic function.

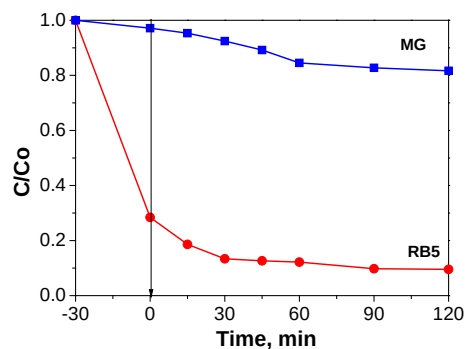


Fig. 4 Concentration changes of both textile dyes based on changes in the intensity of the maximal absorbance peak at 599 nm for RB5 dye and at 615 nm for MG dye respectively, with the course of time.

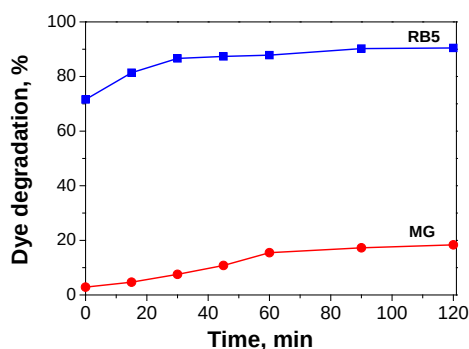


Fig. 5 Degradation degrees of two textile dyes: RB5 and MG over CuO containing powder.

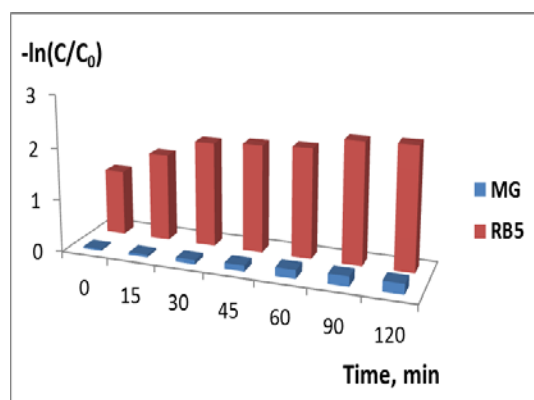


Fig. 6 Dependence of $-\ln(C/C_0)$ with the time of UV illumination for two textile dyes: RB5 and MG over CuO containing photocatalyst.

Table 1. Rate constants and degree of degradation for the both dyes over CuO containing photocatalyst.

Model dye	Rate constant, k ($\times 10^{-3} \text{ min}^{-1}$)	Degradation, % after 120 min
MG	1.7	18
RB-5	8	90

The adsorption spectrum of RB5 has two adsorption peaks corresponding to the $\text{N}=\text{N}$ - bond (at 599 nm) and to naphthalene rings (at 313 nm). Oxidative attack of an azo dye from the phenyl azonaphthol family as RB5 leads to the formation of benzene derivatives and naphthoquinone as primary degradation products. The scheme of possible degradation of Reactive Black 5 can be seen in [22].

The higher photocatalytic efficiency of copper containing photocatalyst to oxidize the azo dye RB5 than those to MG the double ($\text{N}=\text{N}$ -) bond in RB5 is weakened by hyperconjugation and *N,N*-dimethylaminobenzyl in MG [27]. However the central carbon atom possesses also a double bond, connecting it to the third cyclohexadiene ring, which requires also high energy photon for the bond scission. The C-C bond between the central carbon atom and *N,N*-dimethylaminobenzyl in MG, results in the formation of 4-(*N,N*-dimethylamino) methylbenzylone as most common intermediate [28,29]. The decisive argument explaining the activities is the difference in the size of the two conjugated systems. According to the results for Cu-core/CuSO₄-shell nanoparticles possess higher photocatalytic efficiency than Cu nanoparticles [12].

In our case probably the same effect of the presence of copper sulphate plays positive role in the photocatalytic degradation. The results obtained in this article for copper containing photocatalysts are in accordance with our previous studies on ZnO films [29].

4. Conclusions

Photocatalyst containing hydrated copper oxide crystalline phase and additional amount of copper sulfate hydroxide was prepared by thermal decomposition of copper sulfate. The performed PXRD and XPS studies confirmed the presence of copper oxide and some quantity of copper sulfate hydroxide phases. The EPR analysis detected the existence of Cu^{2+} ions in obtained material. The copper oxide containing photocatalyst showed strong difference in its photocatalytic behaviour with respect to the two model dyes, due to differences in their structure and physicochemical properties. The photocatalyst possess much higher adsorption capacity and selectivity to degrade the double diazo bond in RB5 in comparison to the two single carbon-carbon bond in MG. We can recommend copper oxide containing material as relatively new cheap alternative to the already used photocatalysts for degradation of textile azo dyes.

Acknowledgements

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EFFECT OF La DOPING AND THERMAL TREATMENT ON THE PHOTOCATALYTIC ACTIVITY OF ZnO FOR DEGRADATION OF REACTIVE BLACK 5 DYE

ВЛИЯНИЕ НА La-ДОТИРАНЕТО И ТЕРМИЧНАТА ОБРАБОТКА ВЪРХУ ФОТОКАТАЛИТИЧНАТА АКТИВНОСТ НА ZnO ЗА РАЗГРАЖДАНЕ НА РЕАКТИВНО ЧЕРНО 5 БАГРИЛО

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Abstract: The La-doped powder-form ZnO samples were prepared by impregnation using appropriate amounts of aqueous solutions of $\text{La}(\text{NO}_3)_3$. The non-impregnated and impregnated zinc oxide materials were then thermally treated at different temperatures – 350°C and 450°C in air atmosphere. The phase composition and structure of the obtained catalysts were characterized by powder X-ray diffraction analysis (PXRD), EPR and X-ray photoelectron spectroscopy. The PXRD results gave evidence that the average crystallite size of nanosized ZnO phase was varying within the range of 10-14 nm. The present work was focused on the influence of La doping and calcination temperatures on the photocatalytic activities of zinc oxide samples in the reaction of oxidative degradation of industrial textile azo dye Reactive Black 5 (RB5) under UV-light irradiation. The photocatalytic activity tests showed that the La doped ZnO photocatalysts are superior to the non-doped samples and are applicable to decontamination of the textile waste waters.

Keywords: REACTIVE BLACK 5 DYE, La DOPED ZnO, PHOTOCATALYST, PHOTOCATALYTIC ACTIVITY

1. Introduction

Organic dyes find various applications, such as industrial chemicals (textile dyes, surfactants), pharmaceuticals (antibiotics, steroids), antifouling compounds, histopathological applications and staining agents in bacteriological studies. Lately the attention is directed to the elimination or mineralization of different persistent organic pollutants [1].

Wide band-gap semiconductors, such as TiO_2 , ZnO are the promising materials in water purification and disinfection, air purification and hazardous waste neutralization. The photocatalytic efficiency of these oxides in the degradation of different environmental contaminants attracts attention recently [2].

It has been evidenced that the properties of ZnO can be significantly improved by doping with rare-earth elements, which have specific appropriate electronic structure [3]. Lanthanide (Ln = La, Eu, Gd, Dy and Ho) loaded ZnO catalysts (Ln-ZnO) were prepared, characterized and investigated for the discoloration of Methyl Orange [4]. Tingting Wu and coworkers established that La-doped ZnO nanoparticles, obtained by a simple solution combustion method, have superior capacities for the removal of Pb^{2+} and Cu^{2+} ions in waterways than the undoped ZnO nanoparticles [5]. Optical and photocatalytic properties of La-doped ZnO nanoparticles synthesized via precipitation and mechanical milling method are discussed in [6]. The investigations proved that the photocatalytic efficiency in degradation of a Methylene Blue solution using these samples depended upon the number of oxygen vacancies [6]. La-doped ZnO nanowires with different dopant contents were obtained via a solvothermal synthesis route, using ethanol as the solvent. The photocatalytic activity of pure ZnO and La^{3+} -doped ZnO samples was investigated in the degradation of Rhodamine B. The results established that 2 at% of La^{3+} -dopant content in ZnO attribute enhanced photocatalytic efficiency [7].

The present study deals with the effect of La doping and thermal treatment on the photocatalytic properties of zinc oxide materials. For this purpose the synthesis of La doped ZnO samples using impregnation method and calcination at different temperatures were applied. The photocatalytic activity of prepared non-impregnated and impregnated zinc oxide samples was tested

and compared in the reaction of oxidative degradation of Reactive Black 5 dye (RB5) under UV-light irradiation.

2. Experimental

2.1. Preparation of photocatalysts

The method of preparation of activated ZnO powder was described in a Bulgarian Patent [8]. The preparation procedure includes dissolution of commercial ZnO in NH_4OH solution, followed by precipitation as $\text{Zn}(\text{OH})\text{CO}_3$ as a result of CO_2 bubbling through the solution. The La-doped ZnO samples were prepared by impregnation of $\text{Zn}(\text{OH})\text{CO}_3$ with aqueous solution of $\text{La}(\text{NO}_3)_3$ to obtain 1.5wt % La content in La/ZnO composite. The non-impregnated and impregnated zinc oxide materials were then thermally treated at different temperatures – 350°C and 450°C - for 2 hours in air atmosphere. The so prepared samples were denoted as: ZnO-350°C, ZnO-450°C, La/ZnO-350°C and La/ZnO-450°C.

2.2. Methods for investigations of obtained samples

The powder X-ray diffraction patterns (PXRD) of the synthesized powders were recorded on a TUR M62 apparatus, Germany with PC control and data acquisition, using HZG-4 goniometer and $\text{CoK}\alpha$ radiation. The identification of the phases registered in PXRD patterns was accomplished based on JCPDS database (Powder Diffraction Files, Joint Committee on Powder Diffraction Standards, Philadelphia PA, USA, 1997).

The EPR spectra were recorded on JEOL JES-FA 100 EPR spectrometer operating in the X-band with standard TE011 cylindrical resonator. The sample was placed in a special EPR tube and it was positioned in the center of the EPR cavity. All measurements were made in air at room temperature.

The X-ray photoelectron spectroscopy (XPS) studies were performed in a VG Escalab II electron spectrometer using $\text{AlK}\alpha$ radiation with energy of 1486.6 eV under base pressure of 10^{-7} Pa and a total instrumental resolution 1eV. The binding energies (BE) were determined utilizing the C 1s line (from an adventitious

carbon) as a reference signal of energy of 285.0 eV. The accuracy of the measured binding energy was 0.2 eV. The O 1s, Zn 2p, La 3d_{5/2}, photoelectron lines were recorded and corrected by subtraction of a Shirley's type of background and quantified using the peak area and Scofield's photoionization cross-sections.

2.3. Photocatalytic study

The photocatalytic oxidative degradation of Reactive Black 5 (RB5) was carried out using 150 ml dye aqueous solution with initial concentration of 20 ppm. Photocatalytic activity measurements were accomplished using polychromatic UV-A lamp illumination (18 W, 320-400nm) with a maximum of the emission at 365 nm. The process of discoloration was monitored by UV-Vis spectrophotometer CamSpec M501, based on the absorbance of the dye solution in the wavelength range from 200 to 800 nm. The samples were equilibrated in the dark for about 30 min before switching on the illumination. In order to study the photocatalytic activity of ZnO and La-doped ZnO materials, sample aliquots of the suspension were taken away from the reaction vessel at regular time intervals and filtered. The rate constant k was determined as the slope of the linear dependence on time t : $-\ln(C/C_0) = kt$ (where C_0 and C are initial concentration before switching on the irradiation and residual concentration of the solution after illumination for the chosen time interval at 599 nm absorbance maximum, attributed to the peak of the diazo bond (-N=N-)).

3. Results and discussion

The PXRD patterns of prepared non-impregnated ZnO and impregnated La/ZnO samples thermally treated at 350°C and 450°C are represented in Figures 1-4. The presence of ZnO phase (PDF-36-1451) is determined in recorded PXRD spectra of all obtained samples. No La-containing phases could be registered probably because of the low content of La in the La doped ZnO photocatalysts. The calculations of average crystallite size by using PowderCell for Windows Version 2.4 software [9] show that the prepared ZnO and La-doped ZnO materials are nanosized with mean crystallite size of about 10-14 nm.

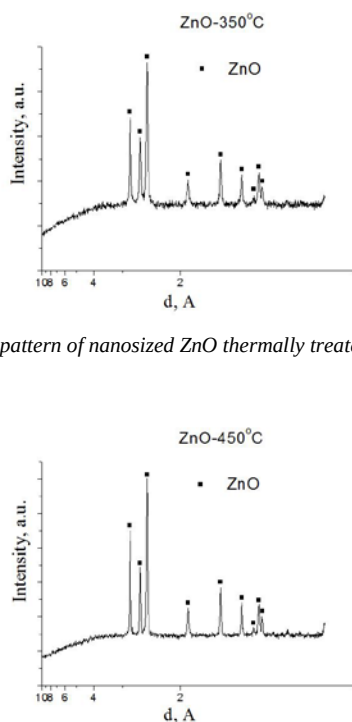


Fig. 1 PXRD pattern of nanosized ZnO thermally treated at 350°C.

Fig. 2 PXRD pattern of nanosized ZnO thermally treated at 450°C.

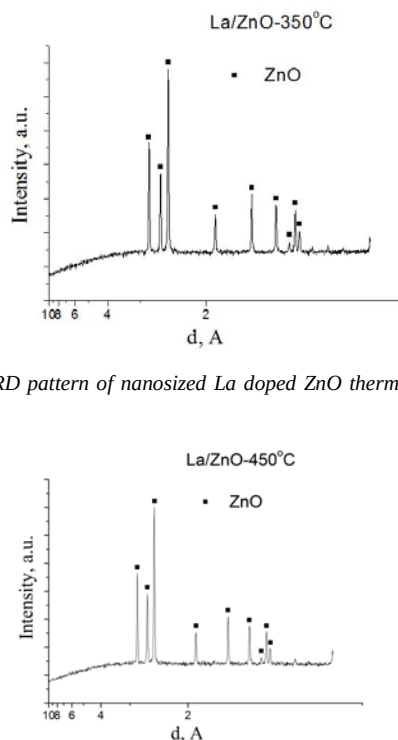


Fig. 3 PXRD pattern of nanosized La doped ZnO thermally treated at 350°C.

Fig. 4 PXRD pattern of nanosized La doped ZnO thermally treated at 450°C.

Electron paramagnetic resonance is a powerful tool to monitor the paramagnetic charge states of vacancies/defects in ZnO. Figure 5a shows the EPR spectrum of ZnO nanocrystals at room temperature, which shows the resonance signal at $g=2.0784$. This signal was attributed to a shell, whose core contains high concentration of surface defects [10]. Such defects have been identified as negatively charged Zn vacancies acting as shallow acceptors [11,12]. When ZnO nanoparticles are modified with La, their EPR spectrum is changed. The spectrum is shown in Fig. 5b. It is interesting to observe that, upon modification of ZnO with La the number of Zn vacancies is decreased. This fact is evidenced by decrease in the resonance signal at $g=2.0784$. In addition a single EPR signal at the g value of 1.9749 has appeared. This signal is attributed to positively charged oxygen vacancies acting as deep donors [12]. Therefore the superior photocatalytic activity of La/ZnO catalyst for oxidative degradation of RB5 dye is probably due to the oxygen vacancies formed during deposition of La on the ZnO surface.

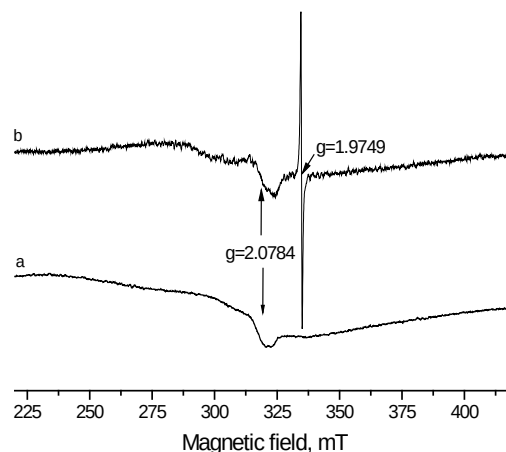


Fig. 5 EPR spectrum at room temperature of: a) ZnO; b) La/ZnO thermally treated at 450°C.

As it has already been discussed in our previous investigation [13] on ZnO and doped ZnO catalysts the surface hydroxyl groups play important role in the mechanism of photocatalytic oxidation.

The investigated O1s photoelectron spectra are represented in Figure 6. It is obvious that there is presence of some more oxygen groups (in addition to the lattice O^{2-}) in both types of ZnO catalysts as well as in the La doped ZnO thermally treated at 350°C and 450°C. The thermal treatment at 450°C leads to appearance of more defects in the both pure ZnO and La-doped ZnO. The higher binding energy shoulder at around 531.5 eV in the O1s photoelectron spectra supplies evidence for that. The percentage of this type of oxygen in the total amount of oxygen, evaluated after deconvolution of the obtained spectra, is increasing from 26.4% up to 35.2% for the ZnO (350°C) and ZnO (450°C), respectively. The same tendency is observed for the La doped ZnO catalyst thermally treated at either of the two temperatures. The percentage of the oxygen, associated with defects, changes with the temperature increase from 24.3% for La/ZnO (350°C) to 35.5 % for La/ZnO (450°C) catalysts. It is worth mentioning here that the formation of additional surface sites in the La-doped ZnO treated at 450°C was detected, which we attributed to water adsorption. The $La3d_{5/2}$ photoelectron peaks of both La-doped ZnO catalysts have been subjected to deconvolutions process, too. The multiplet splitting is typical of the $La(OH)_3$ [14,15], which explains the existence of the additional surface states detected over La/ZnO (450°C).

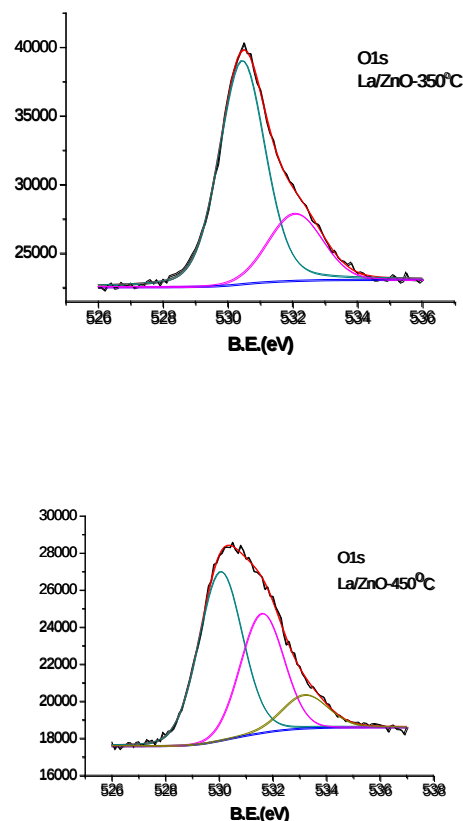
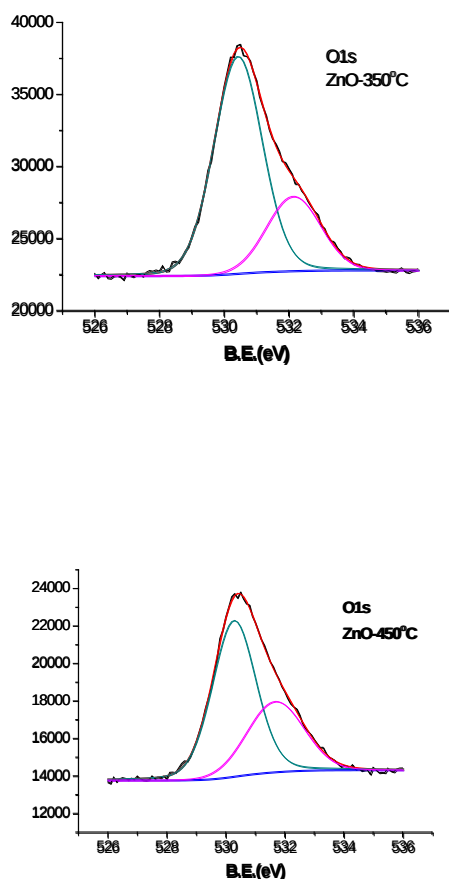


Fig. 6 XPS spectra of nanosized ZnO thermally treated at 350 °C; 450°C and La doped ZnO at 350°C; 450°C.

The photocatalytic activity tests showed that the higher degree of degradation of RB5 dye was achieved in the case of La doped ZnO in comparison with non-impregnated ZnO catalysts. The doping with La influences both the adsorption capacity and photocatalytic efficiency of the samples. As it can be seen from Figures 7 and 8 the doped samples adsorb more dye than the non doped photocatalysts. A. Neren Ökte also reported that La dopant in ZnO promotes higher adsorption capacity and the reaction rate constant values for degradation of the azo dye (Methyl Orange), which is in accordance with our results [4]. The calculated rate constants of prepared nanosized La doped ZnO and ZnO materials thermally treated at 350°C and 450°C approximating to first order kinetics decreases in the following order $La/ZnO-350^{\circ}C$ ($30.4 \times 10^{-3} \text{ min}^{-1}$) > $La/ZnO-450^{\circ}C$ ($30.1 \times 10^{-3} \text{ min}^{-1}$) > $ZnO-450^{\circ}C$ ($14.7 \times 10^{-3} \text{ min}^{-1}$) > $ZnO-350^{\circ}C$ ($6.8 \times 10^{-3} \text{ min}^{-1}$). The rate of oxidative degradation reaction is also higher in the case of lanthanum doped powders. Another research group has also proved the positive effect of La on the photocatalytic degradation rate of the dyes [16].

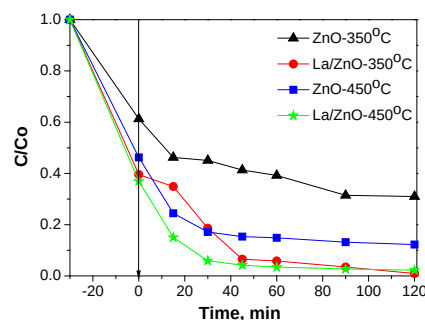


Fig. 7 Reaction course as concentration ratio varying during the photocatalytic oxidation of an initial concentration (C_0) of 20 ppm RB5 dye, based on changes in the intensity of the absorbance peak, corresponding to azo bond ($-N=N-$) as a function of the time interval of irradiation.

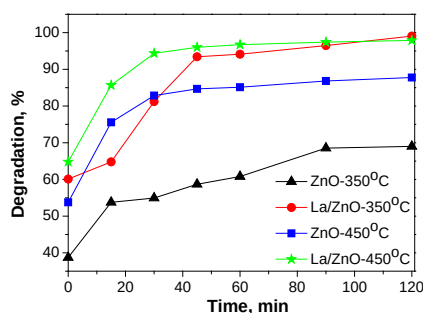


Fig. 8 Degradation of the RB5 dye solution (as conversion degree) after 120 minutes of UV-A illumination over nanodimensional ZnO and La doped ZnO samples calcined at 350°C and 450°C.

It is well known that the photocatalytic activity is closely related to the concentration of defects on the surface of the nanomaterials. The positive effect of lanthanum doping can be explained by the formation of charged surface region due to the surface donor defects on ZnO. The presence of such a region leads to hindered recombination of electrons and holes pairs in ZnO thereby enhancing the photocatalytic efficiency [1,17]. This enhancement of photocatalytic activity of La-doped ZnO can also be explained by more efficient charge carrier separation [18].

We have also studied the influence of calcination temperature on the phase composition, structure and photocatalytic efficiency of doped and non-doped samples. The non-doped powders treated at higher calcination temperature exhibit higher activity than the samples, treated at lower (350°C) temperature. This effect could be due to the higher degree of crystallinity of the samples treated at 450°C (Figure 2). The effect of calcination temperature is less pronounced in the case of doped samples: 99% vs 98% degradation for thermally treated at 350°C and 450°C La/ZnO powders.

4. Conclusions

The present photocatalytic research work established that the degree of degradation of RB5 dye using La doped ZnO is higher than that in the case of non-impregnated ZnO photocatalysts. The higher calcination temperature - 450°C for non-impregnated ZnO leads to increase in the degree of degradation of RB5 (88%), which is superior to that of the ZnO sample calcined at 350°C (69%). The calcination temperature has only a slight effect on the degradation rate over La doped ZnO photocatalysts: 99% vs 98% degradation degree for those thermally treated at 350°C and 450°C, respectively. The La doping of non impregnated ZnO samples leads to increasing of their photocatalytic activity in the reaction of oxidative degradation of RB5 dye used as model contaminant.

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NFC - THE FUTURE OF e-SMART BUSINESS

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Abstract: Near Field Communication (NFC) technology is the future of m-Commerce, which has found possible application in contactless cards and mobile phone devices. NFC is technologically integrated with Data Ware House infrastructure and Cloud computing system which are incorporated in the e-Smart Business system. As a product of the implementation of NFC technology in m-Commerce business models there is a need of expansion B2B2C business model towards integration of services with the aim of creating new products, markets and consumer needs tuning. This paper presents a business model called e-Smart-Business as a system integration concept of m-Commerce through direct marketing and market research with the Data Ware House and Cloud computing systems.

Keywords: NFC, CLOUD COMPUTING, DATA WARE HOUSE, M-COMMERCE

1. Introduction

NFC (Near Field Communication) is a very short-range radio communication that enables contactless cards and NFC mobile devices to communicate, exchange data and share resources, and it represents the technology of future which will change and introduce a completely new way of communication, business, trade, marketing, arts, health, social care, security and the like. NFC technology is the future of m-Commerce, which will, by using other contactless communication systems (RFID, Bluetooth and IrDA), constitute a technical-technological and service integrator with the infrastructure of Data Ware House and Cloud computing system and will be consolidated in e-Smart Business systems.

2. Definition of NFC

NFC is a contactless short-range radio communication that works at frequency of 13.56 MHz, with the possibility to transfer data up to 424 kbit/s between two devices. NFC technology is based on RFID technology (Radio Frequency Identification) and uses the same principles of functioning. NFC standard was established in the 2003 year and is defined in the standard ISO/IEC 18092, and it is compatible with ISO/IEC 14443 and ISO/IEC 15693 and with Sony FeliCa contactless smart cards (Ortiz, 2008). In that way, NFC can use the existing RFID infrastructure eliminating the need for specific technical conditions of its own infrastructure. A key advantage of NFC devices is that they can read RFID transponders and emulate them.

One device, the initiator, uses magnetic induction to create radio waves in the own field scope in order to detect and access to another device and to make wireless transfer of certain amounts of data over relatively short distance greater than 4 inches or 10 cm (Madlmayr et al., 2008). NFC communication flow is activated when two NFC compatible devices are brought into listed immediate nearness or when realize their touch. The offering one device to another, or their touch on the designated space for touch, opens the set-up protocol connection and the connection is accomplished by the exchange of all scheduled data in the field of exchange, which should not be beyond the limit of 10 cm.

Comparison of the NFC with other contactless communication technologies discovers the advantages and disadvantages of this new technology and there is the possibility of application as well as the future. The following table shows the comparison of NFC with RFID (Radio Frequency Identification Tag), IrDA (Infrared Data Association Protocol) and Bluetooth.

Table 1: Comparing NFC to other close range communication technologies (Source: Ortiz, 2008)

	NFC	RFID	IrDa	Bluetooth
Set-up time	<0,1 ms	<0,1 ms	~0,5 s	~6 s
Range	Up to 10 cm	Up to 3 m	Up to 5 m	Up to 30 m

The main advantage of NFC over the other contactless technologies is in the two-way traffic that establishes between two

devices. On that way they can automatically send and receive information, as opposed to Bluetooth technology which is necessary pairing to achieve communication or RFID and IrDA which representing one-way communication, only sending certain information.

On the other hand, this pairing that requires Bluetooth NFC done automatically if the two devices come to the field response (less than 10 cm). This very small distance between two devices set the NFC protocol as the safest protocol for the exchange and sharing of data between devices.

However, NFC has the disadvantage, particularly in comparison with other contactless/wireless protocols such as Bluetooth or Wi-Fi. NFC is slow protocol, with a maximum data transfer speed of 424 Kbps or less than a quarter compared with Bluetooth.

This protocol can be used only for transmission of small amounts of data. But, on the other hand, the NFC has several key advantages over Bluetooth, because it consumes very little power, only 15mA, which is almost nothing for today's jumbo smart phone batteries (Ortiz, 2008).

3. Possibilities of using NFC applications

NFC technology offers new possibilities in creating new services, especially related with issue of contactless smart cards, but most preference gives to mobile applications coupled with m-business. Precisely this advantage within the NFC Forum has been recognized by all major telecommunication's company and mobile telecommunications operators. The fact that the average cost of NFC is about 2.5 USD, with such a great application usage possibilities in many areas of human activity and electronic business, encourage the all mobile phone hardware manufacturers to incorporate these components by default as technologically standard of the future in mobile phone devices (Au and Kauffman, 2008).

There are two directions of massive use NFC technology: smart cards and mobile phone devices. Smart cards present a solution that will launch a massive use of this technology, but because of technological limitations very quickly will be replaced with mobile devices that will become the primary standard for personal communication, identification and business interaction in the sphere of the total e-business.

NFC Forum as a global association of companies that promote and carry out the implementation of NFC technology cites three key usage of NFC concept: information sharing, pairing devices and transactional exchange data.

Information sharing is used similarly to reading QR codes, for example reading tag with these products in order to obtain basic information about the product. One active NFC device such as a smart mobile phone may be interacting with other NFC device or passive NFC tag. NFC technology allows to mobile phones with NFC chip that they can read labels (tags) on products and objects

(Rukzio et al., 2004). Behind these labels are passive NFC chips and thanks to that phones can share information on mutual interests and the messages they want to convey.

Pairing devices will represent in the future one of the main advantages and standard which imposes NFC technology. The advantage is in two-way traffic of NFC protocol that enables fast (instantaneous), easily and securely connection and pairing with other devices.

Transactional data exchange - NFC will be used as the basic communication protocol of transactional data exchange for smart cards and NFC mobile phones in all types of card payment system, for buying tickets in public transport, for new ID cards for access to public places, for ID cards for access high security systems and spaces and so on (Ondrus and Pigneur, 2007).

4. The development of e-Smart Business

e-Smart Business (e-SB) in his retail part of the business is based precisely on NFC technology and with the information obtained through this mode of communication e-SB actively creates market, making it much more efficient and economical.

NFC technology opens up new channels for distribution of services, but on the other side, compatibility with other types of contactless technology allows that within m-commerce are also defined business models as: m-Merchandising, m-Marketing, m-Loyalty, m-Payment, m-Banking, m-Transport, m-Post, m-Health programs, m-Government, m-Tickets, m-Key, m-Entertainment (see Fig. 1). All of these business models are coupled with the Data Ware House concept of accepting and processing data, as well as Cloud computing systems, and thanks to NFC enable creation, monitoring and improvement of products and services offered to the client, as well as developing market which until now may not even exist (Hassinen, 2008).

Information that user exchange between NFC mobile phones and NFC tag or other NFC devices may be subject to processing within the Data Ware House. This aspect is important because in this moment we can use the data of the wishes, needs, demands of a certain client coupled with his personal data. NFC technology provides two-way communication that allows such a flows so that it becomes powerful tool for market research. Using these data in advanced Data Ware House concept of data processing allows perceiving their needs, desires and habits, which gives the possibility to personalize services, modelling of customer needs, improving and expansion of market, modification and improvement of products and services and so on.



Fig. 1 Platform of e-Smart Business

In architecture of Cloud computing, which was leaning against the m-Commerce system recognizes three models:

- SaaS (Cloud Software as a Service) - a system that provides to use the application of service provider running on a "cloud" infrastructure and where applications can be accessed from the

client mobile devices through a Web browser user interface. Characteristics of SaaS approach are: enabled access and management of commercially available software over the network and management of the activities carried out from central location instead of the location of each provider (service providers) respectively, which basically allows users to access to applications from distance through commercial Web sites;

- PaaS (Cloud Platform as a Service) - a system that provides the user to place on "cloud" infrastructure application which he himself created or requested application that was developed using programming languages and tools supported by the service provider. PaaS system contains so called add-on development tools that are used for customization of existing SaaS applications;

- IaaS (Infrastructure Cloud as a Service) - a system that provides the user to manage the processing, storage, network and other basic computing resources where user can set up and run arbitrary software, including operating systems and applications.

Center of e-Smart Business is NFC technology coupled via m-Commerce services with Data Ware House and Cloud computing systems. e-Smart Business model will enable an entirely new platform in serving clients that will be upgraded by the day with the aim to set new quality in service provision and that will lead to greater efficiency, productivity and profitability in the business environment (Cloninger et al., 2011).

There are three recognized phases in the development of the NFC technology which will be a driving force of the e-Smart Business development (NFC Forum):

1. Contactless card phase – this phase is the most common phase at the moment, and this phase will enable numerous advantages of this new technology to be assessed, such as:

- Fast and efficient payment at the point of sale;
- Speeding up the selling process, thus eliminating queues and standstills while paying for goods and services;
- Decreasing number of deceitful actions and better protection of misuses in payments;
- Decreasing the operating and handling costs;
- Eliminating the need to pay in cash.

2. The phase of adding the NFC chip in mobile phones – as hardware/software addition which is optionally built in phones. After the pilot projects, this phase has already come to practice and it represents the adaptability phase of both service users and total market of service providers. The benefits of this phase are:

- Personalized offer and loyalty program development;
- Better client targeting;
- Better and more efficient promotion of goods and services;
- Decreasing costs of card management;
- Market expansion and new markets penetration.

3. Integration phase of the NFC chip into mobile phones – as the last phase of the development of the NFC technology which will definitely change the entire approach in m-commerce and open a way to rendering integral services within the e-Smart Business. Future benefits of this last phase in the NFC technology development will be as follows (Dahlberg, 2008):

- Setting up a virtual m-wallet;
- Personalization of the offer at a selling place;
- Direct marketing at a the point of sale;
- Cross selling at the point of sale;
- Dramatic decrease in misuses and deceitful actions in the process of paying for goods and services;
- Creation of new profit centers;
- Creation of new forms of income for mobile operators.

The greatest danger of introducing NFC technology lies in the personal acceptance of this new service by the client. The adjustment phase must be well promoted in order to break the client's fear of abuse and encroaching upon the privacy by using data about customers and their reactions, purchases and habits. This last problem (invasion of privacy of the client) can be the biggest

obstacle to the rapid implementation of new services in the NFC platform. Privacy and safety are central issues in user's perception in the case of using the service. Beside promotion, also user's education will be necessary to ensure full integration of customers in e-Smart Business models.

Adoption of NFC as a future of e-Smart Business is still not widespread despite its potential. It is necessary to conduct research that provides useful theoretical and managerial implications for mobile phone manufacturers, merchants, software developers, governments and private practitioners when devising their marketing campaigns and business strategies. For this purpose may be used Technology Acceptance Model (TAM). Through this model focus can be on NFC adoption as another form of mobile payment (Tan et al., 2014). Originally, Technology Acceptance Model has variable Perceived Usefulness and Perceived Ease of Use, but in this research framework, were added variable Social Influence, Personal Innovativeness in Information Technology, Perceived Risk, Perceived Financial Cost. Fig. 2 shows the research framework which guided the development of conjectured relationships between the variables.

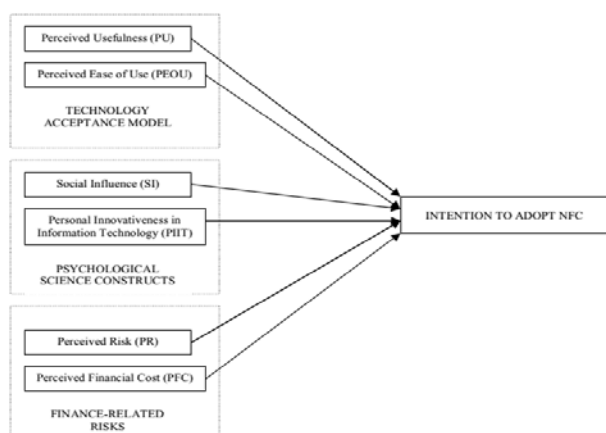


Fig. 2 Research framework

The findings suggest that Perceived Usefulness is a significant construct in predicting the intention to adopt NFC. If consumers find the innovation useful, they are more likely to adopt the services offered. This is particularly in view of the advantages brought about by NFC mobile payment over cash or credit card payment in terms of quicker and more convenient transactions. Likewise, Perceived Ease of Use is a significant factor in predicting NFC acceptance. Social Influence is another influential factor predicting NFC acceptance. Young consumers are usually vulnerable to environmental influences. Since the majority of respondents are young, their decisions whether to adopt certain technologies are likely to be influenced by the roles and opinions of their family members, friends, colleagues, superiors, and classmates (Lopez-Nicolas et al., 2008).

Perceived Risk is a non-significant construct in this research. The reason for this may lie in respondents' age. Majority of them are young users and therefore they may not understand the financial risks involved when adopting NFC. Also, their willingness to try a new technology such as NFC may have helped them to overcome the risks associated with it. Similarly, Perceived Financial Cost was found to be a non-significant factor.

5. Conclusion

NFC technology is the future of m-commerce, created as an extension of RFID technology, using the same principles of functioning. Its compatibility with other contactless communication technologies gives her huge opportunities, especially if it is taken into account that for NFC is not necessary to provide special communication infrastructure. Development opportunities and future application NFC technology will find in mobile handsets as a communication infrastructure that is expanding and which gives a

natural symbiosis between peripheral communication with clients and e-Business. Advantages and opportunities of NFC are quickly recognized by manufacturers of hardware and by mobile telecommunications operators. They are launched NFC Forum as independent association of companies that wish to develop and standardize NFC technology with purpose of its applicability in many areas of business. Exactly they are launched a series of pilot projects that were successful and which already grown into serious e-business projects in many areas of human activity as trade, banking, transport, e-government, postal traffic, telecommunications, health, socially care, entertainment, hospitality, marketing and market research, etc. The 2011th was declared as the year of full commercialization of NFC technology in its applicative and exploitive sense in all areas of business. An important place in the development of a new integrated m-commerce takes marketing and market research with the use of powerful tools Data Ware House and Cloud computing, all of which grew in e-Smart Business. On the other hand, the concept of NFC on the client periphery with usage of other contactless communication system (RFID, Bluetooth and IrDA) presents a technical-technological integrator with an infrastructure Data Ware House and Cloud computing in the concept of e-Smart Business.

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SCP-RPSC – THE KEY TECHNOLOGY FOR THE NEXT GENERATION MICROWAVE COMMUNICATION SYSTEMS

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Abstract: A retrospective review of a new technology, named SCP-RPSC, is given in this report. It is particularly useful as the radio front end of the microwave communication systems with terrestrial and satellite positioning. SCP (Spatial Correlation Processing) technology includes additional pilot signal transmitted in the band of information signals and available in the receiver by one of the known methods of radio access. The receiver terminal is equipped with random phased antenna array. The random phase spread information and pilot signals correlate in a correlator. Its output signal at baseband is the recovered information signal. The application of SCP principle in transmit mode was named RPSC (Random Phase Spread Coding). The transmitted by the random phased antenna array signals have specific phase spread. It can be considered as random spatial coding. The advantages of the SCP-RPSC approach over classic microwave communication systems, based on phased antenna arrays, are shown. A list of possible communication applications as Satellite Digital Video Broadcasting, Inter Satellite Links, Feeder Lines, High Altitude Platform Systems, WIMAX, Aeronautical and Global Navigation Satellite Systems (GNSS) is given too.

Keywords: SCP TECHNOLOGY; RPSC; RPSC-MA, MICROWAVE MOBILE COMMUNICATIONS

1. Introduction

The terrestrial and satellite based broadband communication systems are extremely important for the next generation global information society. They need new and wider frequency bands, available at higher frequencies – up to millimeter wave frequency bands. One of the biggest technical problems of these systems is the way of access to the satellite or terrestrial base stations, particular the used antenna systems. The need to change the polarization, to track Low Earth Orbiting Satellites (LEO,s) or High Altitude Platforms (HAPS), to select one of several Geo Stationary Orbit Satellites (GEO,s) positions, as well as the requirements for two way broadband mobile communications at low price and mass market production leads to unsolved by traditional antennas problems. Their solution needs entirely new approach, which is subject of the last decade research activity of the author. The name of the new technical proposal is Spatial Correlation Processing – Random Phase Spread Coding (SCP-RPSC). A retrospective review of the research step by step approach, used by the author, is given in the report with the main bibliography for details.

2. SCP Technology

The main objectives of the SCP technology [1,2] are:

- To receive one or more radio signals coming from one or several spatially distributed signal sources (satellites, base stations), insuring high gain of the antenna systems and using fixed or mobile receiving terminals, equipped with SCP signal processing equipment;
- To ensure spatial selectivity high enough to cancel the same frequency channel interference, coming from different space directions, using simple one channel receiver.

The objectives stated above are achieved by a patented method for radio communications, which proposes application of additional pilot signal transmitted in the band of information signals and available in the receiver by Code Division Multiple Access (CDMA). SCP system architecture is shown in Fig.1. The SCP receiver terminal is equipped with antenna array with random phase aperture excitation. The phase shifts among the signals, coming from the antenna elements, are random at the antenna output, regardless of the information source direction. These random phase spread signals correlate with the recovered pilot signal, phase spread in the same manner, in a signal recovery unit. The result of the correlation process between pilot and information signals is the recovered information signal at base band.

The described SCP approach solves simultaneously the problems of antenna beam steering and closed-loop satellite tracking. SCP system could be defined as virtually electronic steering and multiple satellites closed-loop tracking system. One of its main parts is the random phased antenna. In principle all kind of antenna arrays could be used, but for Ku and Ka bands particular suitable is the Random Phased Radial Line Slot Antenna (RP-RLSA). Until now it is used as phased array for fixed satellite reception.

The main features of the SCP approach are:

- Simple, cheap and flat passive antenna, suitable for mass production;
- One channel convenient microwave receiver with simple signal processing;
- Omni directional for the cooperative signal source, but with high figure of merit G/T;
- Selection of the different signal sources and polarizations by PN-codes;
- Applications in existing Digital Video Broadcasting – Satellite (DVB-S) systems with minor modifications of the ground transmitters, compatible with the existing satellite transponders;
- Multi-beam and soft handover features.

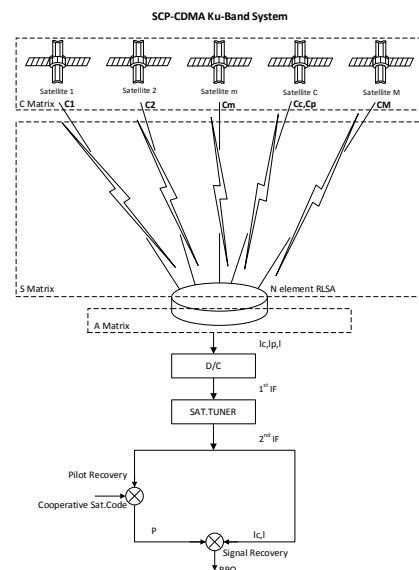


Fig.1 SCP system architecture

3.RPSC Technology

Reliability and availability of real time communications are imperative in the context of wireless communication services. A popular technique used in this scenario is Spread Spectrum (SS). Since the SS approach is not useful in combating white noise, it must have other applications that make it worth considering. These applications include:

- Anti-jam capabilities – particularly for narrow band jamming;
- Interference rejection;
- Multiple access capability;
- Multipath protection;
- Covert operation or low probability of intercept;
- Secure communications;
- Improved spectral efficiency – in special circumstances;
- Ranging.

The recent developments of the broadband terrestrial and satellite wireless communication systems lead to new problems in the field of the conventional SS systems. Because the values of the used Processing Gains are in order of 20 or 30 db, the SS signal bandwidth grows to unpractical high values for adequate signal processing and transmission. The most sensitive to the super wide bandwidth of the SS broadband signals are the antenna beam forming networks.

A new principle to create broadband SS systems was proposed by the author [3]. It is based on transmission of broadband microwave signals in the open space by means of multi element random phased antenna arrays. The sum of the different elements signals in a given point in the space has Gaussian probability distribution and noise like properties. The sums in the different directions of the space are not correlated each other. In such way the proposed principle solves simultaneous the problems of spreading and beam forming of the future sophisticated microwave terrestrial and satellite communication systems with fixed and mobile applications.

A block scheme of a RPSC system is shown in Fig.2, where:

- (1) is a transmitter of SCP signals (modulated information signals and CDMA-spread pilot signals);
- (2) is a RP-RLSA;
- (3) is a conventional microwave receiving antenna;
- (4) is a conventional one channel receiver with low Intermediate Frequency (IF) output;
- (5) is a SCP Pilot recovery unit;
- (6) is a SCP Signal recovery unit (correlator);
- (7) is a baseband signal processing equipment.

The main features of the RPSC technology, when it is used in the up-links of the satellite communication links, additionally include:

- Omnidirectional for the cooperative satellite, but with high equivalent (at base-band) Equivalent Isotropic Radiated Power (EIRP);
- Selection of different terminals and polarizations by Pseudo-Noise (PN) codes;
- Soft handover and virtual multi-beam features;
- The coherent demodulation by means of pilots (specific property of SCP technology) cancels the Doppler shifts and phase jitter, introduced by local oscillators in the satellite system;

- Compatible with the existing bent-pipe satellite transponders;
- Providing of full duplex radiocommunication system with one simple and cheap transmit-receive antenna, using combined SCP-RPSC technology in both directions, particularly in Ku band;
- The transmitted random poly-phase spread signals will not cause significant harmful interference to the conventional satellites, using the same frequency channels. The interference will be similar to that, caused by the sidelobes of an antenna array with random elements distribution and main lobe, phased in another direction;
- RPSC up-links are protected against jamming, coming even from points, close situated to the earth stations – in the main lobe of the satellite up-link receiving antenna. The receiving RPSC circuits will not recovery the jamming signals because of the lack of correlation between the jamming signals, transmitted by conventional high gain antennas, and the recovered random phase spread pilot signals. Situation is similar to the case of CDMA protection against narrowband interference;
- The transmitted random poly-phase spread signals are uniformly radiated in the space above the antenna. Several satellites, equipped with the same SCP receivers and providing space diversity, receive them. The knowledge of the receiving satellite positions for the transmitting equipment is not necessary (as it is for a conventional satellite earth station);
- The transmitted random poly-phase spread signals have low power spectral density and low detection probability for the conventional microwave receivers, leading to low active jamming probability;
- The SCP-RPSC approach could be a breakthrough technology, leading to unpredictable increase of the frequency reuse factor in satellite and terrestrial wideband networks. Close situated subscriber terminals could communicate with base stations, using the same frequency channel without interference. The isolation between the terminals will be provided by their specific random phase spread coding.

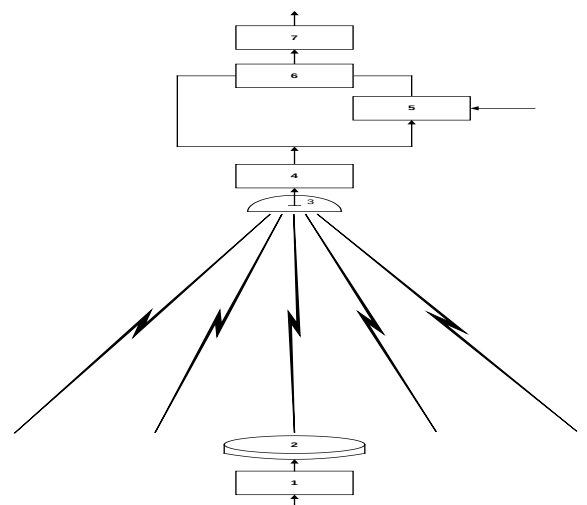


Fig.2 RPSC system architecture

4. SCP-RPSC Applications

4.1. Digital Video Broadcasting - Satellite (DVB-S)

A proposal for SCP-CDMA GEO satellite system, suitable for DVB-S communications in Ku-band for fixed and mobile terminals, is given in [2]. The proposed algorithm for system parameters evaluation, based on link budget calculations, gives good results – Figure of merit (G/T) better than 14 dBi/K for 60 cm antenna diameter at very low price (in order of several \$). Similar proposal for quasi GEO satellites at elliptical polar orbits is given too.

GSO systems provide fixed and mobile communications, as well as TV broadcasting services since 1964. Nevertheless, they still suffer some problems, as follows:

- The amount of the already existing systems limits the frequency and orbital resources in the most desired frequency bands, for example the Ku band.
- The low elevation angles in the high latitude regions hampers the reception in urban areas and rough terrains. Mobile reception using horizontal antennas mounted over mobile platforms is just impossible.

An appropriate decision of the above mentioned problems is the use of satellite systems on high elliptic eccentricity polar orbits, known as Quasi-GEO [2]. The active zone of the satellites here is in the apogee, when the relative satellite -Earth velocity is low.

The application of the SCP technology in GSO systems requires specific approaches. In the case of fixed reception the antenna should be mounted vertically on the wall, looking to the chosen GSO satellite. In the case of mobile reception it should be mounted horizontally on the roof of the vehicle. In Quasi-GEO the antenna should be in horizontal position in both mobile and fixed reception. Soft handovers among different Quasi-Geo satellites is possible due to the ability of SCP technology for multi-beam reception, using several correlators, each one for the different satellite. The result is:

- Ability for soft hand-off between the satellites using single antenna aperture;
- Space diversity, which allows reception of the same information from several satellites, leading to increased reliability in urban and rough terrain areas;
- The collective systems in trains, aircrafts or ships allow the receiving of different TV programs from several satellites by means of a single antenna system;
- Another advantage of SCP technology in Quasi-GEO is the lack of Doppler shift problems; being the same for the pilot signal and the information one in the process of correlation it is compensated.

4.2. Space Links

4.2.1. Inter Satellite Links (ISL)

The space segment of the future global satellite systems for broadband communications can be designed in number of ways, depending on the orbital type of the satellites and the payload technology available on board. The use of different satellite orbits to provide complementary services, each optimized for the particular orbital type, is certainly feasible. Satellites can be used to connect with each other and the ground networks, through the use of Feeder Lines, Inter-Satellite Links or Inter-Orbit Links, which when combined with on-board routing facilities, can be used

to form a network in the sky. The unique properties of the SCP-RPSC approach will give a new support for the future broadband LEO,s communication systems in the service feeder lines, inter-satellite and inter-orbit lines domain. The possible applications of the SCP-RPSC technology in these microwave lines of several different types LEO,s constellations are considered in the report [4]. A review of the possible advantages, supported by a critical analysis, is given too.

4.2.2. Feeder Lines for cellular backhaul and IP backbone trunking

There is a great interest in the satellite society for new networks on MEO satellites, using steerable Ka-band beams to provide lower-cost, fiber-grade access for cellular backhaul and IP backbone trunking in traditionally underserved areas. The main network parameters and architectures are presented in the report [5]. Information concerning the satellite constellation and orbit, satellite and ground antenna beam steering, as well as inter-satellite handover procedures are given too.

A possible solution of the above mentioned system is based on Electronically Steerable Antennas (ESA). Their benefits include:

- An ESA can direct a narrow beam over a sector angle and give coverage like a sector antenna;
- The narrow beam corresponds to a high antenna gain and thus reduces power and amplification requirements on radios;
- The narrow beam-width reduces multipath propagation problems;
- Complex and dynamically re-configurable radio networks can be created exhibiting high spectrum efficiency;
- If the steering of antennas is coordinated it potentially enables the reuse of frequencies and timeslots in different directions;
- The used until now "multiple spot beams" approach is not effective when there is instability or motion of the communication platform. It is due to the necessity of permanent handover among the different spot beams. The ESA approach is good solution in such cases.

The drawbacks of the ESA include:

- There is an increase of complexity in the antenna;
- There will be losses in the RF-electronics in the antenna which lowers the antenna efficiency;
- The use of non-linear devices in the antenna will demand that spectrum issues be addressed;
- The existing ESA designs have only one steering beam. In the case of mobile or unstable platforms we need several hundred independently steering and isolated each other antenna beams.

A new solution for these MEO satellite systems, cancelling the above mentioned ESA drawbacks, could be SCP-RPSC approach [5].

4.3. High Altitude Platform Systems

A new radio technology to realize the last mile access to the broadband fixed networks, named High Altitude Platform Systems (HAPS), is discussed in report [6]. Such a mode of service delivery offers advantages as coverage can be rapidly set-up over any location and can be just as easily removed or relocated; high elevation angles can be achieved to the mobile users; efficient

frequency re-use schemes can be employed to maximize network capacity; the round-trip delay is relatively short; the cost is considerably less than terrestrial or satellite counterparts. The goal of the report is to discuss the possibilities and the advantages of the implementation of SCP-RPSC technology in HAPS feeder lines, as well as in the fixed and mobile terminal communications.

4.4. WIMAX

The goal of the reports [7,8] is to discuss the possibilities and the advantages of the implementation of SCP-RPSC technology in Wi-MAX communications. The implementation of this technology in subscriber terminals is discussed first. After that the possible base station applications are treated too. The applications of SCP-RPSC technology simultaneous at base station and terminal stations are feasible, but they will need additional research and investigations.

4.5. Aeronautical Mobile Satellite Service (AMSS)

Recent evolutions in the context of AMSS have changed the landscape and the role of the different systems that allow aircrafts to maintain a link with the ground while in flight. The increase in capacity needed to support the growth of worldwide air traffic and the need for increased communication safety are driving a transition from voice-centric procedures aided by slow data link connections to data-centric control applications executed on higher capacity communication systems. These future data links have to fulfill very stringent performance requirements. Indeed, the nature of the information they carry which is to become the first mean of air traffic control make their availability critical to the safety of air transportation in the future. Satellite communication systems have many differentiating arguments when compared to terrestrial solutions. Indeed, while the deployment costs of terrestrial systems can be sustainable in high-density areas, their use in low-density remote areas is much less interesting. In high-density areas, satellite could also be useful either as a primary mean of communication or as a secondary one in order to improve the overall communication system's availability. A satellite system, by nature, is able to cover large regions of the earth and can thus provide a cost effective solution to the coverage of both high and low density areas such as oceanic regions where reliable terrestrial coverage is nonexistent. The use of Ku and Ka frequency bands for AMSS leads to unsolved until now problems, which could be solved successfully by SCP-RPSC approach [9].

4.6. Global Navigation Satellite Systems (GNSS)

Historically, the Global Navigation Satellite Services (GNSS) have been delivered through the use of satellites transmitting in L-band (out of which only a few tens of MHz are assigned to GNSS use from regulatory authorities). Targeted to military navigations at first, these services have evolved towards hundreds of civil applications, some of them (for example railway transport) with great accuracy. The use of L-band gives important benefits, such as small onboard antenna size and little or no attenuation due to rain. However, the amount of L-band available, and more specifically the portion allocated to GNSS, is limited. Moreover, frequency reuse due to different orbital slots is extremely limited. The possible transport applications require a much greater accuracy than normally in L-band because of the ionosphere propagation effects.

To definitely overcome the problems due to the L-band, the only choice is to move GNSS to a higher frequency band. Ku-band is an ideal candidate to offer error free GNSS.

An analysis of the possibilities to create new GNSS, working in Ku -band, is given in [10]. SCP technology is proposed as

solution of the possible antenna problems. The possible advantages of such kind systems are discussed, as follows:

- Improving the fade margin of GNSS in Ku-band.
- Drastically decrease of ionosphere propagation errors.
- Improving the GNSS system parameters due to directivity of the SCP virtual antenna pattern – better isolation among different satellite PN-codes, better Pseudo-satellite compatibility, better anti-jamming and multi-path propagation properties.

5. Conclusion

The practical implementation of SCP-RPSC principles will drastically change the existing paradigm in the microwave communication systems. Many of the existing problems, dealing with frequency and orbital resource sharing, beam pointing, mobility, terrorist jamming etc., will be solved successfully.

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SPACE CORRELATED U-PN CODES – A POSSIBLE SOLUTION FOR THE NEW MICROWAVE COMMUNICATION AND RADAR SYSTEMS

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Abstract: A retrospective review of a new approach, named Space Correlated U-PN codes, is given in this report. It is particularly useful as spread spectrum radio access technology in the mobile broadband communication and radar systems with integrated terrestrial - satellite positioning. The principles of U-PN codes generation, as well as the basic methods of their acquisition and tracking, are given too. The proposed SC-CDMA principle uses several space distributed sources of radio-signals. The signals are phase modulated by appropriate PN-codes. The Mobile Stations (MS) receive these signals by means of the well known CDMA technology. For this purpose the same PN-codes are generated and synchronized in the MS receiver. The sum(mod2) of these codes creates a new code, which we named U (Unique)-PN code. This code is used for spreading the information, transmitted by the MS. Similar approaches are used for generation of the Base Station (BS) U-PN codes. Proposals of realistic SC-CDMA mobile communication and SC-MRN radar systems, based on the well developed GPS navigation, are shown in the end of the report.

Keywords: SC-CDMA, MOBILE COMMUNICATIONS, SATELLITE, MULTISTATIC RADAR

1. Introduction

One of the main objectives of the Satellite Personal Communication Networks (S-PCN) is to complement terrestrial mobile networks by providing analogous services in areas where satellite technology is more effective and economic [1]. It can be achieved by the provision of dual-mode user equipment which communicates with both the satellite and terrestrial mobile networks so that when users roam outside of the terrestrial coverage, their requested services can still be supported via the satellite segment. An important topic in this field of research are the Connection Transfer Schemes (CTS) with Soft Handover (SH). SH maintains the call connection through the old link until a new link is firmly established. SH is always associated with diversity (satellite - terrestrial or satellite - satellite). With soft handover, the service will not be interrupted since the old connection is still used for communication during the handover procedures. As a result, seamless handover can be achieved. The CDMA radio-access approach is particularly suitable to realize seamless SH in the Integrated Satellite-Terrestrial Network Scenario.

CDMA Bandwidth efficiency is the main driving force in the use of CDMA since frequency re-use planning is not required. All available frequencies can be re-used in every single spotbeam. CDMA makes use of the Pseudo-Noise (PN) code concept in order to distinguish between different channels. It transmits modulated data onto wideband carriers that are distinguishable from each other by different PN sequences. Receivers retrieve their intended data by searching for their PN sequence. In order to avoid interference, the traffic carriers must be spread with synchronized and orthogonal PN sequences. Although synchronous-CDMA (S-CDMA) proves to be the most efficient to eliminate interference arising from other users sharing the same carrier and the same spot-beam, interference from other spot-beams which overlap the coverage of the intended spot is still considerable. The synchronization process to ensure orthogonality between all links requires signaling to adjust the transmission in both the time and frequency domains for every user independently. If dual satellite (or satellite - terrestrial base station) diversity is deployed, the timing advance will be addressed to only one satellite. Half of the users sharing the same frequency band will statistically be synchronized to this one particular satellite while generating intrinsic noise to the other. The system capacity is subsequently reduced. If orthogonality between PN sequences is not required, i.e. asynchronous CDMA, synchronization is not necessary. Under this situation, the number of available PN sequences will increase tremendously. However, this implies that interference levels generated by co-channel users cannot be suppressed as efficiently which may reduce the system capacity. However, since the number of PN sequences is increased, such a

reduction in system capacity may still be well within the resource utilization efficiency of that offered by S-CDMA. In the case of multi-satellite diversity, longer codes may be required in order to discriminate between different links and consequently, synchronization among different satellites will be more complex. Another problem in the future integrated terrestrial-satellite S-CDMA systems could be the short length of the used PN-sequences, optimized for terrestrial usage, where the radiiuses of the used cells are in order of several kilometers. The use of the same codes for the satellite segment will raise problems due to the ambiguity of their autocorrelation functions.

Bistatic radars and Multistatic Radar Networks (MRN) are subject to problems and special requirements that are either not encountered or encountered in less serious form by monostatic radars [2]. In general, the implementation of a MRN is more easily accomplished when the positions of all transmitting and receiving elements are fixed with respect to each other, for example when located on the ground. Because of the Line Of Sight (LOS) restrictions, they are often designed for operation on high altitude platforms such as satellites and airplanes. In these cases problems with PN code generation, synchronization and isolation appear when Continuous Wave - Phase Modulation (CW-PM) mode of operation is used. On the other hand CW-PM gives the opportunity for coherent signal processing, precise distance and 3-D coordinates measurements, as well as targets resolution by means of their Doppler spectra.

A retrospective review of a new approach, named Space Correlated Unique -Pseudo - Noise (SC U-PN) codes, is given in this report. It is particularly useful as spread spectrum radio access technology in the mobile broadband communication and radar systems with integrated terrestrial - satellite positioning. The principles of U-PN codes generation, as well as the basic methods of their acquisition and tracking are given too. Proposals of realistic SC-CDMA mobile communications and SC-MRN radar systems, based on the well developed GPS navigation, are shown in the end of the report.

The proposed theory was published in several Conferences as scientific reports, some of them in Bulgarian language [3,4,5,6].

2. SC – CDMA approach

2.1. SC-CDMA basic

The proposed SC-CDMA principle [3] uses several space distributed sources of radio-signals, positioned at points O_1 and O_2 (in the case of only two sources) as it is shown in fig.1. The

signals are phase modulated by appropriate PN-codes $C_1(t)$ and $C_2(t)$. The Mobile Stations (MS) receive these signals by means of the well known CDMA technology. For this purpose the same PN-codes are generated and synchronized in the MS receiver. The $sum(mod2)$ of these codes creates a new code, which we named U (Unique)-PN code. This code is used for spreading the information, transmitted by the MS. Similar approaches are used for generation of the Base Station (BS) U-PN codes, named A and B, as follows:

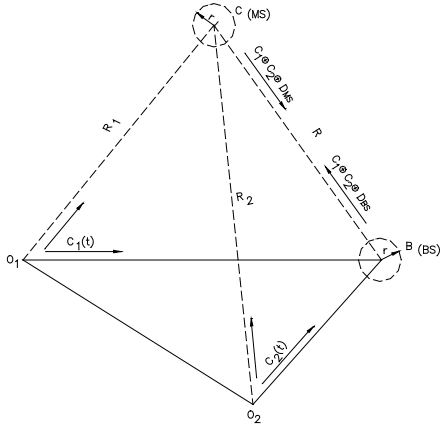


Fig.1 The basic SC-CDMA geometry

2.2.Variant SC-CDMA-A

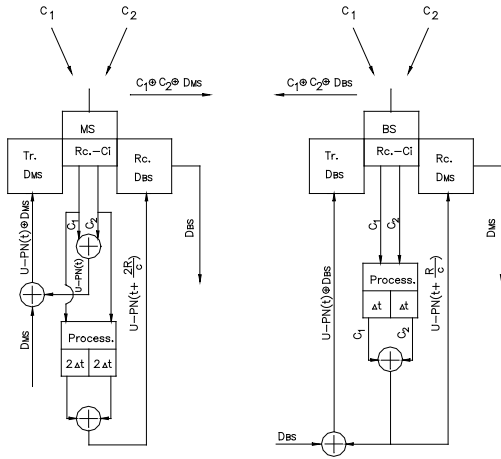


Fig.2 The basic SC-CDMA-A architecture

The block schemes of the MS and BS, using SC-CDMA-A approach, are shown in fig.2. In this particular case the recovered in MS codes $C_1(t)$ and $C_2(t)$ are used as follows:

- In MS after $sum(mod2)$ for U-PN(t) code generation, spreading the transmitted information from MS to BS by means of DS-SSS method;
- In MS for despreading (correlation) of the transmitted from BS to MS information, delayed U-PN(t+2R/C), where R is the distance between the MS and BS, and C is the speed of the light;
- In BS for despreading (correlation) of the transmitted from MS to BS information, delayed U-PN(t+R/C);
- In BS for spreading the information transmitted from BS to MS, delayed U-PN(t+R/C).

The information signal at Base Band (BB) from MS to BS will be:

$$S_{MSout}(t) = C_1(\Omega_C \cdot t + \frac{2\pi}{\lambda_C} \cdot R_1) \oplus C_2(\Omega_C \cdot t + \frac{2\pi}{\lambda_C} \cdot R_2) \oplus D_{MS}(t) \quad (1)$$

The BB signal, received by BS, will be additionally phase shifted as follows:

$$S_{BSin}(t) = C_1[\Omega_C \cdot t + \frac{2\pi}{\lambda_C} \cdot (R_1 + R)] \oplus C_2[\Omega_C \cdot t + \frac{2\pi}{\lambda_C} \cdot (R_2 + R)] \oplus D_{MS}(t) \quad (2)$$

The BB signal from BS to MS will be:

$$S_{BSout}(t) = C_1[\Omega_C \cdot t + \frac{2\pi}{\lambda_C} \cdot (R_1 + R)] \oplus C_2[\Omega_C \cdot t + \frac{2\pi}{\lambda_C} \cdot (R_2 + R)] \oplus D_{BS}(t) \quad (3)$$

Where $D_{BS}(t)$ is the information signal at BB, transmitted from BS to MS. The BB signal, received by MS, will be additionally phase shifted as follows:

$$S_{MSin}(t) = C_1[\Omega_C \cdot t + \frac{2\pi}{\lambda_C} \cdot (R_1 + 2R)] \oplus C_2[\Omega_C \cdot t + \frac{2\pi}{\lambda_C} \cdot (R_2 + 2R)] \oplus D_{BS}(t) \quad (4)$$

2.3.Variant SC-CDMA-B

The block schemes of the MS and BS, using SC-CDMA-B approach, are shown in fig.3. In this particular case the recovered in MS codes $C_1(t)$ and $C_2(t)$ are used as follows:

- In MS after $sum(mod2)$ for U-PN(t) code generation, spreading the transmitted information from MS to BS by means of DS-SSS method (the same as in SC-CDMA-A case);
- In MS for despreading (correlation) of the transmitted from BS to MS information, without delay U-PN(t);
- In BS for despreading (correlation) of the transmitted from MS to BS information, delayed U-PN(t+R/C) (the same as in SC-CDMA-A case) ;
- In BS for spreading the information transmitted from BS to MS, forwarded U-PN(t-R/C).

The BB signals from MS to BS will be described with eq. (1) and (2). The BB signal transmitted from BS to MS and the received by MS signals will be:

$$S_{BSout}(t) = C_1[\Omega_C \cdot t + \frac{2\pi}{\lambda_C} \cdot (R_1 - R)] \oplus C_2[\Omega_C \cdot t + \frac{2\pi}{\lambda_C} \cdot (R_2 - R)] \oplus D_{BS}(t) \quad (5)$$

$$S_{MSin}(t) = C_1(\Omega_C \cdot t + \frac{2\pi}{\lambda_C} \cdot R_1) \oplus C_2(\Omega_C \cdot t + \frac{2\pi}{\lambda_C} \cdot R_2) \oplus D_{BS}(t) \quad (6)$$

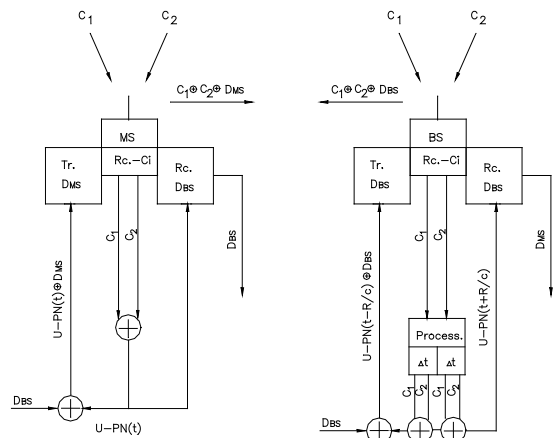


Fig.3 The basic SC-CDMA-B architecture

2.4.EMI SC-CDMA A&B system

Proposal of a realistic SC-CDMA system, based on the existing navigation GPS system, is given in [4]. It was named EMI A&B (Enhanced Mobile Information, variants A & B).

The architecture of EMI - A system is shown in fig.4.

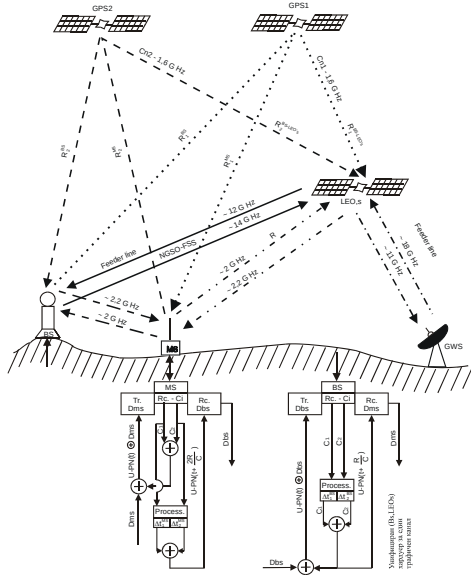


Fig. 4 The basic EMI SC-CDMA-A architecture

The system consists of satellite and earth segments, as follows:

- Earth segment, including subscriber mobile terminals (MS), terrestrial base stations (BS), as well as earth Gate Way Stations (GWS);
- Satellite segment, including Low Earth Orbit satellite base stations (LEO,s) and satellite based sources of PN signals (GPS).

The possible frequency allocations for the different parts of the system are shown in fig. 4, as follows:

- 2 GHz – terminal up-link SC-CDMA;
- 2,2 GHz – terminal down-link SC-CDMA;
- 1,6 GHz – GPS signals, used as satellite based sources of PN signals;
- 12 GHz down-link, 14 GHz up-link of Non Geostationary Orbit – Fixed Satellite Service (N-GSO-FSS) technology for the feeder lines of isolated BS without access to terrestrial telecommunication infrastructure;
- 18 GHz up-link, 11 GHz down-link, NGSO-MSS technology for the LEO,s feeder lines.

The distances among different elements of EMI A&B are important and in fig. 4 they are as follows:

- R – distance between MS and BS;
- $R_{i\ bs}$ – distance between BS and the i -th GPS satellite;
- $R_{i\ bs\ leo,s}$ – distance between a LEO,s and the i -th GPS satellite;
- $R_{i\ ms}$ – distance between MS and i -th GPS satellite.

The most important element of the proposed system is the subscriber radio interface, using SC-CDMA method of access. Similar to the above described theory, we can use the both variants A and B. Obviously, from CDMA technology point of view, variant A is superior and we will focus on it. The time delays, introduced by the system processors, are Δt_{ms} in MS and Δt_{bs} in BS.

The calculations of the time delays, introduced by the system processors in order to ensure the space correlation of the used U-PN codes and the despreading codes, need equalization, as follows in the equation (7):

$$\Delta t_{ibs} + \frac{R_{ibs}}{C} = \frac{R_{ims} + R}{C} \quad (7)$$

and:

$$\Delta t_{ibs} = \frac{R_{ims} + R - R_{ibs}}{C} \quad (8)$$

By means of (8) it is possible to calculate the time delay of the despreading U-PN code in MS:

$$\Delta t_{ms} = \frac{2R}{C} \quad (9)$$

The code acquisition procedure in a SC-CDMA system EMI A&B will be the follows:

- By means of a classical radio interface BS broadcasts information about its space coordinates X_{bs} , Y_{bs} , Z_{bs} in Earth Centered - Earth Fixed (ECEF) coordinate system, used by GPS system.
- By means of a classical radio interface MS broadcasts information about its space coordinates X_{ms} , Y_{ms} , Z_{ms} in ECEF coordinate system;
- The MS processor calculates the distance R as follows:

$$R = \text{SQR}[(X_{BS} - X_{MS})^2 + (Y_{BS} - Y_{MS})^2 + (Z_{BS} - Z_{MS})^2] \quad (10)$$

After that computes Δt_{ms} with equation (9);

- The BS processor computes the distances $R_{i\ bs}$ and $R_{i\ ms}$ in classical way, typical for GPS algorithms, calculates the distance R with (10) and $\Delta t_{i\ bs}$ with (8).
- The calculated Δt_{ms} and $\Delta t_{i\ bs}$ are base only for the acquisition of the U-PN codes. The code tracking could be done by means of a modified “early-late” CDMA method.

The precise determination of the shape of a SC-CDMA autocorrelation cell is a complicate goal, which should be solved in the future. An approximation could be done, based on the assumption that the position in the space of the MS can be determined by the crossing of three spheres with centers GPS1, GPS2 and LEO,s, with corresponding radiuses $R_{1\ ms}$, $R_{2\ ms}$ and R . The wall thickness of each sphere is determined by the width of the used PN code autocorrelation function $2 \cdot tc$, where tc is the chirp time duration of the code and C is the speed of the light. The change of the “wall density” $R(t)$ of each sphere can be calculated, as follows:

$$R(t) = A^2 \left(1 - \frac{t}{t_c}\right) \quad \text{for} \quad t \leq t_c \quad (11)$$

$$R(t) = 0 \quad \text{for} \quad t \geq t_c$$

The mutual crossing of the spheres with finite wall thickness will form a cell with center located at MS and $r = tc \cdot C$. In order to avoid interference among several MS, in this cell only one MS should be positioned. It means that the minimum distance among MS should be greater than $R_{min} = 2 \cdot tc \cdot C$

The GPS system uses two PN codes. First of them is the coarse-acquisition (C-A) code with speed 1,023 MCh/s. The second is the precise (P) code with speed of 10,23 MCh/s. When they will be used for generation of U-PN codes, the autocorrelation cell radiuses will be 293 and 29,3 meters.

In principle in a static SC-CDMA system the generated U-PN codes will repeat in the time due to the repetition character of the primary PN codes. When several LEO or MEO satellites (as it is in GPS) are used as primary PN code sources, their phases will change

fast due to their relative fast speeds (in order of several kilometers per second). The result will be generating of pure noise like U-PN codes with very good and unambiguity auto and crosscorrelation functions.

3. SC-MRN approach

The possible implementations of SC-CDMA approach in a bistatic radar geometry is shown in fig.5. BPSK modulated by PN-codes radio-signals are transmitted from the points O_1 and O_2 (both of them with known coordinates in a 2D coordinate system). These signals are received in the transmitter site and in the receiver site of a bistatic radar system, where the used PN-sequences $C_1(t)$ and $C_2(t)$ are recovered with their phases and used as follows:

- **Transmitter site:**

$C_1(t)$ and $C_2(t)$ are *sum (mod2)* and the resulting U-PN code is used for BPSK modulation of the transmitted radio-signals. The phases of the received PN-codes are determined by the transmitter position. These coordinates are sent to the receiver with appropriate radio-communication link.

$$U - PN_{transmitter}(t) = C_1(\Omega_C t + \frac{2\pi}{\lambda_C} R_1) \oplus C_2(\Omega_C t + \frac{2\pi}{\lambda_C} R_2) \quad (12)$$

Where λ_C is the wavelength and Ω_C is the angle frequency of the used PN-code.

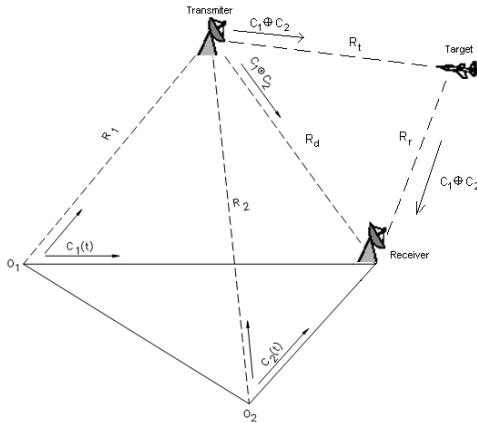


Fig. 5 The basic SC-MRN geometry

- **Receiver site:**

The phases of the received PN-codes are determined by the receiver position in the same 2D-coordinate system. Receiver processor computes the distances R_1, R_2, R_d in order to recovery the transmitted U-PN code in the receiver with phase, given with eq.13. The recovered U-PN code is used for acquisition and tracking of the synchronization link and with introducing the suitable time delay – for measuring the distance $R_t + R_r$ by means of eq.14 and the famous triangle method (using at least three receiver sites [2]).

$$U - PN_{synchronization}^{receiver}(t) = C_1[\Omega_C t + \frac{2\pi}{\lambda_C} (R_1 + R_d)] \oplus C_2[\Omega_C t + \frac{2\pi}{\lambda_C} (R_2 + R_d)] \quad (13)$$

$$U - PN_{target-reflected}^{receiver}(t) = C_1[\Omega_C t + \frac{2\pi}{\lambda_C} (R_1 + R_t + R_r)] \oplus C_2[\Omega_C t + \frac{2\pi}{\lambda_C} (R_2 + R_t + R_r)] \quad (14)$$

An attractive application of the SC-CDMA technology is the use of the satellites of the global positioning system GPS as sources of the PN-modulated signals. In this particular case the U-PN code is *sum (mod2)* of the recovered in the transmitter site GPS receiver

C/A codes of the visible satellites. Because of the very fast relative satellite motion the created in this case U-PN code changes very fast – it looks like a pure random signal. U-PN code acquisition is based on the exchanged between transmitter site and receiver site information about their positions in ECEF geographic coordinate system, used by GPS.

4. Conclusions

A new approach for pseudo-noise code generation and synchronization is proposed in this paper. It is suitable as spread spectrum radio access technology in the mobile broadband communication and radar systems with integrated terrestrial - satellite positioning. The basic Space Correlated system architectures, as well as mathematical description of the proposed method for U-PN code generation and synchronization, are explained. Proposals for real systems, using satellites of the global positioning system GPS as sources of the pseudo-noise signals, are given too.

The implementation of the proposed new Space Correlated – Code Division Multiple Access and Space Correlated – Multistatic Radar Network approach for U-PN code generation and synchronization will give new chance of the future sophisticated mobile communication and radar systems.

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ANALYZING STUDENT DATA WITH DATA MINING METHODS AND TECHNIQUES

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Abstract: Educational Data Mining is a new stream in the Data Mining research field. Analysing data generated within educational institutions, incl. universities, schools, state agencies, NGOs and other organizations concerned with education, can provide valuable information and knowledge to support decision making. The implementation of data mining methods and techniques for analysing student data at universities is a very new approach that is successfully used at leading higher educational institutions worldwide. The extracted knowledge from the available data, in the form of interesting patterns, rules and models, is then used for being proactive, i.e. for taking adequate actions to solve eventual problems before they actually happen. The main purpose of this paper is to provide an overview of the possibilities for using popular data mining methods and techniques to analyse student data in order to support the decision making for various stakeholders, including lecturers, managers, administrative staff, and students.

Keywords: EDUCATIONAL DATA MINING, STUDENT DATA ANALYSIS

1. Introduction

All organizations are working nowadays in a very dynamic and strongly competitive environment. That is valid not only for companies operating in various business sectors, but also for schools and universities, hospitals, non-governmental institutions, etc. In order to survive and remain competitive, organizations need to take timely, adequate and informed decisions that are based not only on intuition and past experience. The globalization processes and the rapid development of Information and Communication Technologies have led to the generation and collection of large volumes of data resulting from the fulfillment of business transactions. However, the availability of data itself does not provide advantages for organizations, unless that data is processed with specialized analytical tools and transformed into valuable information and knowledge to support decision making.

Data Mining is a term that refers to the process of knowledge discovery from databases. Data Mining analytical tools are powerful instruments for extracting existing patterns and models from available data, and using the new knowledge for gaining competitive advantages.

The Educational Data Mining field has been defined and started to develop as a separate research stream during the last decade. It refers to using data mining methods and techniques for extracting valuable knowledge from data generated in the educational sector, in schools, universities, colleges, etc.

Two review papers are providing an overview of the Educational Data Mining research at the beginning of its official promotion. The first paper is published in 2007 (Romero & Ventura, 2007) in the journal of Expert Systems with Applications and summarizes the topics, methods and achieved results during the periods 1995-2005. The second one is published in 2009 (Baker & Yacef, 2009) in the Journal of Educational Data Mining and reveals the efforts in the field during the period 2005-2009. Several new papers have also been published lately to review the performed research in the Educational Data Mining field. Some of them are presented to the social and behavioral sciences community (Mohamad & Tasir, 2013), and others – to the data science and information engineering community (Al-Razgan et al., 2014).

Higher education institutions collect unique data about their students, including data about the student pre-university characteristics and university performance. Important pre-university features are for example the type of school where the student has received the secondary education and especially the profile (e.g. economics, sciences, languages, arts, sports, etc.), the region where the student has finished the secondary education (sometimes there is a substantial difference between the quality of education provided at schools in main cities and in small villages), demographic characteristics (gender, age, ethnicity), final secondary education

score, results shown at the university entrance exams, etc. The university performance characteristics include grades received in different courses, test results, selected educational paths, etc. These types of data are collected in all types of educational models - the traditional classroom form of education, the distance education and the online education. However, additional data is collected in electronic education and that is the data available in the e-learning system log files.

A general overview of the educational data mining process is presented on Fig.1. The main participants in the educational processes at higher education institutions are the students and lecturers, and the university management and administration staff.

Students provide data that is stored in various databases, including data collected during admission campaigns, data resulting from the student university performance and data coming from student interaction with e-learning systems. Students also interact with the University information systems, extracting information about the schedule, test and exam scores, for selecting and registering to various courses, etc. They can use e-learning systems as well, if such opportunities are available in the institution. Lecturers are using student data and university information systems mainly for registering students in their courses, entering student exam scores, providing learning materials for e-learning systems. The university management and administration staff are responsible for the collection and maintenance of the data in the various data repositories, and for the proper operation and the authorized access of different users.

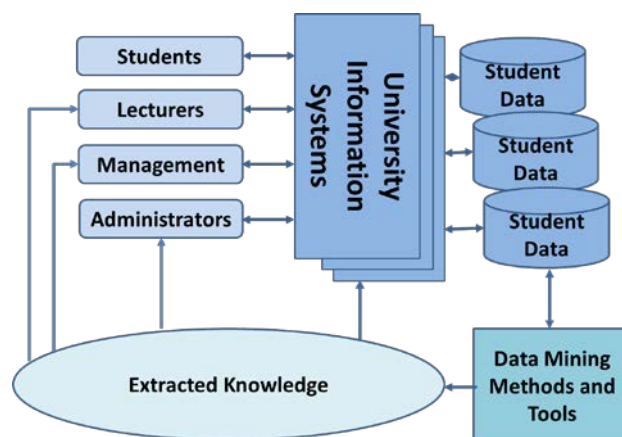


Fig. 1 Educational Data Mining

Unfortunately, most of the data that is available in universities is not extensively used for analysis. Usually only the overall registration and performance of students in different courses, or specialties, or faculties, are calculated and discussed, but that information is very limited and could not support timely and

effective decision making. The implementation of advanced analytical tools, like the methods and techniques for data mining, could contribute substantially to the thorough analysis and extraction of new knowledge from the available data. That knowledge could be used by the university management and administration for improving the organization and implementation of the educational processes, and by the lecturers and students for improving the quality of education.

2. Application of Data Mining Methods and Tools in the Educational Sector

The overview of the published research, concerning the application of data mining methods and techniques in the educational sector, reveals that the problems which are most effectively supported by data mining analyses include university marketing and student retention, analyzing and improving student performance, using different teaching approaches and learning paths depending on the individual student peculiarities, optimizing the organization of the educational processes (e.g. predicting student registration in programmes and courses, optimizing lecturers' loads, optimized use of classrooms and computer resources, etc.), managing research funds and alumni management.

Universities are operating nowadays in a very competitive environment. The problems come, on one hand, from the decreasing number of potential candidates, which is resulting from the negative demographic tendencies available in many of the European countries, including Bulgaria. On the other hand, the variety of opportunities for studying abroad is constantly increasing. Young people often choose to study at prestigious universities all over the world, e.g. in the UK, Germany, the Netherlands, the USA, instead of finishing higher education at their own countries. Moreover, the opportunities for studying abroad are constantly increasing – universities are providing scholarships and preferable conditions, countries are offering student loans and support, etc.

Because of the strong competition, universities have to make additional efforts to attract students and to organize extensive marketing campaigns among potential candidates. However, in order to optimize the costs and to increase the effectiveness, they have to reach the most appropriate students or exactly those who will eventually apply for the university. Data mining methods and techniques could provide very useful information for those purposes, by identifying the most important characteristic features and depicting the profile of the students that most often study at the university.

A serious problem for universities in recent years is student retention. The number of students who cannot finish their education for various reasons constantly increases. The university management is often strongly concerned and therefore needs to analyze the available data to establish the reasons and identify adequate actions.

Predicting student performance has been of interest for various researchers. Vandamme et al. use decision trees, neural networks and linear discriminant analysis for the early identification of low, medium and high risk students (Vandamme, Meskens & Superby, 2007). The implementation of predictive modeling for maximizing student recruitment and retention is presented in the studies of DeLong (DeLong, Radclie & Gorny, 2007) and Noel-Levitz (Noel-Levitz, 2008). Cortez and Silva attempt to predict student failure by applying and comparing four data mining algorithms - Decision Tree, Random Forest, Neural Network and Support Vector Machine (Cortez & Silva, 2008). Dekker et al. deal with predicting students drop out (Dekker, Pechenizkiy & Vleeshouwers, 2009). The development of enrollment prediction models based on student admissions data by applying different data mining methods is the research focus of Nandeshwar (Nandeshwar & Chaudhari, 2009). Kovačić (Kovačić, 2010) uses data mining techniques (feature

selection and classification trees) to explore the socio-demographic variables (age, gender, ethnicity, education, work status, and disability) and study environment (course programme and course block) that may influence persistence or dropout of students, identifying the most important factors for student success and developing a profile of the typical successful and unsuccessful students. Ramaswami et al. focus on developing predictive data mining model to identify the slow learners and study the influence of the dominant factors on their academic performance, using the popular CHAID decision tree algorithm (Ramaswami & Bhaskaran, 2010). Yu et al. explore student retention by using classification trees, multivariate adaptive regression splines (MARS), and neural networks (Yu, DiGangi, Jannasch-Pennell & Kaprolet, 2010).

The analysis from the performed review shows that various data mining methods for classification are most often used for predicting student performance and for finding the factors that influence strongly student retention. Decision tree algorithms and neural networks are the techniques of interest for many of the researchers. However, association analysis and clustering are also data mining techniques that are used to solve problems in the educational field.

Association analysis is for example successfully applied for supporting the developers of electronic course content - for optimizing the organization and usage of available resources, for finding common mistakes that many students make, for giving personalized assignments with different difficulty level, etc. (Saini, Sona, Veeramachaneni & Ronchetti, 2005). The association rules approach is also used for finding interesting relations between the characteristic features of students (Minaei-bidgoli, Tan & Punch, 2004), and for suggesting suitable activities and resources in the learning process (Zaiane, 2002). That kind of information could be very useful to lecturers and could contribute to increasing the quality of provided education.

Knowledge, extracted by applying clustering techniques, could be very useful for grouping students with similar characteristics and using different models for effectively delivering learning content to learners with differing learning needs (Zakrzewska, 2008). Kumari et al. also use clustering approach, and the K-means clustering algorithm in particular, to group students according to the achieved grade values (i.e., Excellent, Good, Average and Poor or Fail) and to find the best cluster centers for attributes like attendance, sessional marks, assignment marks, etc. (Kumari, Nabi & Priyanka, 2014).

The improvement of educational processes and the increasing of institutional effectiveness and efficiency by applying suitable data mining techniques are problems that have been discussed starting more than 10 years ago (Luan, 2004). In 2008 researchers provide also guidelines for using data mining to support the decision making processes at higher education institutions (Delavari, Phon-Amnuaisuk & Beikzadeh, 2008).

3. The Data Mining Process

The review of research activities focused on applying data mining methods and techniques for analyzing student data, provided above, shows that many leading universities have started to initiate and implement data mining projects in order to thoroughly analyze their data and transform it into valuable information and knowledge to support decision making.

The approach that is recently most successfully used for implementing data mining project in various industry sectors, including the educational field, and for organizations of all size, is the so called CRISP-DM model (Cross-Industry Standard Process for Data Mining), which is considered a standard approach for data mining process realization. It is a cyclic approach, including six main phases – Business understanding, Data understanding, Data preparation, Modeling, Evaluation and Deployment, and a number of internal feedback loops between the phases, resulting from the

very complex non-linear nature of the data mining process and ensuring the achievement of consistent and reliable results. The main project phases and activities, to be accomplished during the implementation of a data mining project, based on the CRISP-DM model, are presented on Fig.2.

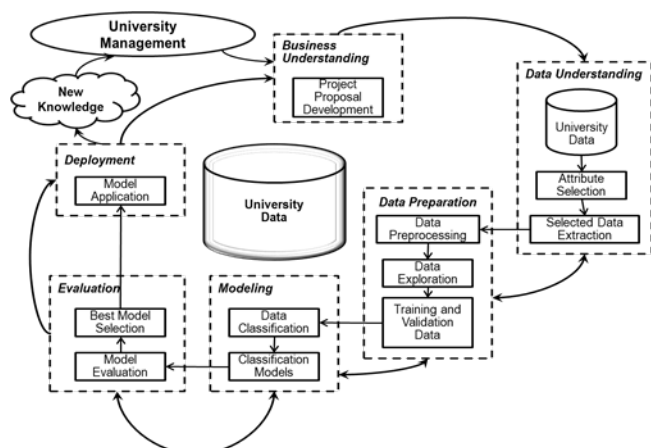


Fig. 2 University Data Mining Research Project Implementation

During the first stage (Business Understanding), the application processes for student enrollment at higher education institutions have to be carefully examined, including the formal procedures and application documents, and the most important problems for the university management should be defined. In the second stage (Data Understanding), the types of data collected from the university applicants and the enrolled students, and that is stored in the university databases in electronic format, should be identified. At this phase, discussions with university management and representatives of the administrative staff, who are well informed and responsible for the university data collection, storage and maintenance, could be very helpful for the successful project implementation.

In the third stage (Data Preparation) it is necessary to decide what data to use for the realization of the defined data mining research tasks. Very often, the available data is stored in various systems and in different formats, and therefore the selected data should be integrated before further processing. The data integration requires also data cleaning, aggregation and transformation, which are also performed in the data preprocessing phase of the project implementation. The next steps include exploring data by using various statistics and visualization techniques.

During the fourth stage (Modelling), the selected data mining techniques are applied. An example for the realization of the classification data mining tasks is shown on Fig.2. The defined business problem, predicting student performance (Successful/Failed) based on their personal, pre-university and university characteristic features, in data mining terms is considered a classification problem. However, in the general case, association analysis and clustering are other data mining tasks that could be implemented. The next step is to select the algorithms that should be used for realizing the defined data mining tasks. For example, the classification task could be carried out by applying different methods (e.g. decision tree, neural networks, K-nearest neighbor approach, rule learners, etc.) and various algorithms (e.g. the decision tree method could be applied by using CART or C4.5 algorithms). Clustering could be realized by using partitioning algorithms (e.g. K-means, K-medoids), hierarchical algorithms, or a combination of both types.

The extracted knowledge, e.g. in the form of classification models, association rules or established clusters, is then evaluated (in the fifth stage – Evaluation) and used (in the sixth stage – Deployment) for solving the initially defined business questions (the important problems identified by the university management).

The data mining project implementation process is cyclic and iterative. The outcomes of each phase could lead to the necessity of going back to previous stages in order to improve the results that are input to next phases. The solving of the defined business problems during the project implementation could also lead to the identification and definition of new problems that could be solve by using data mining methods and techniques.

Conclusions

Universities today are operating in a very complex and highly competitive environment. They are collecting and keeping large volumes of data, referring to their students, the organization and management of the educational process, and other managerial issues. However, managerial decisions are rarely taken based on the information and knowledge that could be extracted from the analysis of the available data. In order to achieve this, they should be introducing innovative management approaches supported by progressive methods and techniques.

Modern universities should focus more on the profile of admitted students, get aware of the different types and specific student characteristics based on the received data and take a decision if they have all the data needed to analyze the students at the entry point of the university or they need other data to help the managers support their decisions in how to organize the marketing campaign and approach promising potential students.

The implementation of data mining methods and techniques for analyzing student data at universities is a very new approach that is successfully used at leading higher educational institutions worldwide. The extracted knowledge from the available data, in the form of interesting patterns, rules and models, is then used for being proactive, i.e. for taking adequate actions to solve eventual problems before they actually happen.

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КОМПЮТЪРНА АНИМАЦИЯ НА ХАРМОНИЧНО ДВИЖЕНИЕ

COMPUTER ANIMATION OF HARMONIC MOVEMENT

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Abstract: In the article is described the creation of animation in Adobe After Effects. The computer animation is considered as a way of modeling and demonstration of various processes. For the realization of the animation are used expressions of Java Script.

Keywords: COMPUTER ANIMATION, EXPRESSIONS, JAVA SCRIPTS, ADOBE AFTER EFFECTS

1. Увод

Компютърната анимация е вид анимация за която се използва компютър, производна от компютърната графика, намираща приложение в развлекателния бизнес, киното, компютърните игри, научните и деловите сфери.

Анимирането на обекти в компютърната анимация се реализира чрез:

Анимация с ключови кадри

Вид близък до традиционната рисувателна анимация, при която се използва компютър. За генериране на междинни кадри се използва специална компютърна програма. Движението се осъществява чрез математически изчисления за запълване на промените в междинните кадри, между два ключови кадър. [1]

Запис на движения

За получаване на данните се използва специално оборудване с реално движещи се обекти, пренася се тяхната имитация върху компютър. Реализира се, чрез Motion Capture. Актьорите са със специални костюми с датчици за движение, използват се камери за запис, обработват се със специализирани програми.

Процедурна анимация

Вид анимация при която движещото се изображение, се генерира автоматично в режим на реално време, зададени са предварително определени закони, правила и ограничения. [2].

С процедурната анимация се реализира:

- Симулация на физическо взаимодействие на твърди тела.
- Имитация на движение на частици, газове и др.
- Имитация на взаимодействие на меко тяло.
- Симулиране на независимо движение на герой.

Програмируема анимация

Езиците за програмиране на движение на анимирани обекти са:

- Java-Script
- Action Script

Предимство на програмируемата анимация е намаления размер на изходния файл. Недостатък - натоварването на процесора.

2. Приложен софтуер и математически зависимости

С Adobe After Effects се създават проекти, композиции, слоеве, маски и добавяне на различни ефекти. Програмата предоставя възможност да бъде използвана, като средство за

реализиране на добри идеи в реалност, създавайки анимации, доближаващи се до действителността. При скриптовете се генерира код, състоящ се от набор от инструкции, автоматизиращ процеса по време на изпълнение.

В езикът Java Script всеки елемент е обект. Всеки обект се характеризира със собствени атрибути и значения на параметрите, които ги отличават от другите обекти. Автоматизирането на задачи, които се повтарят многократно се реализира с Java Script.[4,5]

В Adobe After Effects редакторът за скриптове е ExtendScript Toolkit. Expressions – изрази, които са малки програми на JavaScript подпомагащи създаването на анимации. Езикът поддържа всички оператори и функции необходими за тяхното създаване. Expressions са всички инструкции написани за свойството на слоя, с цел да се постигне определено значение на това свойство. Изразите осъществяват динамичната връзка между различните свойства на слоя. Те подпомагат автоматизирането на процеса по създаване на десетки или стотици ключови кадри на ръка. [6,7]

Използването на expressions е с цел намаляване на времето по създаване на сложни взаимодействия между ефектите на слоевете, като се създава връзка между техните свойства, за реализация на сложни действия с прости методи. [3]

Математически зависимости

Математическите зависимости намират приложение в Adobe After Effects. Те позволяват да се използват формули за различните параметри на дадените слоеве, което дава възможност да се създаде процесуална анимация, без използване на ключови кадри. Мощта при използването на математически зависимости е създаването на програмен код, написан от студенти или програмисти. Използването на математически зависимости позволява задаването на по-реалистичен вид на даденото действие.

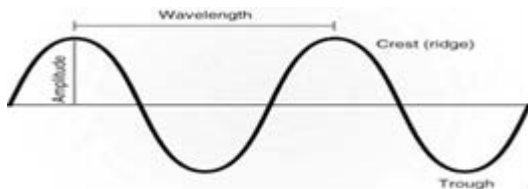
3. Решение на научния проблем

Хармонично движение

Всички вълнообразни движения, включително и хармоничните, се характеризират с две основни характеристики:

- дължина на вълната
- амплитуда

Проста хармонична вълна се нарича вълна, в която всяка част от средата извършва незатихващо хармонично трептене. На фиг. 1 е илюстрирана проста хармонична вълна. С дължината на вълната се описва пространствената периодичност на вълновия процес. Амплитуда на вълната е мярка за максималната стойност на отклонението от равновесното положение на трептяща частица за един период.

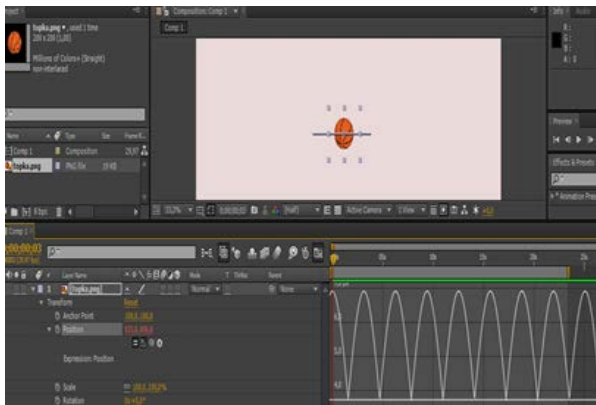


Фиг. 1 Хармонична вълна

4. Резултати

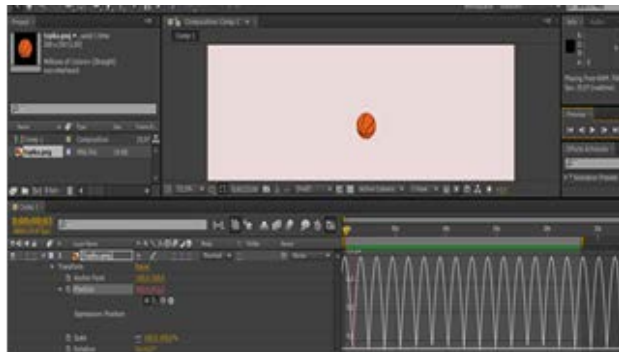
За реализация на вълната са използвани тригонометричните функции $\sin(x)$ и $\cos(x)$. Особеност на затихващото колебание е, че при промяна на амплитудата се създава реалистично движение на анимацията, показани на фиг.2 и фиг.3.

```
x=Math.sin(time)*180
rest=position;
add(rest, [x,0]);
```



Фиг. 2 Реализация на вълна с функцията $\sin(x)$

```
x=Math.cos(time)*180
rest=position;
add(rest, [x,0]);
```

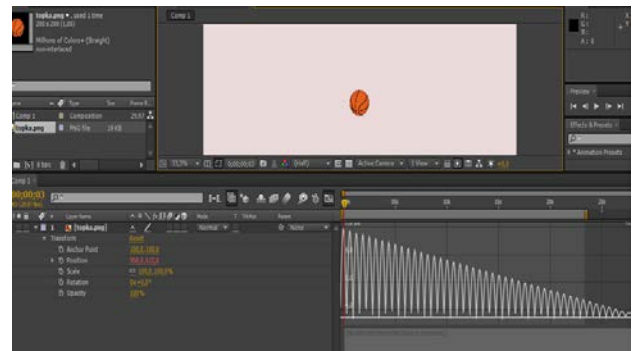


Фиг. 3 Реализация на вълна с функцията $\cos(x)$

Ускоряният процес на затихване се реализира със следния фрагмент:

```
frequency=3;
amplitude=linear(time, 0, out_point-1, 90, 0);
rest=position;
x=Math.sin(time*frequency)*amplitude;
add(rest, [x,0]);
```

На фиг.4 е показана реализация на вълна с намалена амплитуда.

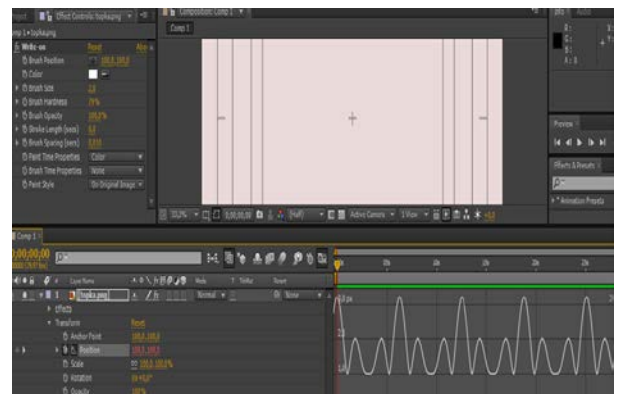


Фиг. 4 Реализация на вълна с намалена амплитуда

Сложни колебания могат да бъдат реализирани чрез:

- събиране на колебание;
- умножение на колебание;

Събиране на колебание е показано на фиг. 5

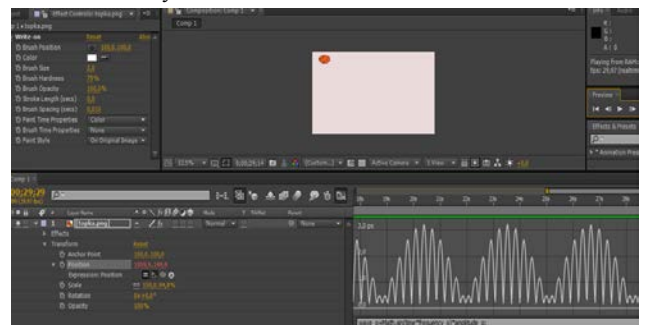


Фиг. 5 Реализация на вълна - събиране на колебание

```
frequency_o=2;
amplitude_o=10;
frequency_t=1;
amplitude_t=20;
wave_o=Math.sin(time*frequency_o)*amplitude_o;
wave_t=Math.sin(time*frequency_t)*amplitude_t;
y=wave_o+wave_t;
x=time*12;
add(effect('Write-on').param(1), [x, y]);
```

Умножение на колебание

С увеличаване на броя на трептенията се увеличава сложността на процеса. На фиг. 6 е показан процеса на умножение на високочестотни и нискочестотни трептения с различни амплитуди.



Фиг. 6 Реализация на вълна – умножение на колебание

Програмна реализация:

```
frequency_o=10;  
amplitude_o=5;  
frequency_t=1;  
amplitude_t=10;  
wave_o=Math.sin(time*frequency_o)*amplitude_o;  
wave_t=Math.sin(time*frequency_t)*amplitude_t;  
y=wave_o*wave_t;  
x=time*32;  
add(effect("Write-on").param(1), [x, y]);
```

5. Заключение

Докладът е насочен към студенти или програмисти, в областта на компютърната анимация доближаваща се до реалността. В expressions са използвани основни математически функции за постигане на визуални ефекти и движение на графика. Приложението им в анимацията е с цел постигане на контрол и ефективност, който не може да бъде реализиран с традиционни техники. Предлага се подход, за генериране на автоматично хармонично движение. Методът е приложим в различни образователни програми, компютърни игри и реклами.

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АНАЛИЗ НА ТРАНСПОРТНА ЗАДАЧА. МАТЕМАТИЧЕСКИ МОДЕЛ. МЕТОДИ ЗА РЕШЕНИЕ. КОМПЮТЪРНА РЕАЛИЗАЦИЯ ЧРЕЗ SOLVER ОТ MICROSOFT OFFICE EXCEL

ANALYSIS OF TRANSPORTATION PROBLEM. MATHEMATICAL MODEL. SOLUTION METHODS. COMPUTER REALIZATION BY USING SOLVER FROM MICROSOFT OFFICE EXCEL

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Abstract: In the paper is presented transportation problem, such as task from the field of linear programming. Three methods for solution are showed - distribution method, u-v method and computer realization by using Solver from Microsoft Office Excel. The proposed methods are used for solutions of practical application tasks.

KEYWORDS: TRANSPORTATION PROBLEM, OPTIMAL SOLUTION, DISTRIBUTION METHOD, U-V METHOD, METHOD OF NORTHWEST CORNER, METHOD OF MINIMUM ELEMENT

1. Ввод

Транспортната задача е задача на линейното оптимиране. Транспортният модел намира приложението при решаване на задачи свързани със съставяне на разписания, назначаване на персонала, разпределение на товари и др. Основната задача, която трябва да се реши преди определяне на оптимално решение, е създаването на математически модел и избор на алгоритъм за получаване на резултата. Сложността на създадените математически модели, броя на ограниченията, времето за получаване на решението са част от причините, които налагат използването на софтуер за решаване на задачата. Средството Solver от Microsoft Office Excel може да се използва за решаване на задачи от транспортен тип и за решаване на задачи от други области [1].

В доклада е представено решение на една класическа транспортна задача. Решението е реализирано чрез използване на основни математически методи – метод на потенциалите и разпределителен метод, както и чрез използване на компютърен софтуер. Причините за избор на инструмент от Microsoft Office Excel са породени от популярността на продукта, удобният и лесен за използване интерфейс.

2. Модел на транспортна задача

2.1. Икономически модел на транспортна задача

Дадени са:

1. $A_1, A_2, \dots, A_m$ – производители на однородна продукция
С a_i е означено количеството продукция, което се произвежда от i -тия производител, където $i=1, 2, \dots, m$.
2. $B_1, B_2, \dots, B_n$ – потребители на продукцията произведена от производителите $A_1, A_2, \dots, A_m$
3. b_j е обозначено количеството продукция, която е необходима на j -тия потребител, където $j=1, 2, \dots, n$.
3. C_{ij} – матрица на транспортните разходи, като $i=1, 2, \dots, m$ и $j=1, 2, \dots, n$.

Цел - Разпределяне на наличната продукция, произведена от производителите, между потребителите, съобразно техните потребности така, че общите транспортни разходи да бъдат минимални.

Видове транспортни задачи:

1. Затворен тип – общото произведено количество е равно на общата потребност
(1) $\sum_{i=1}^m a_i = \sum_{j=1}^n b_j$

2. Отворен тип

2.1. общото произведено количество е по-голямо от общата потребност

$$(2) \sum_{i=1}^m a_i > \sum_{j=1}^n b_j$$

2.2 общото потребление е по-голямо от общото производство [5]

$$(3) \sum_{j=1}^n b_j > \sum_{i=1}^m a_i$$

2.2. Математически модел на затворен тип транспортна задача

С X_{ij} е обозначено количеството продукция, която ще се транспортира от i -тия производител към j -тия потребител

$$(4) Z = \sum_{i=1}^m \sum_{j=1}^n C_{ij} X_{ij} \rightarrow \min - \text{целева функция}$$

Ограничения:

$$(5) \sum_{j=1}^n X_{ij} = a_i, \quad i = 1, \dots, m - \text{доставеното количество}$$

да бъде равно на произведеното

$$(6) \sum_{i=1}^m X_{ij} = b_j, \quad j = 1, \dots, n - \text{полученото количество да}$$

бъде равно на необходимото

$$(7) X_{ij} \geq 0, \quad i = 1, \dots, m, \quad j = 1, \dots, n - \text{условие за}$$

неотрицателност на неизвестните величини

$$(8) X_{ij} - \text{цели числа}, \quad i = 1, \dots, m, \quad j = 1, \dots, n - \text{условие}$$

за целочисленост на неизвестните величини

2.3. Математически модел на отворен тип транспортна задача

$$(9) Z = \sum_{i=1}^m \sum_{j=1}^n C_{ij} X_{ij} \rightarrow \min$$

При ограничения за (2)

$$(10) \sum_{j=1}^n X_{ij} \leq a_i, \quad i = 1, \dots, m$$

$$(11) \sum_{i=1}^m X_{ij} = b_j, \quad j = 1, \dots, n$$

$$(12) X_{ij} \geq 0, \quad i = 1, \dots, m, \quad j = 1, \dots, n$$

При ограничения за (3)

$$(13) \sum_{j=1}^n X_{ij} = a_i, \quad i = 1, \dots, m$$

$$(14) \sum_{i=1}^m X_{ij} \leq b_j, \quad j = 1, \dots, n$$

$$(15) X_{ij} \geq 0, \quad i = 1, \dots, m, \quad j = 1, \dots, n [6]$$

Всяка транспортна задача отворен тип може да бъде сведена до транспортна задача затворен тип, чрез въвеждане на фиктивен потребител за (2) с потребност (16) $b_{m+1} = \sum_{i=1}^m a_i - \sum_{j=1}^n b_j$ и нулев транспортен разход (17) $c_{im+1} = 0, i = 1, \dots, m$ и фиктивен производител за (3) с производство (18) $a_{m+1} = \sum_{j=1}^n b_j - \sum_{i=1}^m a_i$ и нулев транспортен разход (19) $c_{m+1,j} = 0, j = 1, \dots, n$.

На Фиг. 1 е показан алгоритъм за решаване на транспортна задача. [2]



Фиг. 1 Блок – схема за решение на транспортна задача.

3. Постановка и решение на задачата. Резултати и дискусия.

Постановка на задачата.

Фирма за производство на мебели притежава три цеха и три склада за готова продукция. Дневното производство на цеховете е: Цех 1 – 200 изделия, Цех 2 – 110 изделия, Цех 3 – 140 изделия. Дневното потребление на складовете е: Склад 1 – 120 изделия, Склад 2 – 180 изделия, Склад 3 – 150 изделия

Транспортните разходи за превоз на едно изделие от конкретния производител до конкретния потребител са дадени в Таблица 1.

Таблица 1. Транспортни разходи в лева.

	Склад 1	Склад 2	Склад 3
Цех 1	3	4	5
Цех 2	4	2	6
Цех 3	7	3	1

Цел: Да се състави план за превозване на изделията от цеховете до складовете при, който се минимизира сумарния транспортен разход.

Етапи на решение на проблема:

1. Определяне на типа на транспортната задача

$$\text{общо производство} - (20) \quad \sum_{i=1}^3 a_i = 450$$

$$\text{общо потребление} - (21) \quad \sum_{j=1}^3 b_j = 450$$

Транспортната задача е затворен тип, защото съществува баланс между двете величини.

2. Създаване на математически модел

$$(22) \quad Z = 3x_{11} + 4x_{12} + 5x_{13} + 4x_{21} + 2x_{22} + 6x_{23} + 7x_{31} + 3x_{32} + x_{33} \rightarrow \min$$

$$\begin{aligned} x_{11} + x_{12} + x_{13} &= 200 \\ x_{21} + x_{22} + x_{23} &= 110 \\ x_{31} + x_{32} + x_{33} &= 140 \\ x_{11} + x_{21} + x_{31} &= 120 \\ x_{12} + x_{22} + x_{32} &= 180 \\ x_{13} + x_{23} + x_{33} &= 150 \\ x_{ij} &\geq 0, \quad i = 1, \dots, m, \quad j = 1, \dots, n \\ x_{ij} &\text{ – цели числа, } \quad i = 1, \dots, m, \quad j = 1, \dots, n \end{aligned}$$

Общият брой на променливите е $m \cdot n$. Броят на ограниченията е $m+n$. С m е обозначено броя на редовете, а с n – броя на колоните [4].

3. Определяне на начално допустимо базисно решение

- 3.1. Метод на северозападния ъгъл

План № 1 е представен на Таблица 2.

Таблица 2. Разпределение на изделията по метод на северозападния ъгъл.

	Склад 1	Склад 2	Склад 3	
Цех 1	120	80	-	200 / 80 / 0
Цех 2	-	100	10	110 / 10 / 0
Цех 3	-	-	140	140 / 0
	120 0	180 100 0	150 140 0	

- 3.2. Метод на минималния елемент - при всяка стъпка се извършва максимално извозване на товара от клетката с минимална тарифа.

Таблица 3. Разпределение на изделията по метод на минималния елемент

	Склад 1	Склад 2	Склад 3	
Цех 1	120 ³	70 ⁴	10 ⁵	200/80 / 10/0
Цех 2	⁴	110 ²	⁶	110 / 0
Цех 3	⁷	³	140 ¹	140 / 0
	120 0	180 70 0	150 10 0	

Във всеки план пълните клетки са базисни променливи и трябва да бъдат $m+n-1$, а празните клетки са свободни променливи.

4. Проверка за оптималност на План № 1 определен по метода на северозападния ъгъл.

- 4.1. Метод на потенциалите – въвеждат се специални променливи наречени потенциални. Съставя се система линейни алгебрични уравнения. Уравненията се формират по формулата (23) $U_i + V_j = C_{ij}$, където U_i и V_j са потенциални, а C_{ij} - транспортни разходи. На един от потенциалите се дава стойност нула, а останалите се определят. За празните клетки се изчисляват индексните оценки (24) $\Delta_{ij} = U_i + V_j - C_{ij}$.

Критерият за оптималност е всички индексни оценки да се отрицателни [2].

Таблица 4. Стойностите на потенциалите за План №1.

	$V_1=3$	$V_2=4$	$V_3=8$
$U_1=0$	120 ³	80 ⁴	⁵
$U_2=-2$	⁴	100 ²	10 ⁶
$U_3=-7$	⁷	³	140 ¹

$$\begin{aligned} U_1 &= 0 \\ U_1 + V_1 &= C_{11} \\ U_1 + V_2 &= C_{12} \\ U_2 + V_1 &= C_{21} \\ U_2 + V_2 &= C_{22} \\ U_3 + V_1 &= C_{31} \\ U_3 + V_2 &= C_{32} \end{aligned} \quad \text{и} \quad \begin{aligned} \Delta_{13} &= U_1 + V_3 - C_{13} = 3 > 0 \\ \Delta_{21} &= U_2 + V_1 - C_{21} = -3 < 0 \\ \Delta_{31} &= U_3 + V_1 - C_{31} = -11 < 0 \\ \Delta_{32} &= U_3 + V_2 - C_{32} = -6 < 0 \end{aligned}$$

Индексната оценка на клетка (1,3) е положителна. Планът не е оптимален и се преминава към етап 5.

- 4.2. Разпределителен метод – образува се цикъл за всяка от празните клетки. Клетките от цикъла се маркират последователно с знаци + и - [5]. Относителната оценка на клетката се определя, като сбора от транспортните разходи на клетките от цикъла маркирани със знак плюс минус сбора от клетките от цикъла маркирани със знак минус. Критерият за оптималност е всички относителни оценки да са положителни.

Таблица 3. Цикъл за всяка от празните клетки

	Склад 1	Склад 2	Склад 3
Цех 1	- 120 ³	80 ⁴	
Цех 2		100 ²	10 ⁶
Цех 3			140 ¹

$$\Delta_{13} = (5 + 2) - (4 + 6) = -3 < 0$$

$$\Delta_{21} = (4 + 4) - (2 + 3) = 3 > 0$$

$$\Delta_{31} = (7 + 6 + 4) - (1 + 2 + 3) = 11 > 0$$

$$\Delta_{32} = (3 + 6) - (1 + 2) = 6 > 0$$

Относителната оценка на клетка (1,3) е отрицателна. Планът не е оптимален и се преминава към етап 5.

4.3. Средството Solver в Microsoft Office Excel 2010

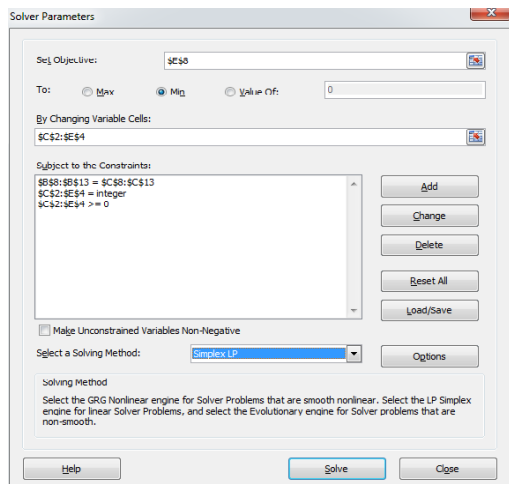
В работния лист на Excel показан на Фиг. 3 е въведено начално допустимото базисно решение определен по един от двата метода на етап 3 и математическия модел създаден на етап 2.

	A	B	C	D	E	F	G	H	I	J	K	L
1			Склад 1	Склад 2	Склад 3							
2		Цех 1	120	X ₁₁	80	X ₁₂	0	X ₁₃				
3		Цех 2	0	X ₂₁	100	X ₂₂	10	X ₂₃				
4		Цех 3	0	X ₃₁	0	X ₃₂	140	X ₃₃				
5												
6												
7	Ограничения	I част	II част									
8	I част	II част										
9	X ₁₁ -X ₁₂ -X ₁₃ =200	200	200									
10	X ₂₁ -X ₂₂ -X ₂₃ =110	110	110									
11	X ₃₁ -X ₃₂ -X ₃₃ =200	140	140									
12	X ₁₁ -X ₁₂ -X ₁₃ =200	120	120									
13	X ₂₁ -X ₂₂ -X ₂₃ =200	180	180									
14	X ₃₁ -X ₃₂ -X ₃₃ =200	150	150									

Фиг. 3 Математически модел на транспортна задача зададен в Excel.

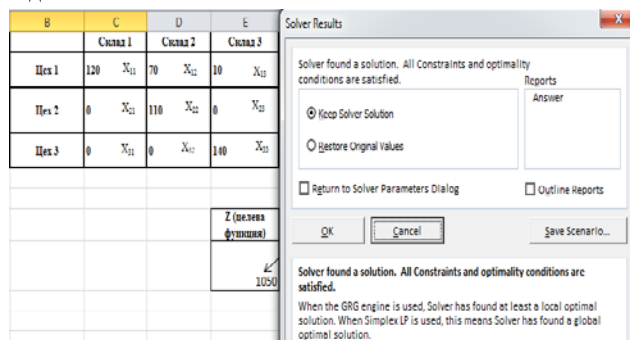
От меню Data се избира Solver.

В прозореца Solver Parameters в полето Set Objective се задава адреса на целевата функция. Избира се радио бутона Min. Задава се началното решение в By Changing Variable Cells. Чрез бутон Add в областта Subject to the constraints се въвеждат ограниченията. На Фиг. 4 е представен попълнения прозорец.



Фиг. 4 Модела на транспортната задача въведен в прозореца на Solver.

След натискане на бутон Solver се преминава към прозореца показан на Фиг.5, който предоставя възможност за запазване на решението получено в резултат на оптимизация и създаване на отчет.



Фиг. 5 Solver Results

Алгоритмът по който се извършва оптимизационната процедура остава скрит за потребителя [3].

5. Създаване на подобрен План № 2 и връщане към етап 4, за да се направи проверка за оптималност на създадения план.

5.1. Подобрен план и проверка за оптималност по метода на потенциалите (4.1.).

Таблица 4. Цикъл на клетката с неблагоприятна индексна оценка

	V ₁ =3	V ₂ =4	V ₃ =8
U ₁ =0	120 ³	80 ⁴	
U ₂ =-2		100 ²	10 ⁶
U ₃ =-7			140 ¹

Построява се цикъл на клетка (1,3). Тя ще влезе в базиса със стойност определена от минималното количество (от клетките с знак минус), което ще се размести по контура и. min(80,10)=10 Извършват се операциите по цикъла. Новите стойностите за клетките са:

$$(1,2)=80-10=70$$

$$(1,3)=10$$

$$(2,2)=100+10=110$$

$$(2,3)=10-10=0 \text{ (свободна променлива)}$$

Таблица 5. Подобрен План № 2

	Склад 1	Склад 2	Склад 3
Цех 1	120 ³	70 ⁴	10 ⁵
Цех 2		110 ²	
Цех 3			140 ¹

$$Z_2 = 3 \cdot 120 + 4 \cdot 70 + 5 \cdot 10 + 2 \cdot 110 + 140 = 1050$$

След създаване на новия план трябва да се направи проверката за оптималност.

Таблица 6. Проверка за оптималност на План № 2

	V ₁ =3	V ₂ =4	V ₃ =5
U ₁ =0	120 ³	70 ⁴	10 ⁵
U ₂ =-2		110 ²	
U ₃ =-4			140 ¹

Изчисляване на индексните оценки:

$$\Delta_{21} = -3 < 0$$

$$\Delta_{23} = -3 < 0$$

$$\Delta_{31} = -8 < 0$$

$$\Delta_{32} = -3 < 0$$

Планът е оптимален.

Z_{min}=1050 при следното разпределение - X₁₁=120, X₁₂=70, X₁₃=10, X₂₁=0, X₂₂=110, X₂₃=0, X₃₁=0, X₃₂=0, X₃₃=140

5.2. Подобрен план и проверка за оптималност по разпределителния метод (4.2.).

Клетка (1,3) е с неблагоприятна относителна оценка. Тя ще влезе в базиса със стойност определена от минималното количество (от клетките с знак минус), което ще се размести по контура и. $\min(80,10)=10$ Извършват се операциите по цикъла. Стойностите в клетките са:

$$(1,2)=80-10=70$$

$$(1,3)=10$$

$$(2,2)=100+10=110$$

$$(2,3)=10-10=0 \text{ (свободна променлива)}$$

Таблица 8. Цикъл за всяка от празните клетки

	Склад 1	Склад 2	Склад 3
Цех 1	120 ³ - + - +	70 ⁴ - + - +	10 ⁵ + - + -
Цех 2	+ - + -	110 ² - + - +	6 ⁶ + - + -
Цех 3	+ - + -	3 ⁷ - + -	140 ¹ - + - +

Изчисляване на относителните оценки:

$$\Delta_{21} = 3 > 0$$

$$\Delta_{22} = 3 > 0$$

$$\Delta_{31} = 8 > 0$$

$$\Delta_{32} = 3 > 0$$

Планът е оптимален.

$Z_{\min} = 3 \cdot 120 + 4 \cdot 70 + 5 \cdot 10 + 2 \cdot 110 + 140 = 1050$ при следното разпределение $X_{11}=120$, $X_{12}=70$, $X_{13}=10$, $X_{21}=0$, $X_{22}=110$, $X_{23}=0$, $X_{31}=0$, $X_{32}=0$, $X_{33}=140$

4. Заключение

Решаването на задачи в областта на линейното оптимиране е свързано със създаване на адекватен математически модел, познаване на множество математически методи, както и познания в областта на математическото моделиране. С предложените методи могат да се решават широк клас задачи с практическо приложение в различни области.

В доклада са систематизирани два основни метода – разпределителния и метода на потенциалите, за решаване на транспортна задача. Използването на компютър и подходящ софтуер спомага за ускоряване на изчислителните процедури, което е свързано с намаляване на времето за получаване на решението. Функционалността на Solver дава възможност за решаване, както на транспортна задача, така и на оптимизационни задачи от други области.

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VIRTUAL ASSISTING AGENTS IN INTERNET OF THINGS

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Abstract: The development of new technologies – RFID, sensor networks in addition to the wider availability and falling prices of microprocessors, controllers and communication created a new digital revolution – Internet of Things (IoT). This phenomenon allows not only the digitalization and control of information (mass usage of PC and Internet) but also things of our surrounding. These “things” are part of our homes, offices, schools, universities, cities, etc. The interaction with these objects is carried out in various ways but one type appears to be very promising – virtual assisting agents, or so called avatars. The paper investigates different approaches in using avatars, opportunities and risks, linked to them.

Keywords: INTERNET OF THINGS, VIRTUAL AGENTS, AVATARS

1. Introduction

Our present environment is changing by the day. The continuing digital revolution from the 1990-ies, which introduced personal computers, digital devices, mobile phones and Internet to the majority of the countries and people, continues in a new direction – Internet of Things (IoT). This phenomenon starts forming new paradigm, which encompasses every process and every object around us – household and office appliances, cars, clothes, phones, watches, food, utilities, health, entertainment, etc, through smart chips, all connected in networks and accessible to man. The networked environment allows people to collect, share, and process data from all those processes and objects, having at the same time options for feedback influencing those very processes and objects. The term IoT was proposed in 1999 [1] but became popular only in the last couple of years.

The new technologies, which drove computers and networking devices into small sizes and affordable for most people prices, led to the creation of a variety of tiny devices and new generation of sensors and sensor networks, which can be applied in almost all areas of human life. Sensors are primary transducers which transform physical, chemical or biological quantities into useful output signals (often electrical or optical). The resulting signal can be converted in digital form, after which it can be used by microcontroller or microprocessor for further processing and action. Sensor technology continues its advances and finds application in more and more areas [2]. In addition to the advance in sensors, a new types of devices became very popular – RFID (Radio Frequency Identification). They (also called RFID tags) can be attached, embedded or glued to almost any object in our environment for the purpose of identifying, tracking or data collection. RFID tags can be attached to any object during production, so its progress at the assembly line can be monitored continuously, it can be attached in passports, clothing and labels, RFID microchips can be implanted in pets, livestock and even people. All this can allow digital identification, tracking, control and processing of items, people, animals, plants, etc., for various purposes – economical, security, health and others.

According to data from the European Commission [3] the expected number of devices of an average person connected to the Internet will become 7 at the present year, and in global aspect this will make 25 billion wirelessly connected devices. The number could get twice as bigger in five years time. By 2040 the networks could connect 50 to 100 trillion different objects [4].

2. Application Areas for the IoT and its effect on the world

The transfer of activities from applications, related to computers and Internet (office applications, communication, e-trade and e-business, entertainment, reference making, etc.) to applications, related to every possible object, which can be interconnected and

used in almost any area of our live is radical. Sensing the environment and interaction with the physical world can lead to unexpected and unknown so far ways (or existing only in science fiction) to actuate, command and control almost everything and everywhere around us. This however will require the development and acceptance of unifying technologies – software, firmware and middleware, which will allow all kind of data from all kind of sources to be embedded and linked in one common network. The revolution of interconnected objects into smart environment is on its way but there are a lot of standards and solutions to be adopted. Table1 lists some of the major application areas of IoT.

Table 1: Application areas of IoT with examples.

IoT application areas	Activities and functions	Examples	Benefits and dangers
Home, building	Light and temperature control, energy optimization, connected appliances, control over activities of junior and elderly inhabitants, access control, entertainment, home security	Smart home appliances (fridge, oven, vacuum cleaner, etc), remote utility control (heating, electricity, gas, water)	Better air quality, ease of use of appliances, better utilization of resources (energy, food, etc.), hazard detection, intrusion detection and control; privacy and unauthorized access
Cities	Traffic control, surveillance, street lighting control, integrated system control, water and gas management, waste management	Smart cities, smart lighting, smart roads, smart transport, smart social services, residential e-meters	Energy efficiency, less air pollution, noise control, hazard detection, better business environment and quality of life; security, privacy
Industry	Machine to machine applications, proper air, temperature and gas control, monitoring and control of production, inventories	Smart asses tracking, flow optimization, real time inventory, safety, predictive maintenance	Energy and material efficiency, hazard detection, production optimization; security
Transport	Route optimization, incident prevention, condition of transported goods, location of items, detection of incompatibility storage, tracking of fleet	Smart cars, routing, smart railroads, monitor and control of bridges, roads, tunnels	More efficient transport, better incident management, instant tracking and location information; security
Healthcare	Remote health monitoring, patients surveillance,	Fall detection, smart implants and aids, smart	Prevention of critical and dangerous health

Healthcare	hospital access tracking, drug tracking, access control	heart and blood monitors, emergency notification	situations, real-time monitoring, proper treatment; privacy and security
Environment	Monitoring of air, water and soil quality, forest fire detection, snow level quality, earthquake, flood, landslide, avalanche detection, irrigation	Flood and pollution warning systems, landslide and avalanche prevention, forest fire prevention systems, soil irrigation	Better living environment for people, animals and plants, better quality of water, air, hazard detection and prevention; security
Trade, education, science, other	Intelligent shopping applications, smart advertizing, supply chain control, monitoring, control and feedback in education, data collection from people, activities, animals, plants, environment	Smart payment, smart product management, smart product and services supply, smart classrooms, smart universities, smart entertainment	More efficient commerce and trading, better quality education, measure, collect and analyze big data. Possible revolution in targeted marketing of products and services

The interaction with the objects and the attached to them tags goes in a variety of ways – one approach is to use existing networks and network resources. Such can be Wi-Fi, 3G and 4G cell phone accesses. These networks, however, have been in place for rather different purposes and have different terminating equipments. So the technological advances in the last decades led to the creation of a number of wireless sensor networks (WSN). Other technologies that connect sensors are NFC, Bluetooth, wired solutions and mixed wireless and wired systems. Networks that connect sensors enable machines or users to collect, process analyze and disseminate data and information gathered from various environments. The problems in these types of connections are significant – unlike computers and digital devices, sensor nodes are very heterogeneous in nature and in the general case – distributed. There are different hardware platforms for WSN, different software communication stacks, different middleware and different security requirements.

One can say that the years to come look “smart”. According to recent surveys 70% of the interviewed believe in the future of smart technologies for resource optimization of future smart environments [5]. And according to Cisco, one of the leading world companies in the area of IoT (actually, Cisco uses the term “Internet of Everything”) the market potential of IoT is some \$19 trillion - \$14.4 trillion in the private and \$4.6 trillion in the public sectors over the next decade [6].

The interaction with the objects in IoT can go in various ways but one particular approach appears to be promising – the use of avatars, or virtual assisting agents.

3. The Virtual Assisting Agents in IoT

Virtual Assisting Agents or ‘Avatars’ are an idea with multiple applications in modern artificial intelligence. Concerning today’s Web 3.0 technological trends, avatars’ integration in IoT devices is an expected innovation perspective together with robotics rebirth by means of drones recent popularity growth and human-machine interaction naturalism improvement, noting emotions and behavior better machine processing towards Web 4.0.

Several examples in this context could be noted around the new on-line Voki [7] service and Intel entertainment Pocket Avatars application [8]. As these ideas are quite promising the lack of sensors integration is rather frustrating. Such solutions, using voice interaction and multiple environment sensors systems are Cleopatra [9], Melissa [10] and ALEX [5] but not for mobile platforms. They have applicable sensors systems integrating:

barometric, light and behavior monitors, allowing the real combination of sensors and avatars practical benefits usage.

Different approaches, using virtual avatars for educational applications and implementing sensors are: *Virtual Eve* [11] and *ITA* [12]. They provide some interactive sensors’ integration, allowing limited emotions understanding and even real time data Internet access.

The greatest problem so far is the signal processing computational power energy consumption which does not allow direct integration in IoT devices. Luckily, due to cloud solutions and wireless technologies development, the problem is expected to be partially solved soon.

A practical framework for avatar integration in IoT sensors is presented in Figure 1.

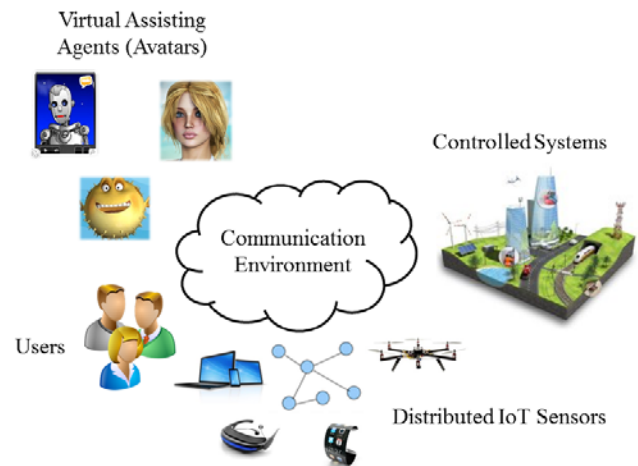


Figure 1 Practical framework for avatar integration in IoT sensors.

As it is clear from the framework, given in Figure 1, modern *Virtual Assisting Agents*–‘Avatars’ (with human, animal or gadget real or cartooned appearance) will provide both natural interface and smart control, using *Distributed IoT Sensors* in multiple devices (tablets, smartphones, smart watches, biometric and users’ activities gadgets, augmented reality devices, drones and other environment monitoring sensors). Apart from this, the variety of *Controlled Systems* is rather rich in nowadays and future digital world (see Table 1). The *Communication Environment* in this context is also with broad interaction modalities: audiovisual, tactile and ‘emotional’ human-machine interaction. Numerous wireless devices and sensors communication protocols, based on the sensors networks evolutionary development, are currently implementing ideas like: Wi-Fi, Bluetooth, ZigBee, IrDA, ANT.

4. Cyber risks & threats

Whilst this framework looks quite convenient and useful for our everyday quality of life improvement, there are also some aspects, related to its cyber security threats and risks.

Though a rather innovative area of research –IoT and avatars still have some new related studies, noting the critical role of human factor and expected trends for smart environments [5], [12].

A recent questionnaire based survey on possible cyber risks and threats, concerning IoT and avatars (see Table 2) has been organized, during a training course on ‘Security Foundations in Cyber Space’ [13].

The evaluation was performed in four areas, similar to integration framework from Figure 1: ‘Avatar Interface’, ‘Communication Environment’, ‘Sensors Things’ and ‘Controlled Things’. Seven cyber threats/risks (‘Malware’, ‘Targeted Attacks’, ‘Compromised Devices’, ‘Data Breaches’, ‘Privacy’, ‘Social Engineering’) were evaluated by means of their significance, using three level scale: low (green), high (yellow), and severe (red).

Table 2: IoT& avatars cyber threats and risks.

Threat/Area	Avatar Interface	Communication Environment	Sensor Things	Controlled Things
Malware				
Targeted Attacks				
Compromised Devices				
Data Breaches				
Privacy				
Social Engineering				

Briefly the results from Table 2 could be summarized as follows: high and severe cyber threats/risks, related to 'Privacy' and 'Social Engineering' emerged for the users' from 'Avatars Interface' and 'Communication Environment'. The 'Sensor Things' and 'Controlled Things' are the mostly threatened areas by: 'Malware', 'Targeted Attacks', 'Compromised Devices' and 'Data Breaches'. Finally, the 'Communication Environment' is also highly risky from: 'Targeted Attacks', 'Data Breaches', 'Privacy' and 'Social Engineering'.

5. Discussion

The combination of IoT and Virtual Assisting Agents – 'Avatars' is producing a rather useful and promising direction for both web technologies and services in the new digital area with useful social effect, noting the technological progress influence in the mankind evolution.

Apart of this, a number of obvious and hidden threats have to be expected and addressed for both technologies and users. They are however dynamic and require further situational analysis and validation. The comprehensive understanding of the problem will guarantee a modern smart world with multiple artificial conveniences.

4. Acknowledgement

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ANALYTICAL ANALYSIS OF THE INVERSE STABILITY PROBLEM FOR SOME CLASSES OF NON-LINEAR DYNAMICAL SYSTEMS WITH A SMALL UNCERTAIN PARAMETER

АНАЛИЗ ОБРАТНОЙ ЗАДАЧИ УСТОЙЧИВОСТИ ДЛЯ НЕКОТОРЫХ КЛАССОВ НЕЛИНЕЙНЫХ ДИНАМИЧЕСКИХ СИСТЕМ С МАЛЫМ НЕОПРЕДЕЛЕННЫМ ПАРАМЕТРОМ

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Abstract: In this paper we propose a method of solving inverse stability problem for some classes of non-linear dynamical systems with a small uncertain parameter. The method is based on T. Kato's perturbation theory of linear operators. We illustrate our method by solving inverse stability problem in the situation of monomerization reaction inside the cascade of chemical reactors.

KEYWORDS: LOW UNCERTAINTY OF PARAMETERS, PERTURBATION THEORY, SOLUTION IN A BOUNDARY LAYER

1. Introduction

This paper presents an analytical solution of the inverse problem of stability in the cascade process of monomerization when three chemical stirred tank reactors are used under the conditions of uncertainty of some of the reactor's parameter. The decision is based on the perturbation theory of linear operators of Kato-Rellich [1]. The process is carried out by distilling monomerization reagent from one reactor to another. The necessary cooling of the substance is carried out by the coolant in the reactor jacket. The scheme of this stage [2] is shown in Figure 1.

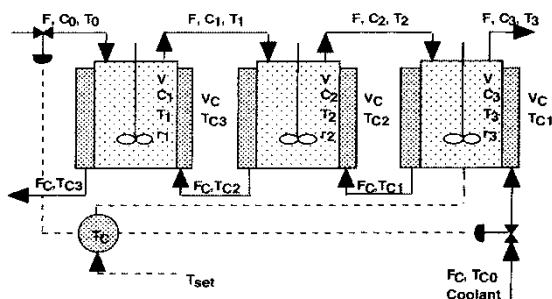


Fig.1. Scheme of the cascade of chemical reactors

The equations describing this process are as follows [2, 3, 4]:

$$\begin{aligned} V \frac{dC_1}{dt} &= F(C_0 - C_1) - Vk(T_1)C_1, \\ \rho c_p V \frac{dT_1}{dt} &= F\rho c_p(T_0 - T_1) + Vk(T_1)C_1\Delta H - \\ &\quad - K_t A(T_1 - T_{c3}), \\ \rho c_p c_{pc} V_c \frac{dT_{c3}}{dt} &= F_c \rho c_p c_{pc}(T_{c2} - T_{c3}) + K_t A(T_1 - T_{c3}), \\ V \frac{dC_2}{dt} &= F(C_1 - C_2) - Vk(T_2)C_2, \\ \rho c_p V \frac{dT_2}{dt} &= F\rho c_p(T_1 - T_2) + Vk(T_2)C_2\Delta H - K_t A(T_2 - T_{c2}), \\ \rho c_p c_{pc} V_c \frac{dT_{c2}}{dt} &= F_c \rho c_p c_{pc}(T_{c1} - T_{c2}) + K_t A(T_2 - T_{c2}), \\ V \frac{dC_3}{dt} &= F(C_2 - C_3) - Vk(T_3)C_3, \\ \rho c_p V \frac{dT_3}{dt} &= F\rho c_p(T_2 - T_3) + Vk(T_3)C_3\Delta H - K_t A(T_3 - T_{c1}), \\ \rho c_p c_{pc} V_c \frac{dT_{c1}}{dt} &= F_c \rho c_p c_{pc}(T_{c0} - T_{c1}) + K_t A(T_3 - T_{c1}) \end{aligned} \quad (1)$$

The parameters of the process are given in Table 1 [2, 3, 4].

Table 1. Process parameters

№	Name	Description	Demention
1	A	Surface contact area	m ²
2	C ₀	Initial concentration of the reactant in the first reactor	kmol/m ³

3	C _j	Concentration of the reactant in the j-th reactor	mol/m ³
4	ρ	Density of the reagent	J/kg·K
5	ρ _c	Density of the refrigerant	J/kg·K
6	E	Activation energy	J/ mol
7	F	Flow rate in the reactor	m ³ /s
8	F _c	Flow rate of the refrigerant	m ³ /s
9	R	Gas constant	J/mol·K
10	c _p	Specific heat of a substance	kg/m ³
11	c _{pc}	Specific heat of the refrigerant	kg/m ³
12	T _{cj}	Temperature of the refrigerant in the cooling part of the j-th reactor	K
33	T _{c0}	Initial temperature of the refrigerant	K
14	K _t	Coefficient of thermal conductivity	J/m ² ·s·K
15	V	Volume of the reactor	m ³
16	V _c	Volume of cooling part of the reactor	m ³
17	Z	Multiplier by the Exhibitor	
18	ΔH	Thermal effect of reaction	J/ mol

From a mathematical point of view, the sustainability of monomerization is equivalent to the stability of solutions of the above system (1) of the equation. However, the technical parameters of the system can not be given exactly. The **main objective** is to evaluate the allowable errors of these parameters, which preserve the stability of the process.

2. The perturbation theory of linear operators Kato-Rellich

Let us consider a process that occurs in a dynamic system described by the following differential equation [1, 5]:

$$\dot{x} = Ax + B, \quad (2)$$

where x- state vector, A - matrix of the system parameters (matrix states), B - matrix of absolute terms.

We will use the method of accounting for uncertainty parameters of the system, based on the theory of perturbation of the eigenvalues of component matrices:

$$A = A_0 + \varepsilon A_1 + \varepsilon^2 A_2 + \dots, \quad (3)$$

where we assume that $\varepsilon^2 \ll \varepsilon$. It is known that the eigenvalues of A in this case can be represented as [5]:

$$\lambda_i(\varepsilon) = \lambda_i^{(0)} + \varepsilon \lambda_i^{(1)} + \varepsilon^2 \lambda_i^{(2)} + \dots, \quad (4)$$

where $\lambda_i^{(0)}$ – is j-th eigenvalue A_0 . Right and left eigenvectors corresponding to the eigenvalues $\lambda_j(\varepsilon)$, for which the following equation: $y_j^T(\varepsilon)x_j(\varepsilon) = 1$ holds true, also expanded in power series: $x_j(\varepsilon) = x_j^{(0)} + \varepsilon x_j^{(1)} + \varepsilon^2 x_j^{(2)} + \dots$, $y_j(\varepsilon) = y_j^{(0)} + \varepsilon y_j^{(1)} + \varepsilon^2 y_j^{(2)} + \dots$. And eigenvalues $\lambda_j^{(1)}$ и $\lambda_j^{(2)}$ are calculated as follows:

Step 1. Calculate the eigenvalues λ_j of matrix A_0 .

Step 2: Finding the right and the left normalized eigenvectors A_0 :

$$(A_0 - \lambda_j I)x_j = 0, y_j^T(A_0 - \lambda_j I) = 0, |x_j| = 1, |y_j| = 1.$$

Step 3. The matrix Z_{k0} is constructed: $Z_{k0} = \frac{\prod_{j=1, j \neq k}^s (A_0 - \lambda_j I)}{\prod_{k=1, j \neq k}^s (\lambda_k - \lambda_j)}$,

where s is dimension of A.

Step 4. The matrix E_j is calculated: $E_j = \sum_{k=1, k \neq n}^s \frac{1}{\lambda_j - \lambda_k} Z_{k0}$.

Step 5. Calculated coefficients of the expansion (4) by the formulas: $\lambda_j^{(1)} = y_j^T A_1 x_j$, $\lambda_j^{(2)} = \text{tr}(B E_1 A_2 Z_{10})$.

In this task we assume that $\varepsilon^3 \ll \varepsilon^2$. Therefore, in the above formula (4) it is sufficient to consider the first three terms.

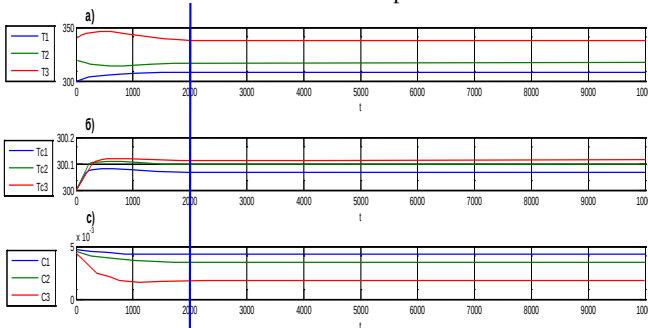
As a criterion for the stability of the system we will use the root criterion, that is, the permissible range of the parameter ε , which is characterized by a system of inequalities of the form for sufficiently small α :

$$\lambda_j(\varepsilon) < -\alpha^2, \quad (5)$$

Solution of the inequality (5) is the intersection of the intervals that are solutions of each inequality. It is obvious that the intersection is not empty, due to the fact since the solution of each inequality will contain zero.

3. Reaching the main objective

Perturbation operators theory developed by Kato, refers to linear operators in function spaces, and the system of equations (1) is non-linear. However, the system (1) can be linearized. Indeed, the experiment [2,3] (Figure 1) shows that the dynamics of changes in the main characteristics of the system admits a linearization, from some point of time from the beginning of the process, and this initial period of time is small relative to the total process time. Thus, during the initial period of time, as it is so small, it is possible to seek the solution of the system by expanding in the time series, and the remaining slot to linearize in the usual manner. At the same time as the initial value of the interval being we linearized site can take the final value of the initial period.



1. a) The plot of a change of a temperature; b) the plot of the change of the temperature of the coolant; c) the graph of the concentration change of the substance

3.1. Constructing an analytical solution of the system at the initial time interval

To unify the system (1) we introduce the following notation:

$C_i = X_i$, $T_i = X_{i+3}$, $T_{ci} = X_{i+6}$, $i = 1, 2, 3$. Then the system of equations for the first reactor takes the following form (the other equations will be similar):

$$\begin{aligned} \frac{dX_1}{dt} &= \frac{F(C_0 - X_1)}{V} - Z \exp\left(\frac{-E}{RX_4}\right) X_1, \\ \frac{dX_4}{dt} &= \frac{F(T_0 - X_4)}{V} + \frac{ZX_1 \Delta H}{\rho c_p} e^{\left(\frac{-E}{RX_4}\right)} - \frac{K_t A (X_4 - X_9)}{\rho c_p V}, \\ \frac{dX_9}{dt} &= \frac{F(X_8 - X_9)}{V_c} + \frac{K_t A (X_4 - X_9)}{\rho c_p V_c}. \end{aligned} \quad (7)$$

Denote $t = T\tau$, where T – the time course of the whole process, and $X_j = \bar{X}_j x_j$, $j = 1, 2, \dots, 9$. Note, that x_j и τ – dimensionless quantities and $\tau \ll 1$. Then the system describing the dynamics of the process in the first reactor takes the form (the other equations will take the same form):

$$\begin{aligned} \frac{dx_1}{d\tau} &= \frac{FTC_0}{V\bar{X}_1} - \frac{FT}{V} x_1 - ZT e^{\left(\frac{-E}{R\bar{X}_4 x_4}\right)} x_1, \\ \frac{dx_4}{d\tau} &= \frac{FTT_0}{V\bar{X}_4} - \frac{FT}{V} x_4 + \frac{ZT\bar{X}_1 x_1 \Delta H}{\rho c_p \bar{X}_4} e^{\left(\frac{-E}{R\bar{X}_4 x_4}\right)} + \frac{K_t AT (x_4 - \frac{\bar{X}_9}{\bar{X}_4} x_9)}{\rho c_p V}, \\ \frac{dx_9}{d\tau} &= \frac{F_c T \left(\frac{T_c}{\bar{X}_9} - x_9\right)}{V_c} + \frac{K_t AT \left(\frac{\bar{X}_4}{\bar{X}_9} x_4 - x_9\right)}{\rho c_p V_c}. \end{aligned}$$

We seek a solution of the system on a small initial period of time as a power series in the small parameter τ : $x_j(\tau) = C_0^j + C_1^j \tau + C_2^j \tau^2 + \dots$, where C_0^j are known and the initial values of parameters of the input vector. The expression $e^{\left(\frac{-E}{R\bar{X}_4 x_4}\right)}$ is expanded in a series

$$\begin{aligned} \text{as a function of the } \tau: \quad e^{\left(\frac{-E}{R\bar{X}_4 x_4}\right)} &= e^{\left(\frac{-E}{R\bar{X}_4 C_0^4}\right)} + e^{\left(\frac{-E}{R\bar{X}_4 C_0^4}\right)} \frac{EC_1^4}{R\bar{X}_4 (C_0^4)^2} \tau + \\ &+ \frac{1}{2} e^{\left(\frac{-E}{R\bar{X}_4 C_0^4}\right)} \frac{E(2R\bar{X}_4 (C_0^4)^2 C_2^4 - 2R\bar{X}_4 C_0^4 (C_1^4)^2 + E(C_1^4)^2)}{(R\bar{X}_4 (C_0^4)^2)^2} \tau^2 + o(\tau^3). \end{aligned}$$

Representation of the solution of the system in the form of a power series in the variable τ and its further substitution in the system of equations gives, by equating the coefficients of corresponding powers of τ , a recurrent system of equations for the coefficients of the expansion of the solution. Here is a small piece of this scheme:

$$\begin{aligned} C_1^1 &= \frac{FTC_0}{V\bar{X}_1} - \frac{FTC_0^1}{V} - ZT e^{\left(\frac{-E}{R\bar{X}_4 C_0^4}\right)} C_0^1, \\ C_1^4 &= \frac{FTC_0}{V\bar{X}_4} - \frac{FTC_0^4}{V} - \frac{ZT\Delta H}{\rho c_p} e^{\left(\frac{-E}{R\bar{X}_4 C_0^4}\right)} C_0^1 - \frac{K_t AT \left(C_0^4 - C_0^9 \frac{\bar{X}_9}{\bar{X}_4}\right)}{\rho c_p V}, \\ C_2^1 &= \frac{1}{2} \left(-ZT e^{\left(\frac{-E}{R\bar{X}_4 C_0^4}\right)} C_1^1 - ZT e^{\left(\frac{-E}{R\bar{X}_4 C_0^4}\right)} \frac{EC_1^4 C_0^1}{R\bar{X}_4 (C_0^4)^2} - \frac{FTC_1^1}{V} \right). \end{aligned}$$

So it's clear that all the coefficients are calculated consistently.

3.2. Linearization of the system of differential equations of the dynamics of chemical reactors

In the previous section solution of the system at the initial time interval was constructed. Now we construct a solution of (1) in the remaining time interval by its linearization. Note that the solution obtained in the above initial time interval at the end of this interval is the vector of initial values for the remaining time interval.

Represent x_j as follows $x_j = X_j^0(1 + y_j)$, $j = 1, 2, \dots, 9$, where y_j – small quantity, which allows to neglect the terms containing the second order y_j . The main issue arises when converting linearization terms of the form e^{x_j} . For this we use the Taylor

formula:

$$e^{-\frac{c}{x_j}} = e^{-\frac{c}{x_j^{(0)}(1+y_j)}} = e^{-\frac{c}{x_j^{(0)}}} + e^{-\frac{c}{x_j^{(0)}}} \left(\frac{c}{x_j^{(0)}(1+y_j)} \right)'_{x_j=0} \cdot x_j + O(x_j^2).$$

Neglecting the second order x_j^2 , we obtain approximately: $e^{-\frac{c}{x_j}} = e^{-\frac{c}{x_j^{(0)}(1+y_j)}} = e^{-\frac{c}{x_j^{(0)}}} + e^{-\frac{c}{x_j^{(0)}}} \cdot \frac{c}{x_j^{(0)}} \cdot x_j$. Thus, the system of equations for the first reactor takes the form:

$$\begin{aligned} \frac{dy_1}{d\tau} &= \xi_{11}y_1 + \xi_{14}y_4 + b_1 \\ \frac{dy_4}{d\tau} &= \xi_{41}y_1 + \xi_{44}y_4 + \xi_{49}y_9 + b_4, \end{aligned} \quad (8)$$

$$\begin{aligned} \text{where } \xi_{11} &= \left(-\beta e^{-\frac{c}{x_4^{(0)}}} - \alpha \right) X_1^{(0)}, \xi_{14} = \beta \frac{X_1^{(0)}}{X_4^{(0)}} e^{-\frac{c}{x_4^{(0)}}}, \xi_{41} = \\ &= \frac{\beta_H X_1^{(0)}}{\delta} e^{-\frac{c}{x_4^{(0)}}}, \xi_{44} = X_4^{(0)} \left(-\alpha - \frac{\gamma}{\varphi} \right) + \beta_H c \frac{X_1^{(0)}}{X_4^{(0)}} e^{-\frac{c}{x_4^{(0)}}}, \xi_{94} = \\ &= \frac{\gamma \rho}{\varphi c} X_4^{(0)}, \xi_{99} = X_9^{(0)} \left(-\alpha_c - \frac{\gamma}{\varphi c} \right), \quad \text{but} \quad b_1 = \left(-\beta e^{-\frac{c}{x_4^{(0)}}} - \right. \\ &\left. \alpha \right) X_1^{(0)}, b_2 = \left(-\alpha - \frac{\gamma}{\varphi} \right) X_4^{(0)} + \frac{\gamma}{\varphi \eta} X_9^{(0)} - X_1^{(0)} \frac{\beta_H}{\delta} e^{-\frac{c}{x_4^{(0)}}} - \\ &\alpha \theta_4, b_3 = \left(X_9^{(0)} + \theta_9 \right) \alpha_c + \frac{\gamma \eta}{\varphi c} X_4^{(0)}. \quad \text{Where} \quad \varphi = \delta V, \varphi_c = \\ &\delta_c V_c, \beta_H = \beta \Delta H, \eta = \frac{X_4^{(0)}}{X_9^{(0)}}, \theta_4 = \frac{T_0}{X_4^{(0)}}, \theta_9 = \frac{T_c}{X_9^{(0)}}, \quad \text{где} \quad \alpha = \frac{FT}{V}, \beta = \\ &= \frac{ZT}{V}, \gamma = K_t AT, \alpha_c = \frac{F_c T}{V_c}, \delta = \rho c_p, \delta_c = \rho c_p c. \end{aligned}$$

So we obtain:

$$A = \begin{pmatrix} \xi_{11} & \xi_{14} & 0 \\ \xi_{41} & \xi_{44} & \xi_{49} \\ 0 & \xi_{94} & \xi_{99} \end{pmatrix}, b = \begin{pmatrix} b_1 \\ b_2 \\ b_3 \end{pmatrix}, x = \begin{pmatrix} y_1 \\ y_2 \\ y_3 \end{pmatrix}.$$

4. Uncertainty parameters of the matrix A

Let's suppose that the uncertainty in parameters reflecting the heat of reaction $-\Delta H$.

Suppose, therefore, that $\Delta H^0 = \Delta H(1 + \varepsilon)$, $[\varepsilon] \ll 1$. Then $\beta_H^0 = \beta \Delta H(1 + \varepsilon)$, and, in turn, the matrix parameters ξ_{41} and ξ_{44} take the form:

$$\begin{aligned} \xi_{41} &= \frac{\beta_H^0 X_1^{(0)}}{\delta} e^{-\frac{c}{x_4^{(0)}}} = \frac{\beta \Delta H^0 X_1^{(0)}}{\delta} e^{-\frac{c}{x_4^{(0)}}} = \frac{\beta \Delta H}{\delta} e^{-\frac{c}{x_4^{(0)}}} (1 + \varepsilon) X_1^{(0)} = \\ &= \frac{\beta \Delta H}{\delta} e^{-\frac{c}{x_4^{(0)}}} X_1^{(0)} + \left(\frac{\beta \Delta H}{\delta} e^{-\frac{c}{x_4^{(0)}}} X_1^{(0)} \right) \varepsilon = \xi_{41}^0 + \xi_{41}^1, \\ \xi_{44} &= X_4^{(0)} \left(-\alpha - \frac{\gamma}{\varphi} \right) + \beta_H^0 c \frac{X_1^{(0)}}{X_4^{(0)}} e^{-\frac{c}{x_4^{(0)}}} = X_4^{(0)} \left(-\alpha - \frac{\gamma}{\varphi} \right) + \\ &+ \beta \Delta H^0 c \frac{X_1^{(0)}}{X_4^{(0)}} e^{-\frac{c}{x_4^{(0)}}} = X_4^{(0)} \left(-\alpha - \frac{\gamma}{\varphi} \right) + \beta \Delta H c \frac{X_1^{(0)}}{X_4^{(0)}} e^{-\frac{c}{x_4^{(0)}}} (1 + \varepsilon) = \\ &= X_4^{(0)} \left(-\alpha - \frac{\gamma}{\varphi} \right) + \beta \Delta H c \frac{X_1^{(0)}}{X_4^{(0)}} e^{-\frac{c}{x_4^{(0)}}} + \left(\beta \Delta H c \frac{X_1^{(0)}}{X_4^{(0)}} e^{-\frac{c}{x_4^{(0)}}} \right) \varepsilon = \xi_{44}^0 + \\ &+ \xi_{44}^1. \end{aligned}$$

Thus, we obtain:

$$A = A_0 + \varepsilon A_0 = \begin{pmatrix} \xi_{11} & \xi_{14} & 0 \\ \xi_{41}^0 & \xi_{44}^0 & \xi_{49} \\ 0 & \xi_{94} & \xi_{99} \end{pmatrix} + \varepsilon \begin{pmatrix} 0 & 0 & 0 \\ \xi_{41}^1 & \xi_{44}^1 & 0 \\ 0 & 0 & 0 \end{pmatrix},$$

5. Summary

In this paper, we propose a method of analysis of a nonlinear dynamical system, which describes by a standard process of monomerization cascade of chemical substances in the stirred tank reactors, provided that certain parameters of the reactor have undefined values. Namely: 1) an algorithm to obtain an approximate analytical solution of the corresponding system of nonlinear differential equations has been developed; 2) on the basis of the solution a fairly simple algorithm for its numerical implementation has been derived; 3) the corresponding system of differential equations is transformed to a form, which allows you to explicitly take into account the uncertainty of the parameters of the system, and, therefore, to use the methods of perturbation theory of linear operators by Rellich - Kato.

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PRESENT STATE OF LASER MARKING ON PLASTICS

ЛАЗЕРНО МАРКИРАНЕ ВЪРХУ ПЛАТМАСИ

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Abstract: Paper discusses technological progress for laser marking of plastic products. Various methods for marking are systematized and considered. Advantages that provide this innovative marking technology are presented, too. It has been discussed the absorption process in polymeric materials, as well as laser sources suitable for the realization of the technological operations. In each case of marking, not only high performance, durability, etc. but the aesthetic appearance of the product could provide by correct chosen method and in conjunction with appropriate laser equipment.

Keywords: LASER MARKING; PLASTICS; LASER

1. Въведение

Въпреки, че лазерната технология за цветно маркиране се появи през последните 20 години, нейното реализиране в практиката вървеше бавно, поради:

- възможността да се реализират само ограничен вид цветни маркировки на дадени материали;
- високата цена на технологичното оборудване.

Днес тези два недостатъка в голяма степен са преодоляни. Съвременното производство на полимери и оцветители от различни производители позволи да се разшири значително цветовия асортимент, който може да бъде реализиран при лазерна маркировка. С появата на новото поколение фибер и диодни лазери, значително се повиши производителността и се снижиха разходите за сервиз и поддръжка. Благодарение на тези съвременни тенденции интереса към технологията за лазерно маркиране на пластмасови изделия се възроди [1,2,3].

Лазерното маркиране е екологично чиста технология, която успешно конкурира традиционните технологии като тампонен, мастилено струен и сито печати. Програмното обезпечаване на лазерно технологичните системи позволява бързо да се премине от един вид надпис към друг, това прави технологията значително по-гъвкава в сравнение с другите методи. Разходите за сервиз и поддръжка са значително по-ниски от тези при традиционните технологии, при които се използват шаблони, разтворители, мастила и други.

Днес лазерната технология за маркиране на пластмасови изделия намира все по-широко практическо приложение в различни области на промишлеността. Лазерният лъч успешно може да маркира върху повърхността на изделията или опаковката им: дата, серийни номера, текст, лого, бар кодове и др. (табл. 1) Така например производителите на детайли и модули за автомобилната промишленост и електрониката използват широко тази технология при нанасяне на специфична информация за производствения процес и такава, необходима конкретно за потребителя. Лазерното маркиране позволява да се нанасят изображения на: бутони, пултове за управление, клавиатури на компютри, таблети, мобилни телефони и друга битова електроника. При осветяване на някои бутони се реализира и така нареченото “ден/нощ” маркиране (изображенията/информацията се възприема визуално, както през деня, така и през нощта) (фиг.1).

През последните години се изследва възможността за лазерно маркиране на голяма група от полимери: полибутилен-терефталат (PBT), поликарбонат (PC), полиетилен оксид/полистирен (PPO/PS), акрилонитрил-бутадиен-стирен (ABS), стирен-акрилонитрил-смола (SAN) и др. Изследванията показваха, че всички те различно се поддават на маркиране. Някои базисни материали от групата на полимерите показват добра абсорбция в зоната на въздействие, при което се

получава равномерна маркировка с добър контраст. Други като полипропилен (PP), полиетилен (PE) и полиметил-метакрилат (PMMA) показват ниска степен на абсорбция и не са така добре податливи на маркировка. Понастоящем в много изследователски и научни лаборатории се провеждат научни изследвания за получаване на цветна маркировка върху различни видове пластмасови материали [1,2].



Фиг. 1 Лазерно маркирани детайли от интериора на автомобила

Табл.1 Видове пластмаси и изделия, подлежащи на лазерно маркиране

Вид	Приложение	Лазерна маркировка
PC	Ключове за осветление Бутонка за вода Електрически компоненти	Лого на фирми Технически параметри Серийни номера
ABS	Корпуси на електрически модули Панели и табла в автомобили Клавиатури	Технически параметри Данни за качеството на изделието Символи
Смес PC/ABS	Корпуси на електромери	Лого на фирма Технически параметри Показания
PBT	Клавиатури Корпуси на електрически модули Щекеи	Идентификация на параметрите Технически параметри Символи
Смес PPE/PS	UPS захранване Панели за навигационни системи Електрически компоненти	Лого на фирма Технически параметри Специална идентификационна информация
PEI PA6/PA6.6	Щекеи Щекеи Миниатюрни изключватели	Технически параметри BAR-кодове Серийни номера Технически параметри

2. Методи за маркиране

2.1. Набъбване на материала

При този метод основния материал се загрява за кратко време и се топи. В стопилката се образуват газови мехурчета, които след изстиване на обработената зона остават вътре в нея. В резултат на това, като видима следа се получава една набъбнала зона (фиг.2). В дълбочина, зоната е около $h_1 = 60\mu\text{m}$, а над повърхността тя е с височина $h_2 = 40\mu\text{m}$. Образува се

повърхностна структура, която е с друг коефициент на отражение. Маркировката е с по-светъл цвят от основния материал. Този ефект осигурява висок контраст на маркировката. Добри резултати с този метод са постигнати на полиоксиметилен (POM), полиамид (PA) и термопластичен еластомер (TPE).



Фиг.2 Метод на маркиране чрез набъбване

2.2. Карбонизация

Тъмна маркировка върху светла основа може да се получи в резултат на лазерно въздействие върху повърхността на определени полимери. Този ефект се наблюдава най-добре, ако фона е светъл. Полимерът локално се нагрява и значително променя физическите си свойства, като се образува тъмнокафява или черна маркировка.

При този метод погълнатата лазерна енергия е достатъчна да нагрее зоната на въздействие до температура, при която настъпва термично разрушаване на повърхността на полимера. В присъствието на кислород от въздуха протича реакция на горене и овъгляване в обработваната зона. Маркировката е с добър контраст спрямо основния светъл фон (фиг.3). Подходящи материали за целта са: PC, PS, полиетилен терафталат (PET), ABS, PBT, PE и PP.



Фиг. 3 Карбонизация на повърхността на материала при лазерно въздействие

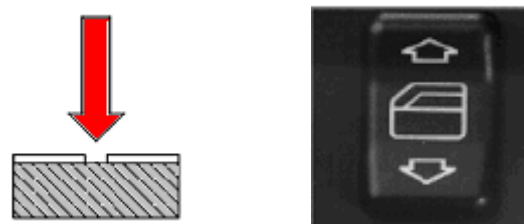
2.3. Избелване на повърхността

Лазерното въздействие върху полимера може да доведе до избледняването ѝ, в резултат на което се образува бяла маркировка на тъмен фон. Взаимодействието на лазерното лъчение е само с пигмента, без да се засяга основния материал. Пример за такъв вид маркировка е полимер с добавки на сажди и неорганични оцветители. При нагряването въглеродните сажди се отстраняват, като в зоната на въздействие остават само неорганичните оцветители. Този ефект може да се наблюдава при сравнително малък кръг пластмасови материали в комбинация с определени пигменти. Поради тази причина тук контрастът е значително по-нисък в сравнение с другите техники на маркировка.

2.4. Отнемане на повърхностен слой (аблация)

При аблационният процес, посредством изпарение, се отнемат слоеве (багирило, метал, специални лакове и др.), нанесени предварително на повърхността. По този начин се получават различни видове цветни маркировки, като тази техника се използва при на изображения върху бутони, сигнални, предупредителни и забранителни надписи („ден/нощ“). При тази техника, предварително нанесен тъмен слой се изпарява, в резултат на което се създава възможност през полупрозрачната пластмаса на основния материал да

премине светлина от светлинен източник вграден в бутона. Маркировката се реализира при висока скорост на обработка и се използва за оформяне на информационни знаци по арматурното табло на превозни средства.



Фиг.4 Метод на маркиране чрез отнемане на повърхностен слой нанесен предварително върху полимера

Изисквания към лазерния източник при маркиране с ефекта „ден/нощ“ са:

- високо качество на лъча с цел осигуряване на добра фокусировка и острота на шриха;
- стабилност на честотата на следване на импулсите (честота до 100 kHz);

В този случай е особено важно абсорбционната способност на слоя да е голяма за дадената дължина на вълната на лазерното лъчение, а за основния материал лъчението да е прозрачно. При това отделните импулси на лазера трябва да имат еднакви характеристики. Особено важно е да има възможност за добра фокусировка на лазерното лъчение. Напрежната му структура на лъча да е близка до основен мод TEM₀₀, при която се реализира минимално фокусно петно на работната повърхност.

2.5 Гравирание

При този метод на маркиране материалът се топи и изпарява. Поради това, че топлопроводността на материала е малка и количеството стопилка в зоната на обработка е малко, практически там настъпва сублимационно изпарение. По ръба на канала се получава вал в резултат на термично разめждане и възникналите термонапрежения. Методът успешно може да се прилага и при трите основни групи пластмаси (термопласти, дуропласти и еластомери).



Фиг. 5 Метод на лазерно гравирание върху повърхността на материала

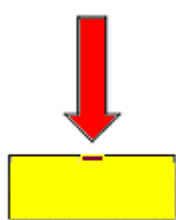
2.6 Оцветяване

Различни цветни ефекти при лазерно въздействие върху материала могат да се постигнат чрез добавки (сляда, сажди), предварително вкарани в структурата на пластмасата. При маркировката се отстраняват специалните пигменти от основния материал. Така може да се постигне един изключително много добър контраст с резки контури, които подобряват четимостта на маркирания знак. Също и в бъдеще този вид пластмаси ще има водещо значение при изделия, подложени на лазерно маркиране за получаване на различни ефекти: тъмна маркировка върху светла основа, светла маркировка върху тъмна и цветна маркировка върху цветен материал (фиг. 6).

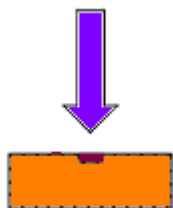
2.7 Фотохимично въздействие

При използване на лазери, излъчващи в ултравиолетовата област се откриха нови възможности за маркиране. Ултравиолетовото късовълново лъчение предизвиква директна

фотохимична реакция на основния материал без да го загрева и без да предизвиква разрушение на повърхността (фиг. 7).



Фиг. 6 Оцветяване на повърхността на някои полимерни материали при лазерно въздействие

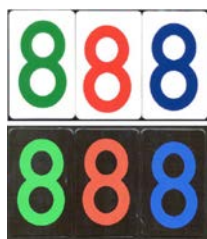
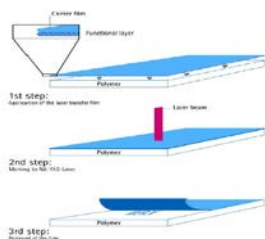


Фиг. 7 Фотохимично „студено“ маркиране с ултравиолетов лазер

Този метод е особено удачен при маркиране на пластмасови материали, които са лесно запалими. При него се постига добър контраст и висока скорост на маркиране.

2.8 Лазерно трансферно цветно маркиране.

Методът на лазерното цветно трансферно маркиране е известен в специализираната научна литература, като Laser Color Transfer (LCT®). Техника на маркиране (LCT®), която успешно се прилага на пластмаси от типа термопласти. Въпреки, че в някои отношения има общи черти с изобретените до тук методи (лазерното лъчение действа на повърхността, като топлинен източник), той има и своя характерна специфика.



Фиг. 8 Цветно трансферно маркиране (LCT®) [4]

Задължително се преминава през три стъпки (фиг.8). Първо върху пластмасовата повърхност чрез вакуум се прилепва цветно трансферно фолио. Вакуумът е необходим, за да се обезвъздуши пространството между полимера и фолиото. Ако останат въздушни мехурчета в междината между фолиото и повърхността на материала, те се явяват пречка за последващата технологична операция, при това качеството на маркирания знак се влошава. При въздействието лазерното лъчение загрева фолиото и материала под него. В резултат на това багрилото от трансферното фолио се пренася върху основния материал (полимера). Образува се здраво цветно съединение между разтопената повърхност на полимера и багрилото (фиг.8). Възможно е методът да се реализира върху един и същ материал в шест цвята (черен, червен, син, зелен, жълт и бял). Това е съществено предимство пред метода описан в точка 2.6, където е възможно само получаването на един цвят върху повърхността на даден материал.

2.8 Комбиниран

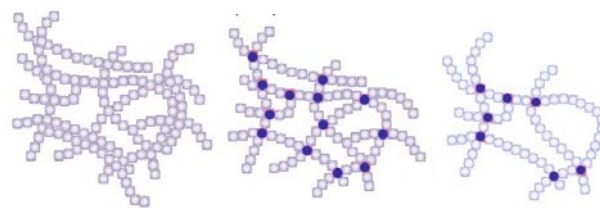
Всички изброени по-горе ефекти могат да се комбинират по определен начин помежду си, като за целта задължително се отчитат два фактора влияещи на абсорбционната способност: дължината на падащото лазерно лъчение λ и физическите свойства на пластмасата. Изборът на определен метод зависи също и от предназначението на изделието, и неговите функционални особености. Така например за набъбване се изисква по-голяма падаща енергия на лазерното лъчение. За постигане на определен комбиниран ефект може да се наложи и допълнително отлагане на слоеве върху основния материал или промяна на неговия състав чрез добавка на пълнители, багрила и др.

3. Абсорбционно поведение на пластмасите

Пластмасите са систематични органични материали. Те се състоят в повечето случаи от въглеродни съединения, които образуват макромолекули. Според своята структура пластмасите се делят на три основни групи (фиг.9):

- термопласти
- дуропласти
- еластомери

Термопластите притежават нишковидни макромолекули, които са преплетени една в друга, но не са свързани помежду си. При дуропластите макромолекули са частично свързани помежду си, като са създадени здрави химични връзки. Третата група - еластомерите са еластични пластмаси, на които макромолекулите са съединени помежду си, но имат слаби химични връзки.



Фиг. 9 Структури на различните видове пластмаси

В основната структура на пластмасите могат да се внедряват примеси от различен вид:

- пълнители – сажди, кварц, стъкловолокна;
- помощни материали – смазки;
- добавки – химически стабилизатори;
- разтворими органични стабилизатори;
- оцветители, пигменти [5]

Процесът на лазерно маркиране и получения ефект върху полимерната повърхност зависят от степента на абсорбция на лазерното лъчение в материала (фиг.10). При лазерно въздействие енергията на лъчението се поглъща на повърхността на материала. Макромолекулите на основния материал абсорбират добре лъчения с дължини на вълните от далечната инфрачервена и ултравиолетова области (това са дължините на вълните на CO₂- и ексимерните лазери). Добри примери в тази насока са PC, поливинилхлорид (PVC), PET и ABS и др. (фиг.11). Те добре абсорбират лазерно лъчение от този спектрален диапазон и при тях не е необходимо включването на специални добавки.

Други индустриални пластмаси, като PP, PE и PMMA показват ниска степен на абсорбция и не са така податливи на маркировка. (табл.2).

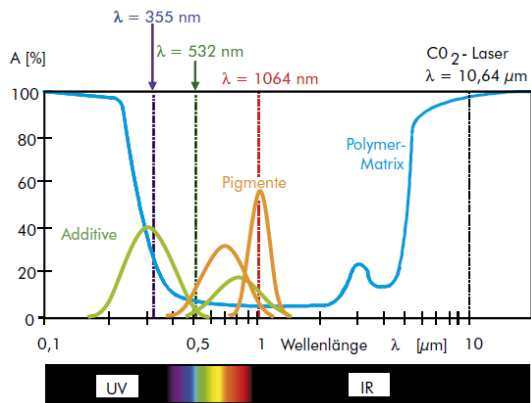


Fig.10 Абсорбционният спектър за някои полимери. Посочени са дължините на вълните на най-често използваните лазери за маркиране CO₂ и Nd:YAG лазери. [6]

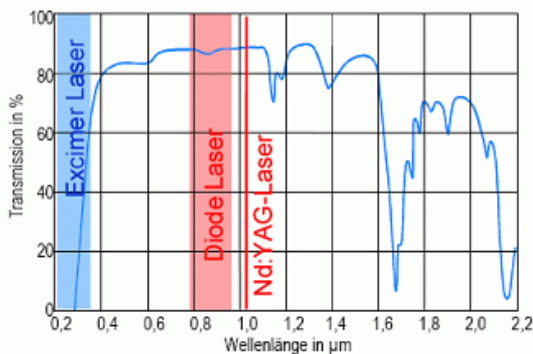


Fig.11 Трансмисионен спектър за поликарбонат (PC) с дебелина 3,2 mm

Затова в тях е необходимо предварително да се включат добавки, оцветители и пълнители, които оказват силно влияние на абсорбцията и повишават чувствителността на полимерите към лазерното въздействие. Добавките подобряват повърхностната абсорбция на лазерното лъчение и повишават скоростта на маркировка. От своя страна добавените багрила и оцветители засилват цветовия контраст при реализиране на конкретната маркировка. Това позволява лазерно лъчение от близката инфрачервена $\lambda = 1064$ nm и видимата област $\lambda = 532$ nm сравнително добре да се абсорбира и в тези материали. В резултат на този феномен става възможно при лазерно маркиране с дължини на вълните от този спектрален диапазон да се постигне добър контраст при висока скорост на маркиране. Напоследък се създадоха специални пластмаси с определени добавки, които са чувствителни към лазерно въздействие и с тях изделията лесно се маркират [7]. Типични пластмаси, които са податливи на маркиране след поставяне на тези добавки са полиформалдехид (POM) полиуретан (PU), PE, PP, PS и PVC.

Табл. 2: Класификация на пластмасите според податливостта им към лазерно маркиране без и с добавки

добра маркировка без добавки	добра маркировка само ако има в пластмасата добавки	възможна маркировка само ако има специални добавки за лазери
■ ABS ■ PC ■ PPSU ■ PBT ■ PBTP ■ Styrol (SAN) ■ PEEK ■ UREA	■ PS ■ PI ■ PETP ■ POM ■ PPS ■ ASA ■ PES ■ PEI ■ PE ■ PA ■ PVC	■ Polyester ■ PU ■ Polyolefine (PEHD, PP) ■ PMMA ■ PTFE

4. Лазерни източници

Най-широко разпространените лазерни източници, които се използват в маркиращи системи са: CO₂ и Nd:YAG лазерите, диодните и ексиммерните лазери, както и появилите се напоследък фибер лазери. Те покриват доста широк диапазон от електромагнитния спектър (фиг.12). Сравнение между различни видове лазери, дължините на вълните на излъчване и възможните методи за маркировка с тях е представено на табл. 3

Табл. 3 Видове лазерни източници за маркиране, спектралните им диапазони и методи на приложение

ВИД	спектрална обл.	λ , nm	метод
CO ₂	инфрачервена	10 600	гравировка
Nd:YAG	инфрачервена	1064	карбонизация
Nd:YAG	видима	532	оцветяване, набъбване
Ексимерни	ултравиолетова	191-352	оцветяване чрез въздействие на пигменти

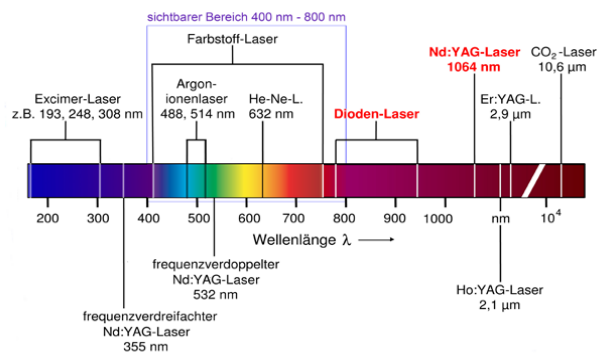


Fig.12 Дължините на вълните на излъчване при различните видове лазерни източници

TEA - CO₂ лазера (Transversal Excited Atmospheric) работи на базата на въглероден двуокис, като активна среда и излъчва лъчение в далечната инфрачервена област на спектъра $\lambda = 10600$ nm. Този лазер предимно се използва за маркиране чрез гравироване. Енергията на лъчението отива предимно за нагряване и стопяване на материала в зоната на обработка. Поради сравнително големия диаметър на работното петно този лазер успешно се използва за маркиране с помощта на маска, при нанасяне на лого на фирма и други изображения върху повърхността на изделието. Подходящи материали са венилхлорид (VC), карбамидоформалдехидни смоли и пластмаси с пълнители на слюда и филосиликати.

Nd-YAG (Neodymium:Yttrium-Aluminium-Granat) лазерът е най-широко разпространения лазер за маркировка, като главно се използва за въздействие върху термопласти. Този лазер с подходящ скенер и софтуер за управление предлага добра комбинация от скорост, качество и гъвкавост при реализиране на маркировката. Той излъчва главно в близката инфрачервена област $\lambda = 1064$ nm. За маркировка могат да се използват и хармоничните му честоти при $\lambda = 532$ nm и $\lambda = 355$ nm. Типични мощности, които се използват за маркирането на пластмаси са в интервала 50 ÷ 250 W, продължителност на импулсите от 10 ns до 100 ns и честота на следване на импулсите до 120 kHz. Лъчението се поддават се на фино фокусиране, като диаметърът на работното петно може да достигне 30 μm. Тази прецизна фокусировка е много полезна за маркиране на много малки елементи от микроелектрониката и соларната техника.

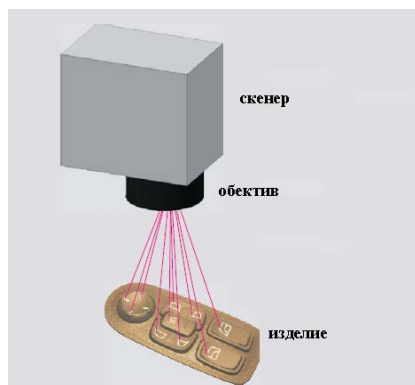
Диодните лазери притежават доста широк диапазон на спектрално излъчване от 780 nm до 980 nm. Диапазонът на мощностите е от няколко вата до няколко киловата. Обаче качеството на лъча и възможността му да се фокусира на малка площ са доста ограничени, но за сметка на това имат висок коефициент на полезно действие, достигащ до 50%.

Ексимерните лазери предлагат също доста широк спектрален диапазон от 193 nm до 351 nm. Те имат и по-висока разрешителна способност при маркиране, тъй като могат да се фокусират в петно с по-малки размери, отколкото лъчението на Nd-YAG лазерите. Може също да се прилага при технологията за маркиране с проекционния способ - чрез маска. Като цена са по-скъпи в сравнение с Nd-YAG лазерите. Все пак те имат своя завоювана ниша, каквато е маркирането на изделия за космическата техника и самолетостроенето, където се изисква висок контраст и същевременно почти липсват изменения на свойствата на материала. Производителите на лесно запалими материали също предпочитат техните изделия да се маркират с UV лазери, тъй като липсва нагряване в зоната на въздействие каквато е случаят при въздействие с дължини на вълните от инфрачервената област. Аналогична е ситуацията и при приложението за маркиране на медицински инструменти, тук е особено важно да се запази гладкостта на повърхността, за да не станат зоните на обработка центрове, където могат да се натрупват бактерии.

Файбер лазери се появиха през последните 10 години, но притежават редица предимства пред другите източници на лазерно лъчение [8]:

- лесен транспорт на лазерното лъчение по стъкловолокно до зоната на обработка;
- много добро качество на лазерния лъч;
- висок коефициент на полезно действие – ниски разходи за захранване на напompващите диоди;
- висок експлоатационен ресурс – времето на живот на диодите е над 100 000 часа;
- времева и пространствена стабилност на лъчението през цялото време на въздействие;
- малки габарити, което е предпоставка за мобилност;
- лесно вграждане в технологични линии с непрекъсваем процес.

Поради тези си предимства файбер лазерите все по-често измества другите лазери от утвърдени вече промишлени технологии за маркировка.



Фиг. 13 Сканер с обектив от технологична система за маркиране на пластмасови изделия

При маркиране с твърдотелни Nd-YAG, файбер и диодни лазери най-често за управление и преместване на лъча в рамките на работната зона се използва сканер. Двойка галвано огледала отклоняват лъча по X и Y, а обективът фокусира лъчението върху работната повърхност (фиг.13). С него са приложими, както метода на векторно маркиране, така и на растерно. Максималната скорост на преместване на лъча е 12 m/s, което позволява да се маркират 100 символа в секунда. Работното поле е от 60 x 60 mm до 290 x 290 mm.

5. Заключение

Твърдотелните лазери с диодно напompване и файбер лазерите се наложиха на пазара през 1998 г., а UV – лазерите се появиха едва преди 9 години. Пробиът на файбър лазерите в бранша на лазерното маркиране на пластмаси е през последните 5 години. Ексимерните (UV) – лазери напоследък също започнаха да търсят незаети ниши в този бранш.

Глобализацията на производството и търговията поставя нови и нови изисквания към маркировката на изделията, които се предлагат на пазара. Едно, от които е изискването за автоматизирано разчитане на информацията. Задължителна практика, съгласно международните стандарти вече е да се нанася на изделията маркировка във вид на bar-кодове и 2-D матрични кодове. Посредством нанесената върху тях информация потребителят получава данни за производителя, държавата, технически характеристики за изделието и др. През последните години изключително нарасна ролята на лазерната маркировка и като възможност за защита на интелектуалната собственост и предпазване на производителя от появата на фалшификати на пазара с имитация на неговите продукти.

Много е направеното в областта на лазерното маркиране, но многообразието е огромно и все още има широки възможности за нови иновации в тази област, затова и активните изследванията и развитието продължават и ще продължи и за в бъдеще.

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SIMPLIFIED ANALYSIS OF DISPERSION AND ATTENUATION OF THE BRAGG FIBER

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Abstract: In this article the mechanism of spreading of optical radiation in a Bragg fiber is considered. A mathematical model for analysis of a Bragg fiber viewed as a flat multilayered dielectric structure has been proposed. The method of geometrical optics of description of spreading the light is used. Formulas connecting the clad refractive index with fiber parameters are given. The light attenuation at its refraction in the multilayered clad and chromatic dispersion are calculated, as well as the dielectric loss of the clad material. The dispersion and the width of the waveband of Bragg fibers with different number of layers and low waveguide modes have been compared. Examples of fibers with different coefficient of dielectric material loss are included.

Keywords: BRAGG FIBER, GEOMETRICAL OPTICS, DISPERSION, ATTENUATION

1. Introduction

In the conventional optical fibers, propagation of the light only in the core is caused by the total internal reflection from the clad. This is possible when the effective refractive index of the core is greater than the cladding. The Bragg fiber is one dimensional fiber and is constructed as uniaxial cylindrical layers. The fiber cladding is a dielectric mirror, realized as a multilayer dielectric coverage [2]. This kind of fibers is a part of so called Photonic Crystal Fibers (PCF) or microstructured fibers. The term marks the most of the optical fibers with a complicated clad structure; which often includes one- or two-dimensional periodic structures and has substantial influence on the optical properties of the fiber [3]. PCF decrease significantly the restrictions, caused by the materials and the construction of the conventional optical fibers and allow the characteristics of the fibers as bandwidth, dispersion, nonlinearity, modal area to be controlled more freely [5]

The attenuation of the light in the fiber during transmission to long distances is critical. In the usual fibers, the attenuation is limited by the Rayleigh scattering of the energy of spreading modes. Because of that, when manufacturing, the fibers should use pureness materials with low dielectric losses.

All PCF allow easy changing of dispersion and can compensate the dispersion in the telecommunication fibers. The high attenuation can be overcome by a new design [6].

Cross-sections of different kinds of optical cylindrical PCF are shown in fig. 1. These fibers have different mechanism to keep the light inside the core.

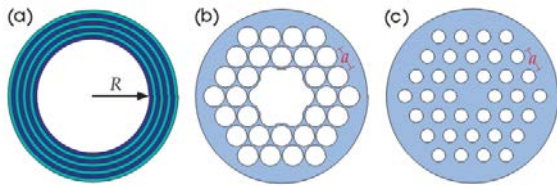


Fig. 1 PCF fibers. (a) Bragg fiber, with a one-dimensional periodic cladding of concentric layer; (b) Two-dimensional periodic structure (a triangular lattice of air holes – “holey fiber”), confining light in a hollow core by a band gap; (c) Holey fiber that confines light in a solid core by index guiding.

Nowadays there is no universal and precise enough method of evaluation of the fiber losses, which allows an optimizing of construction properties (diameter, layers thickness, refractive index of the material) in a given frequency band. Numerical solution of the Maxwell equations is realized in many software systems, but it needs significant computation power. Solution of the system of partial differential equations takes tens of minutes or hours. Despite of some accessible software modules, creating such a completed software tool is not an easy task. The software systems, ready to use, are specialized to analyze a group of similar problems and they are expensive.

Next we will propose an engineering accuracy method for analyzing the light propagation in a multilayer Bragg fiber with a hollow core as a result of tunneling and taking into account the dielectric losses of the fiber clad.

2. Mathematical model

Suppose we have a Bragg optical fiber with M cylindrical layers of cladding. The core refractive index is n_a . A cross-section view of the fiber is presented in Fig. 2.

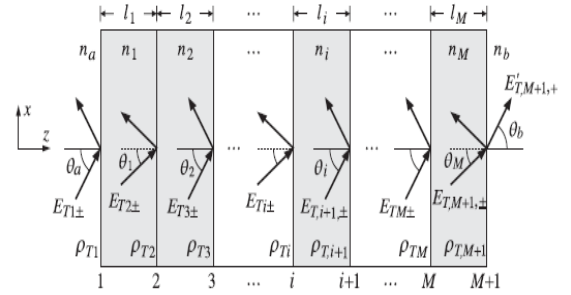


Fig. 2 Oblique incidence in multilayer dielectric structure

Because of central symmetry of the fiber, only half of a longitudinal section is shown. We suppose that the fiber is like a flat multilayer dielectric structure [1]. From the left to the right in the figure are located the core, layer 1, layer 2, layer 3,..., layer M of the cladding. The symbol n_a marks the core refractive index. n_i is the refractive index of the layer number i . n_b is refractive index of the uppermost layer. The thickness of the layer i is signed as l_i , $i=1, 2, 3,...,M$. Here $E_{T,k\pm}$, $k=1, 2,..., M+1$ marks falling (+) or refracted (-) parts of electrical field at the border of layer k and the layer on the left before it. The leaking field from waveguide is signed as $E'_{T,M+1,+}$. The Snell's law describes the relationship between the angles of incidence and refraction and the refractive indexes of the material at the border surface between every two of all $M+1$ boundary layers:

$$(1) \quad n_a \sin \theta_a = n_i \sin \theta_i = n_b \sin \theta_b,$$

when $i=1, 2, 3,..., M$.

We suppose there is no incident field on the right of the structure. Here ρ_{Ti} is a transverse refractive index of surface number i , defined as:

$$(2) \quad \rho_{Ti} = \frac{n_{Ti-1} - n_{Ti}}{n_{Ti-1} + n_{Ti}}, \quad i=1, 2, 3,..., M+1,$$

where $n_{T0} = n_a$ and $n_{TM+1} = n_b$. The phase shifting of incident beams, passing through the layer number i is given by $\delta_i = k_0 n_i \cos \theta_i$, where k_0 is the wave number in the free space, $k_0 = \frac{2\pi}{\lambda}$.

In every layer, the transverse refraction factors for *TM* and *TE* polarization are described as:

$$(3) \quad n_{Ti} = \begin{cases} \frac{n_i}{\cos \theta_i}, & \text{TM polarization} \\ n_i, & \text{TE polarization} \end{cases},$$

where $i = a, 1, 2, \dots, M, b$.

The spreading matrix associates the electric field density of the incident with refracted beam recursively:

$$(4) \quad \begin{bmatrix} E_{Ti,+} \\ E_{Ti,-} \end{bmatrix} = \frac{1}{\Gamma_i} \begin{bmatrix} \exp(j\delta_i) & \rho_{Ti} \exp(-j\delta_i) \\ \rho_{Ti} \exp(j\delta_i) & \exp(-j\delta_i) \end{bmatrix} \begin{bmatrix} E_{Ti+1,+} \\ E_{Ti+1,-} \end{bmatrix},$$

where $i=M, M-1, \dots, 1$. Here the refractive factor is $\Gamma_{Ti} = E_{Ti,-}/E_{Ti,+}$ and associates Γ_{Ti+1} with recursion:

$$(5) \quad \Gamma_{Ti} = \frac{\rho_{Ti} + \Gamma_{Ti+1} \exp(-2j\delta_i)}{1 + \rho_{Ti} \Gamma_{Ti+1} \exp(-2j\delta_i)}, \quad i=M, M-1, \dots, 1,$$

where $\Gamma_{T,M+1} = \rho_{T,M+1}$.

A similar association exists between electric and magnetic field on the boundary between 2 layers:

$$(6) \quad \begin{bmatrix} E_{Ti} \\ H_{Ti} \end{bmatrix} = \begin{bmatrix} \cos \delta_i & j\eta_{Ti} \sin \delta_i \\ j\eta_{Ti}^{-1} \sin \delta_i & \cos \delta_i \end{bmatrix} \begin{bmatrix} E_{Ti+1} \\ H_{Ti+1} \end{bmatrix},$$

where $i=M, M-1, \dots, 1$.

In (6) the transverse characteristic impedances are defined as:

$$(7) \quad \eta_T = \begin{cases} \eta \cos \theta & \text{TM polarization} \\ \frac{\eta}{\cos \theta} & \text{TE polarization} \end{cases},$$

where $\eta_{Ti} = \eta_0 / n_{Ti}$. The total power of incident beam P_{in} towards the wave vector direction, its z component and the input power into first layer P_1 for *TE* and *TM* polarizations are given by:

$$(8) \quad P_{in} = \frac{1}{2\eta_a} |E_{in}|^2, \quad P_{in,z} = P_{in} \cos \theta_a,$$

$$\eta_a = \eta_0 / n_a, \quad P_1 = P_{in,z} (1 - |\Gamma_1|^2).$$

The losses of reflection are:

$$(9) \quad \frac{P_1(\lambda)}{P_{in,z}(\lambda)} = 1 - |\Gamma(\lambda)|^2,$$

The normalized attenuation is:

$$(10) \quad B(\lambda) = \frac{P_{in,z}(\lambda) - P_1(\lambda)}{P_{in,z}(\lambda)} = |\Gamma(\lambda)|^2.$$

We discuss a fiber with radius a , core refractive index n_a , cladding refractive index n_1 . The light is spreading when $\sin \theta_a > n_1/n_a$. Fig. 3 shows the trajectory of beams.

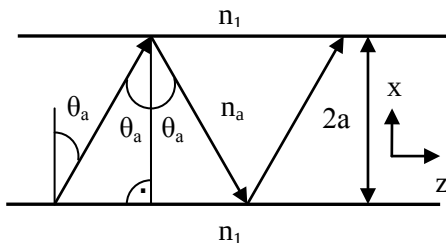


Fig. 3 Meridional beams in the core

The spreading modes of index m have discrete values of the angle θ_a . The transverse resonance condition expresses the phase change for one zigzag of the beam, multiple by 2π :

$$(11) \quad 4ak_0 n_a \cos \theta_a + \varphi = 2m\pi$$

where φ is a phase changed by reflection from the boundary core - cladding. Between two sequential refraction, the path of light beam is $lz = 4a \cdot \tan \theta_a$. If the length of the fiber is equal to L , there are N reflections inside the core, where $N = L/lz$. The losses $B(\lambda)$ in a fiber with length L for *TE* and *TM* polarization are proportional to N :

$$(12) \quad B(\lambda) = N |\Gamma(\lambda)|^2 = \frac{L |\Gamma(\lambda)|^2}{lz}.$$

The reflection factor is $\Gamma(\lambda) = |\Gamma(\lambda)| \exp(\arg(\Gamma(\lambda)))$, and the phase change when the beam passes through the entire fiber is $N \cdot \arg(\Gamma(\lambda))$. The delays of beams with *TE* and *TM* polarization are respectively τ_e and τ_m . They are calculated by an expression [4]:

$$(13) \quad \tau(\lambda) = \frac{\lambda^2}{2\pi \cdot c} \frac{d(\arg(\Gamma(\lambda)))}{d\lambda},$$

where $\Gamma(\lambda)$ is reflection factor for *TE* and *TM* modes.

The chromatic dispersion of the fiber d_{cr} is given by the expressions:

$$(14) \quad d_{cr}(\lambda) = \frac{d\tau(\lambda)}{d\lambda} = \frac{2\tau(\lambda)}{\lambda} - \frac{\lambda^2}{2\pi \cdot c} \cdot \frac{d^2(\arg(\Gamma(\lambda)))}{d\lambda^2}$$

The total attenuation $BN(\lambda)$ along the whole length of the fiber is expressed as a sum of the particular area attenuations $Bi(\lambda)$ in which the reflected beam is signed with integer number $1, 2, 3, \dots, N$, as follows:

$$(15) \quad \begin{aligned} B_N(\lambda) &= B_1(\lambda) \cdot B_2(\lambda) \cdot B_3(\lambda) \dots B_N(\lambda) = \\ B_i^N(\lambda) &= (\Gamma^2(\lambda))^N. \end{aligned}$$

In expression (15) $\Gamma(\lambda)$ are complex refractive coefficients in areas with incident angle θ_a :

$$(16) \quad \Gamma(\lambda) = \alpha + j\beta.$$

The real part α accounts the propagation losses, and the imaginary part β is a phase coefficient. When in the clad there are dielectrical losses, the refractive index n and wave vector k are complex numbers too:

$$(17) \quad n = n' - jn'', \quad k = k' - jk'',$$

The propagating electrical field trough z axis is represented as:

$$(18) \quad \begin{aligned} E(z) &= E_0 \exp(-\Gamma z) = E_0 \exp(-\alpha z) \exp(j\beta z) = \\ &= E_0 \exp(-jkz) = E_0 \exp(-k''z) \exp(-jk'z) = \\ &= E_0 \exp(-k''z) \exp(-j \frac{2\pi n'}{\lambda} z). \end{aligned}$$

The phase coefficient β can be expressed by the real part of the refractive coefficient α and the wave length in free space λ as $\beta = \frac{2\pi n}{\lambda}$. Usually

$$(19) \quad \alpha [dB/km] = 10 \lg(\alpha z).$$

From (17, 18, 19) follows:

$$(20) \quad \alpha = k'' = \frac{2\pi n''}{\lambda}, \quad n'' = \frac{\lambda \alpha}{2\pi}.$$

When dielectrical losses are low, $n'' \approx \tan \delta$.

3. Examples

Let's have a M -layers Bragg fiber with an air core, a core radius $a=62\text{ }\mu\text{m}$; $n_a=1.0$, $n_b=1.5$. The cladding consists of three different materials, each of them having different losses. (H , L , b layers). The thickness of the layers is chosen so as to make a phase difference of 90° for the central wave length $\lambda_0=1500\text{nm}$.

The user enters loss coefficients of the layers α_H , α_L , α_b . After solving the characteristic equation (11) for $m=1$ and doing some calculations according to the above proposed mathematical model, we obtain as a result the refractive coefficients of the multilayer cladding.

Then we calculate the normalized attenuations $B_{te}(\lambda)$ for TE polarization in [dB] for a fiber without deformation.

After that, we obtain the group delay and dispersion. The influence of the losses α [dB/km] of the clad on the attenuation of TE wave is shown in fig. 4.

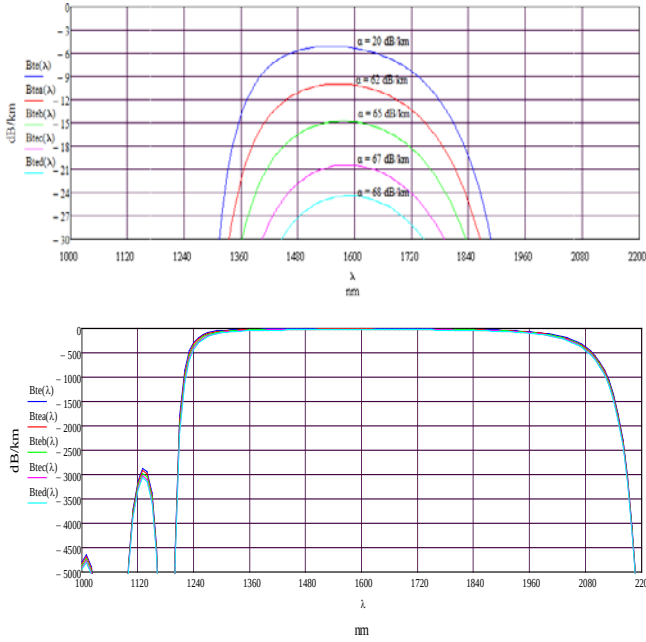


Fig. 4 Attenuation $B_{te}(\lambda)$ when the material has different losses. The upper diagram range is 30 dB; the lower diagram range is 5000 dB

Fig. 5 shows a comparison between attenuations B_{te} of the first TE mode in the Bragg fiber with $M=9$ layers of the cladding and conventional SMF, depending on losses of material α [dB/km], when the wavelength is fixed to $\lambda=1550\text{nm}$.

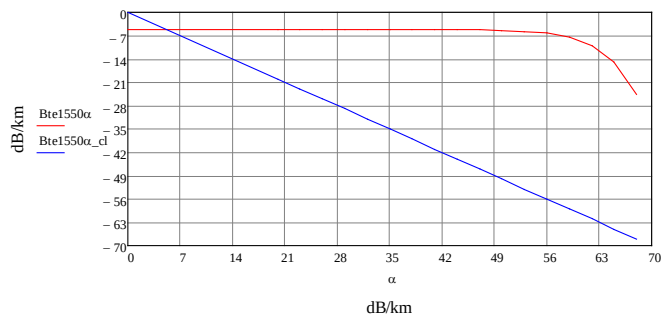


Fig 5 Attenuation of Bragg fiber and SMF when losses of the clad are different

The comparison of the attenuation of the Bragg fiber and conventional SMF shows, that in case of $\alpha < 7\text{dB/km}$ the conventional SMF has lower attenuation per unit length. When losses α rise above 7dB/km , the Bragg fiber can have lower attenuation than SMF.

Fig. 6 shows changing of the attenuation of the fundamental TE mode ($m=1$), in a Bragg fiber with core radius $a=62\text{ }\mu\text{m}$, $\lambda=1550\text{nm}$, as function of losses in material α . Here are some

diagrams of the attenuation $B_{te}(\alpha)$ in a fiber with different number of clad layers ($M=9-21$). The diagram shows, that with increasing of the number of the dielectric clad layers the attenuation of the fibers decreases, this decreasing changing more intensively in fibers containing fewer numbers of layers in the clad, than in fibers containing over 13 layers in the clad. The increasing of α above 50dB/km abruptly increases total attenuation of the fiber. However, even in fibers with 11 layers and losses $\alpha < 68\text{dB/km}$, total attenuation is less than -20dB/km .

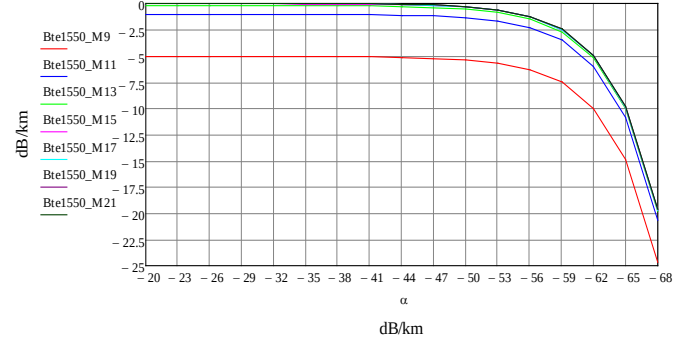


Fig. 6 Attenuation $B_{te}(\alpha)$ in a Bragg fiber with $M=9-21$ cladding layers

Fig. 7 shows shifting of the maximum of the wave characteristic of the Bragg fiber with different numbers of layers $M=9, 11, 13, 15$, when losses of material in cladding α increase. It is shown that this shifting depends more strongly on losses of the material cladding α in fiber with larger numbers of layers in the clad.

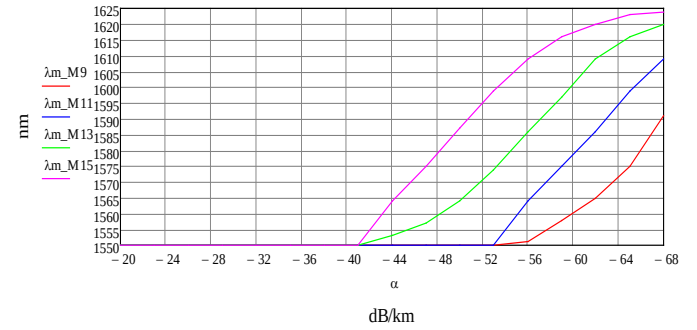


Fig.7 Maximum of the wave characteristic, depending on the losses in a fiber with different number clad layers

Fig. 8 shows the changing of the bandwidth $\Delta\lambda$ [nm] of the wave characteristic $B_{te}(\lambda)$ on level -3dB , depending on the losses of the fiber cladding material α [dB/km] when $M=9, 11, 13, 15$ cladding layers.

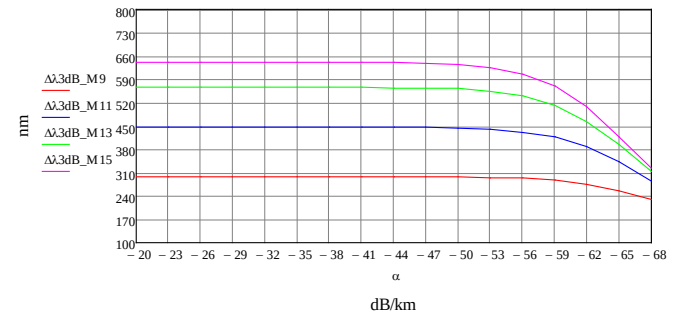


Fig. 8 Changing the bandwidth, depending on losses in a fiber with different number clad layers

The bandwidth $\Delta\lambda$ is narrower in fiber with fewer numbers of layers and decreases when α rises. For example, when $M=9$ layers, and $\alpha=0\text{dB/km}$ the bandwidth is $\Delta\lambda=300\text{nm}$ and when $\alpha=68\text{dB/km}$ the bandwidth decreases to $\Delta\lambda=230\text{nm}$.

Fig. 9 shows the changing of the steepness st_{plus} and st_{minus} of short wave and long wave slopes of the wave characteristic

$Bte(\lambda)$, depending on the losses α [dB/km], the number of clad layers being $M=15$.

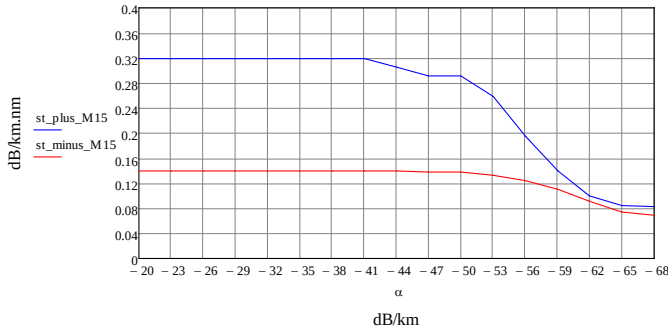


Fig. 9 Slope of the wave characteristic as a function of losses

The studies show that steepness of the slopes of wave characteristics rises when the number of fiber layers rises due to the decreasing of the attenuation and increasing the flatness of the wave characteristic $Bte(\lambda)$ in the bandwidth.

Fig. 10 shows the attenuation $Bte(\lambda=1550nm)$ in the fiber as a function of clad material losses $\alpha=20-68dB/km$. On a common diagram are represented attenuations in fibers with $M=9$ layers and different core radius ($a=10-100\mu m$).

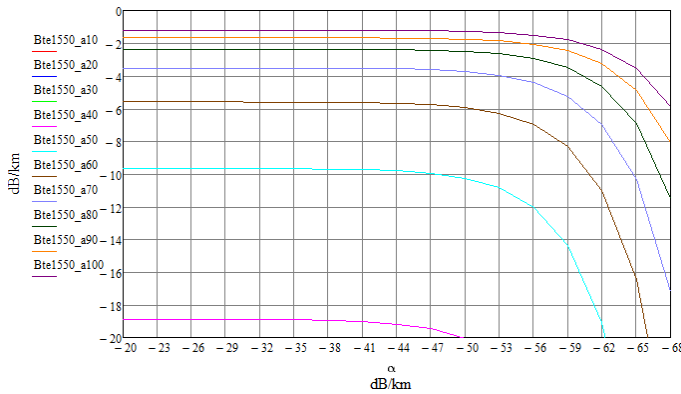


Fig. 10 Attenuation, depending on the losses in a fiber with different core radius

The chart demonstrates the decreasing of attenuation of the Bragg fiber, when the radius of the hollow core increases.

Fig. 11 presents the attenuation of the same fiber as a function of the clad material losses, presented by $tg\delta$ and with different fiber core radius ($a=10-100\mu m$).

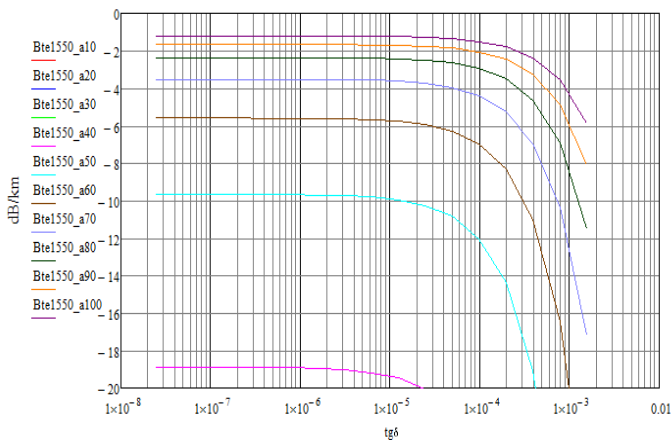


Fig. 11 Attenuation of the fiber as a function of clad material losses and core radius

4. Conclusion

The proposed mathematical model and the calculation algorithm allow an approximate analysis of the basic characteristics of Bragg fiber. This method makes it possible for optical fibers with M ($M \leq 21$) clad layers to be analysed. The obtained numerical results show the influence of losses of real dielectric materials over the attenuation of the wave propagation in the Bragg fibers.

The comparison between the attenuation of Bragg fiber with small numbers of layers ($M=9$) and conventional SMF with the same dielectrical losses, α of the material clearly shows that the Bragg fiber has an attenuation greater than the usual SMF, when the losses in the dielectric clad are small ($\alpha < 7dB/km$) due to limited transparency of the cladding. The increasing the losses in the dielectrical cladding ($\alpha > 7dB/km$) makes the Bragg fiber attenuation less than the attenuation in the SMF. In case when $\alpha < 20dB/km$, losses of the dielectric material slightly influence over the attenuation in the fiber. This difference becomes very small when losses exceed $60dB/km$ ($tg\delta > 10^{-4}$). The attenuation increases very fast (by more than $20dB/km$) when $\alpha > 70dB/km$. This means that to manufacture Bragg fibers, it is not necessary to use the complicated technology, to get pure materials, usually used for conventional optical fibers.

Increasing the fiber air core radius decreases the attenuation in the fiber.

The bandwidth decreases relatively slightly when the losses of the material increase. The wave characteristic is asymmetric, its short wave slope being shorter and steeper and the long wave one more gradual and longer. The steepness of the slopes depends on value of the losses. When the losses of clad material increase, the steepness of short wave slope decreases and the steepness of the long wave one increases.

When the dielectric losses increase, the dispersion and the group delay time decrease.

The method of geometrical optics is less accurate than numerical methods of calculations of the field, used in some software packets, based on a large group of general and specific methods of solving Maxwell equations. The obtained quantitative and qualitative dependences for PCF Bragg fiber are similar to the other ones, for example [3], [7], [9]. This analytical method of calculation is a lot faster than the numerical ones, because of its simplicity.

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RESEARCH OF THE CHARACTERISTICS OF A STEGANOGRAPHY ALGORITHM BASED ON LBS METHOD OF EMBEDDING INFORMATION IN IMAGES

ИЗСЛЕДВАНЕ НА ХАРАКТЕРИСТИКИТЕ НА СТЕГНОГРАФСКИ АЛГОРИТЪМ БАЗИРАН НА LSB МЕТОДА ЗА ВГРАЖДАНЕ НА ИНФОРМАЦИЯТА В ИЗОБРАЖЕНИЯ

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Abstract: The article deals with the steganography system which hides text inside images without losing data. The secret message is hidden in the cover image using Last Significant Bit (LSB) algorithm. To evaluate steganography system properties the measures like Signal-to-Noise Ratio (SNR), Peak Signal-to-Noise Ratio (PSNR), Mean Squared Error (MSE) and Structural Similarity Index for measuring (SSIM) are used. Experimental results show the advantages of the described steganography system.

Keywords: STEGANOGRAPHY, LSB, SNR, PSNR, MSE

1. Introduction

Modern world communication between companies and consumers needs a more protected and secure exchange of confidential information via Internet. One way to achieve this is, through the use of stenography. It ensures secure data transfer, due to the very fact of hiding the implementation of secret communication. Two steganographic categories are defined in [1]. The first, called Fragile includes embedding information in a file that will be destroyed if it is changed. The other type of steganography is considered to be Robust. Its purpose is to embed information in a file that cannot be easily destroyed. Steganography algorithms can also be classified according to other criteria. According to the object in which the secret message will be embedded, steganography can be achieved through images, audio and video files, text or web protocols.

To be able to select a steganography algorithm for a particular application, it is necessary to clearly distinguish between the pros and cons of each one of them. A major factor is the identification of specific indicators by which to evaluate algorithms. The criteria which one steganography algorithm must meet are invisibility, amount of embedded data, type of files, sustainability of stego-analysis and sustainability of modification.

All criteria of a method cannot be optimized simultaneously. For example, if you need to embed a large amount of data, the image quality will deteriorate and/or a compromise on any of the properties of the method will have to be done. Adding extra property to the method of hiding data (such as detecting illegally altered areas in the image) reduces the maximum amount of embedded data and/or reduces the quality of the image. When evaluating methods for hiding data, these compromises should be taken into account.

2. Basic characteristics of steganography algorithms evaluation

When comparing two images four major statistical properties which describe the degree of similarity between the images are calculated: *MSE* (Mean Squared Error), *PSNR* (Peak Signal-to-Noise Ratio), *SSIM* (Structural Similarity Index for Measuring), and images entropy.

The calculation of the *MSE* (Mean Squared Error) is a standard statistical approach to objectively measuring the degree of difference between two images. A small value of the *MSE* means that the average level of difference between them is little. In the case of two identical images, the *MSE* value is zero. Unlike

the *MSE*, a greater value of *PSNR* means better image quality. When there is uniformity of two images, *PSNR* has a value tending towards infinity. The main purpose of all steganography methods is to minimize the value of the *MSE*, and accordingly maximizing the value of the *PSNR*.

The characteristics studied are represented by formulas (1) and (2), the *PSNR* is based on values obtained for the *MSE*:

$$(1) \quad MSE = \frac{1}{mn} \sum_{i=0}^{m-1} \sum_{j=0}^{n-1} [I(i, j) - K(i, j)]^2,$$

Where m and n are the width and height of the image; $I(i, j)$ and $K(i, j)$ are relevant pixels with coordinates (i, j) in the original stego-image.

$$(2) \quad PSNR = 10 \cdot \log_{10} \left(\frac{max^2}{MSE} \right) = 10 \cdot \log_{10} \left(\frac{max}{\sqrt{MSE}} \right),$$

where $max = 255$ for 8 bit images.

The degree of similarity of the images before and after the embedding of the data, measured by the *MSE* and the *PSNR*, determines the quality the stego-image [5]. When the similarity between the images studied is small it is assumed that the quality of the stego-image is lower.

Figure 1 is a block diagram visualizing the steps of calculating the basic functions of the images quality. From the figure it becomes clear that they are interrelated and derived from one another.

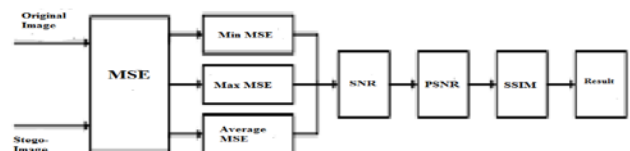


Fig. 1. Block diagram of the transformation of the basic qualitative characteristics of an image

The *SSIM* index (Structural Similarity Index for measuring) is similar to the *MSE* and the *PSNR*, but is designed to improve them both. As an indicator it measures changes in brightness, contrast and structure of an image. What is needed to obtain the *SSIM* is, to combine the values obtained for the average intensity of the brightness, the variations in the contrast and the structure of the cross-correlation between the original and stego-image. In [8], the brightness, contrast, and the value of structural similarity are represented by equations (3), (4) and (5):

$$(3) \quad l(x, y) = \frac{2\mu_x\mu_y + C_1}{\mu_x^2 + \mu_y^2 + C_1}$$

$$(4) \quad c(x, y) = \frac{2\sigma_x\sigma_y + C_2}{\sigma_x^2 + \sigma_y^2 + C_2}$$

$$(5) \quad s(x, y) = \frac{2\sigma_{xy} + C_3}{\sigma_{xy} + C_3},$$

where C_1 , C_2 and C_3 are constants obtained by the equations.

$$(6) \quad C_1 = (K_1 L)^2, C_2 = (K_2 L)^2.$$

In (6) $L = 255$ for an image with 8 bits/pixel, and $K_1 \ll 1$ and $K_2 \ll 1$ are very small constants.

The values obtained in (3), (4) and (5) are combined into a final average value for the SSIM index

$$(7) \quad SSIM(x, y) = [l(x, y)]^\alpha \cdot [c(x, y)]^\beta \cdot [s(x, y)]^\gamma,$$

Where $\alpha > 0$, $\beta > 0$ and $\gamma > 0$ are parameters which determine the relative importance of the three components in the value of the $SSIM(x, y)$. In the article was accepted equal importance of brightness, contrast and value of structural similarity, i.e. $\alpha = \beta = \gamma = 1$ and $C_3 = C_2/2$.

From the above-mentioned equation (7) follows in (8), which represents the final form of the SSIM index between two images of x and y :

$$(8) \quad SSIM(x, y) = \frac{(2\mu_x\mu_y + C_1)(2\sigma_{xy} + C_2)}{(\mu_x^2 + \mu_y^2 + C_1)(\sigma_x^2 + \sigma_y^2 + C_2)}$$

$SSIM(x, y)$ takes values in the range $[0; 1]$, and when $x = y$, the value of $SSIM(x, y) = 1$.

In the article of [10] is proposed constraints analysis of the MSE and the PSNR and they are compared with the SSIM.

In [9] a special case of (8) is discussed, in which $C_1 = C_2 = 0$. A disadvantage of these parameters is that when the denominator of (8) tends to 0, the resulting measurement becomes unstable. This problem has been successfully solved in [8] by adding two constants C_1 , C_2 , for which is calculated by (6) that are $K_1 = 0,01$ and $K_2 = 0,03$.

According to Shannon Entropy E is a measure of uncertainty that exists in a source of information with respect to some variable or event.

3. Steganography algorithm based on the LSB method of embedding information in images

Stego-image 24-bit format file storage using RGB (Red, Green, Blue) color model [3] is a prerequisite for the presence of a large excess of information that can be used for the purpose of steganography. Steganography synthesized algorithm for embedding information in images uses up to three of the last significant bits in each color channel pixels.

Additionally, the opportunity for selecting a color-channel and pixels in which the information is embedded is achieved.

Steganography modification principle [2] is used to implement the functions of embedding and retrieving data in the cover image, where the pre-existing cover images are changed during the process of embedding. An algorithm is used for insertion into the LSB (Last Significant Bit) for hiding information in image [2], [7]. Through the LSB method is obtained embedding of the message bits in the last significant bits of the color components of individual pixels of the image. It is symmetrical, which means that for embedding and extracting a message, identical operations are performed in the same order. The effect of the algorithm is based on the fact that the secret information is stored in the last significant bits of the pixels of an image, without causing visible differences in its view.

Figure 2 is a general block diagram of the algorithm, in which is checked whether there is a data entry or retrieval. Thus is

checked what operation will be realized and is proceeded to the incorporation or extraction of the confidential information

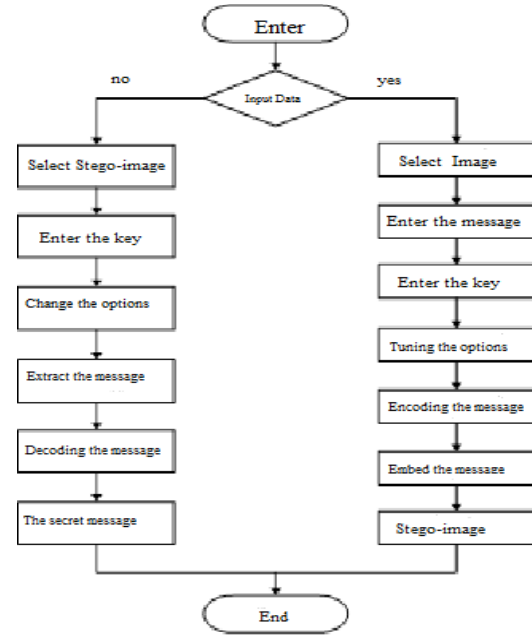


Fig. 2. Block diagram of the software system

The proposed algorithm can work with BMP, PNG and TIFF file formats of images without size limitations. Since it does not have a block for pre-compression, the maximum amount of information that will be embedded in the image is determined depending on the size of the carrier file minus the information in the header file (service information), while also allocating bytes for the generated code of the password.

The amount of the stego-file is the same as that of the carrier file. A stego-key can be typed in the algorithm. The stego-key is used to control the process of embedding confidential information and limit the ability to find and recover the secret message [6]. Rijndael symmetric encryption algorithm is used in the proposed algorithm for protecting the stego-key.

4. Experimental set of images

By implementing a program system for embedding/ extracting text messages many tests with different size messages and images have been carried out. The studied algorithm is based on the LSB method applied and tested on BMP image formats. Test results of the qualitative characteristics MSE, SNR, PSNR, SSIM and E are analyzed. Visual analysis of the compared images shows lack of visual differences in visual control. Histogram analysis and the results of the qualitative characteristics are obtained by MATLAB. Table 1 presents the results of the qualitative characteristics of embedded text files in English with a size of 170 to 240 kB and cover digital image parrot.bmp is used.

Table 1. Qualitative characteristics of parrot.bmp image in embedding a different size of the secret message

Size	MSE _{av}	SNR	PSNR	SSIM	E
170B	2,6809e ⁻⁵	79,4718	86,2179	1	7.6200
300B	4,471e ⁻⁵	77,2806	84,0267	1	7.6200
600B	9,081e ⁻⁵	74,2614	81,0075	1	7.6200
10kB	0,0015	61,9987	68,7448	1	7.6202
30kB	0,00455	57,2162	63,9623	1	7.6204
40kB	0,00485	56,0551	62,8012	1	7.6204
50kB	0,0076	55,0116	61,7577	0,998	7.6207
60kB	0,0089	54,2661	61,0122	0,998	7.6208
70kB	0,0125	52,7076	59,7072	0,998	7.6209
80kB	0,0178	51,2512	57,9974	0,998	7.6215
120kB	0,0355	48,2430	54,9891	0,997	7.6224
240kB	0,0355	48,2429	54,9890	0,997	7.6224

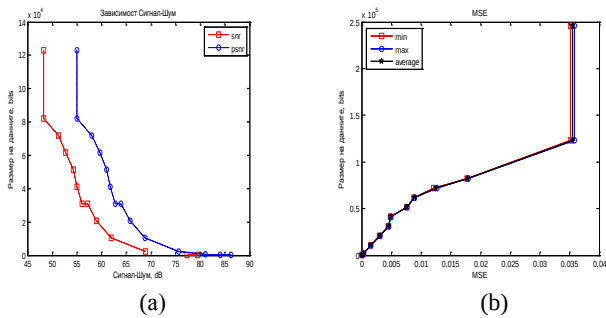


Fig. 3. Dependence of (a) SNR and PSNR and (b) MSEav. for parrots.bmp image for values of 170 to 240 kB

The difference between the minimum and maximum value of MSE is difficult to establish because the change is only in the thousands. The average MSEav. was obtained as the average of the minimum and maximum MSE and is visualized in the graph of Figure 3(b).

With the increasing amount of embedded data, PSNR values decrease and the values of MSE grow. At 10 kB embedded information is observed value of PSNR, which [4] proposed as excellent and their value is 43,6396 dB.

Table 2 presents the results for the tested qualitative characteristics in the embedding of 60 kB information. When embedding the information one, two or three last significant bits in the three color components of individual pixels of the parrots.bmp image are used respectively. From the results presented in Table 2, it can be concluded that the basic statistical characteristics of the image are deteriorated by an increase in the number of the used last significant bits of embedded information.

Table 2. Values of the studied statistical characteristics of the parrot.bmp image with integrated 60 kB text in English with increasing the number of the used last significant bits from 1 to 3 inclusive

Number of last significant bits of embedded information	MSE_{av}	SNR	PSNR	SSIM	E
1	0,0089	54,2661	61,0122	0,998	7,6208
2	0,0242	50,2316	56,9777	0,998	7,6208
3	0,0620	45,9034	52,6495	0,998	7,6210

Table 2 corresponds with the graphic results in Figure 4.

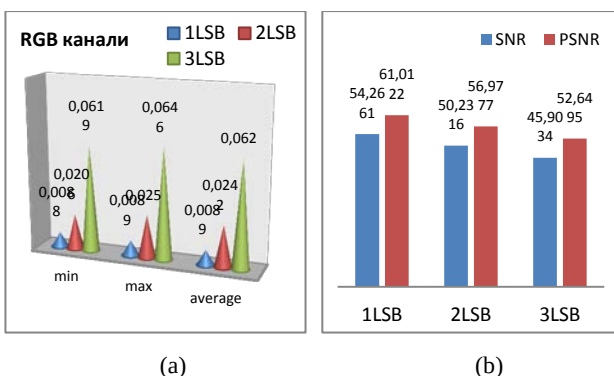


Fig. 4. Dependency in (a) MSE and (b) SNR, PSNR in embedding of 60 kB information in three color channels of the parrots.bmp image, using 1, 2 or 3 significant bits

Graphical visualization of the results is presented in Figure 5.

Table 3. Embedding of 4 kB text in Bulgarian and English in different images

Original image	Type of text	MSE_{av}	SNR	PSNR	SSIM	E
Alps	engl.	0,0014	62,265	69,8157	1	7.5557
Alps	bg	0,0013	62,4801	70,0309	1	7.5549
Paradise	engl.	0,0011	60,1414	69,8151	1	6.456
Paradise	bg	0,00098	60,1312	69,8050	1	6.466
change	engl.	0,0012	64,1293	69,9402	1	4.9676
change	bg	0,0015	63,8985	69,7094	1	4.9698
Marbles	engl.	0,0013	66,9616	72,1563	1	6.9900
marbles	bg	0,0012	67,6274	72,8221	1	6.9874
Ice	engl.	0,0012	61,538	69,7777	1	6.5832
ice	bg	0,0013	61,5217	69,7613	1	6.5833
snow	engl.	0,0012	63,5232	69,7424	1	7.2032
snow	bg	0,0011	63,5473	69,7664	1	7.2032
tahaa	engl.	0,0013	64,3824	69,7678	1	7.7233
Tahaa	bg	0,0011	64,4358	69,8212	1	7.7232

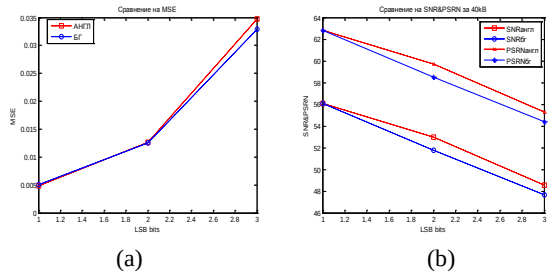


Fig. 5. Dependency in embedding of 4 kB in the last significant bit of information in Bulgarian and English with indicators (a) MSEav and (b) SNR, PSNR parrost.bmp image

Table 3 presents the results of the studied qualitative characteristics in embedding of 4 kB information in English and the same amount of information in Bulgarian at the same other input parameters of the software system. Various images, whose dimension is different, are used.

In Figure 6 can be seen histograms of original and stego-image obtained by embedding of 10 kB information at base settings of the steganography algorithm, i.e. successively embedding in the three color components of pixels without using protection by stego-key in a pepper.bmp cover image.

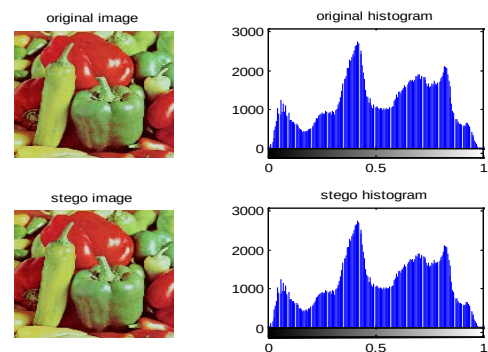


Fig 6. Histogram of original and stego-image, which has 10 kB of embedded information

Difference in the histograms is hardly observed. This result can be attributed to the fact that the embedded message is not particularly large.

5. Conclusion

The results from the research can be summarized in the following conclusions about the characteristics of the studied steganography algorithm:

- By increasing the size of the embedding data the statistical characteristics of the images deteriorate,

although, the visual quality of the images processed with steganography system remains excellent.

- Using more than one of the last significant bits in the bytes representing each pixel increases the ability to embed a larger amount of data.
- The used cryptographic algorithm ensures additional security during transmission and recovery of the stego-message.
- In embedding in the same image of equal length messages in Cyrillic and Latin, the stego-images obtained have approximately 0,033% difference in the values of the parameters examined.
- This regularity is sometimes in favor of images containing text in Bulgarian, as the percentage is almost the same, i.e. less than 1%.
- The modification of the *PSNR* in embedding of the same amount of information using one and three bits from the last significant bits is about 15%.

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CLOUD BASED SOLUTION IN DENTAL PRACTICE – AUTHORS MODEL

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Abstract: The healthcare sector is in a period of rapid change, which requires continuous innovations. The epidemic of chronic diseases, changing demographics and advances in medical technology, have a key contribution to escalating costs. All stakeholders expect more value for their money. And patients are beginning to play a greater role in the management of their care. Driven by the economy, health care and business models in accordance with personal values and prosperity are signaling a fundamental change in the way healthcare organizations will compete and work in the coming years. Recent CEO survey, conducted by IBM, shows that only 34% of CEOs of health institutions are focused on simplifying the management operations, aiming a greater efficiency. Similarly, only 55% of payers for health care believe that their organizations are ready for the upcoming complexity. Yet there is a new environment in which they must work.

The article is dedicated to author's solution for cloud-based software in dental practice, and is made a comparison with other, available on the web, systems. It is prepared a SWOT analysis, dedicated to the challenges and barriers for deployment of cloud solutions in healthcare and in general.

.Keywords: HEALTHCARE, CLOUD, DENTAL PRACTICE

1. Introduction

In healthcare, the pace of change increases, together with the complexity of providing higher quality care for considerably less payment per patient. Hospitals and doctors are looking for strategies to increase business agility, while demonstrating higher value for healthcare. To achieve this, it is necessary a transformation from institutional-centered, low-data system to a patient-oriented, information -rich health system.

Flexible and scalable approach to applications and infrastructure can help healthcare organizations to support new business approaches and continuous patient experience. [3,4,5]

2. Material and method

Cloud computing can play a critical role in containing healthcare integration costs, optimizing resources and ushering in a new era of innovations. Current trends aim towards accessing information anytime, anywhere, which can be achieved when moving healthcare information to the cloud. This new delivery model can make healthcare more efficient and effective, and at a lower cost to technology budgets (Horowitz, 2011), but also, it brings certain obstacles due to concerns related with safeguarding confidential patient information and compliance with key regulations such as HIPAA. Despite these security and privacy risks, healthcare organizations can certainly take advantage of cloud computing solutions and bring tremendous benefits such as help to improve patient quality of service and reduce overall healthcare costs (Muir, 2011). One of the key benefits will be the ability to exchange data between disparate systems. This capability is something healthcare IT is desperately needs. For instance, cloud computing can support healthcare organizations to share information such as EHR, doctor's references, prescriptions, insurance information, test results stored across different information systems. [2]

When offloading healthcare organizations the IT staff required to maintain network availability, security updates, backups and others can be free up to attend to more critical tasks in an efficient and cost-effective manner (Muir, 2011). In addition, more reliable and powerful infrastructures will be available pay-as-you-go and it can be managed dynamically.[2]

Cloud computing has given opportunities for clinics, hospitals, insurance companies, pharmacies, and other healthcare companies to agree in collaborating between them and share healthcare information to offer better quality of service and reduce costs. Looking over the changes occurring in the market, it appears that cloud-based systems will likely become the norm in healthcare once all the challenges it brings are overcome.[2]

Healthcare organization have been dealing with growing amounts of electronic records and digital images, would seem a good fit for cloud storage services. Among the reasons for this sudden interest in cloud-based computing and communications are the need for collaboration among the increasing number of remote and mobile workers, several office locations, a desire to improve patient quality of service and the ever present goals of improving operational excellence while driving down technology equipment and healthcare management costs (Whitemore, 2012). To help healthcare organizations decide whether they ready to move to the cloud there are a few important points to consider.[2]

Strengths	Weaknesses
• Eliminating of the existing software and hardware obstacles for locally installed systems (costs, complexity); • Smaller hospitals and medical practices typically don't have internal IT staff to maintain and service in-house structure ; • Pay as you go model is attractive to physicians and healthcare organizations; • Provide the necessary resources that would allowed applications to scale as needed ; • Reduces the need for organizations to maintain large IT staff; • Unlimited capacity for data storage; • Improving productivity.	• Lack of clear rules, regulations and standards for cloud-based applications in healthcare, as well as lack of knowledge and experience; • Lack of expertise to evaluate the new approach in healthcare sector; • Insufficient evidence to show new approach is suitable for healthcare sector; • Issues of security and privacy.
Opportunities	Threats
• This new model of delivering cloud services implies massive global investment in many sectors, including healthcare; • Many cloud service providers develop modern and innovative cloud-based information technology in order to provide high-quality services; • Internationally, many governments take measures to produce regulation and legislation to protect customer data security and privacy.	• Healthcare professionals' lack of trust in the new approach; • Current lack of international or national regulations and standards; • Obstacles: ✓ Possible data lock-in ✓ Security of data ✓ Data transfer issues ✓ Data interoperability ✓ Legal issues

Table 1. SWOT analysis (cloud computing in healthcare)

3. Literature review

In the modern world, the traditional model of software for management of the dental practice is shifting increasingly by cloud-based solutions. Using traditional software in dental practice, you need IT specialist to take care of maintenance of computers and network. Furthermore, this type of software systems, require constant improvements in software and hardware, which takes time. Using cloud-based application eliminates the constant need of improvements and saves time and money. One of the leading benefits of the use of cloud applications in dental practice is the safe and secure storage of data in the cloud. The future of the dental industry is increasingly focused on the use of cloud-based systems that terminate upgrades and backup, decrease IT costs and provide easier access to the data. Cloud-based dental applications optimize workflow, increase productivity and communication structures. And all of this with the possibility of remote access from any device with an Internet connection. With cloud-based systems in the field of dentistry, renovation and addition of functionalities happen automatically. [1,3]

Tablets are becoming a powerful business tool in many areas. The field of dentistry could also benefit from the advantages

of using this type of device. Working with cloud-based application, using tablet, gives access to information from everywhere at any time. In addition, to simplifying the process, the tablets can be used for direct communication with patients, organizing daily program, etc. Integration of tablets in the dental practice will facilitate the workflow and create a fully mobile environment. Through cloud-based application on a tablet, specialists have access to patient information remotely, even when they are outside of the office. Moreover, they can view test results and other data from anywhere, at any time. Inside the office, dentists can use tablets to visualize and inform the patient about any type of images, including X-rays. The tablet can also be used for recording of information about the treatment plan in real time, and to be used as an educational tool. [7]

Here we present cloud-based solutions in dental practice, available on the web:

PracticeDent

PracticeDent is an innovative service, born out of the recent advances in cloud technology and the ubiquity of internet access in our society. It is meant to provide dental practices and professionals with an improved way to manage all aspects of their business, better suited for today's digital reality. PracticeDent is a completely cloud-based online service, accessible via any internet-enabled computer, tablet or smartphone. PracticeDent is part of a comprehensive cloud-based ecosystem (MediCloud) that brings closer all the players in the dental sector – dentists, suppliers, laboratories and patients. MediCloud is an innovative startup with more than two decades of joint experience in IT and cloud technology, determined to bring healthcare management on par with the current level of technological progress, and even prepare it for future

improvements.[7]

Fig.1 Patient profile

(www.practicedent.com)

DENTSIO

DENTSIO is a cloud-based iPad app for dental practice. The app has the following features:

- oral examination – start with a general examination of the patient; easily select from lists of most common pathologies;
- dental chart – navigate through option and see a complete state of patients' teeth; [9]
- periodontal chart – detect and evaluate pathologies to determine a treatment plan;

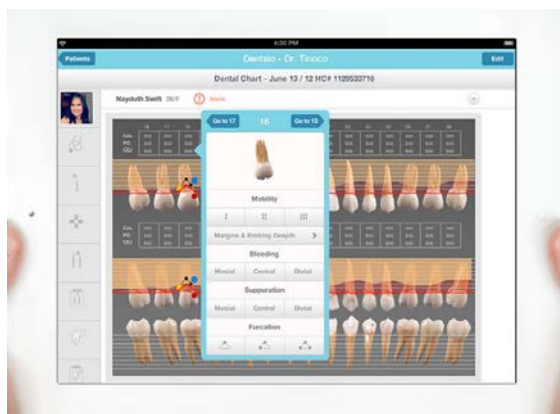


Fig. 2 Dental chart (www.dentsio.com)

Umbie DentalCare

Umbie DentalCare is a cloud-based dental practice management software. It optimizes office workflow, increases productivity, and structures communication, serving single or multiple offices - without servers, free upgrades, and using any device with web access. Builds authentic patient relationships, by adapting to the values, demands and habits of ever evolving generations - patients likely to be anywhere, at any time, and using any device. The software has the following features:

- Clinical charting - Convenient and accurate treatment documentation
- Imaging with ease - Intraoral camera's and X-Ray viewing and capturing
- E-Prescribing - Send prescriptions right to the pharmacy
- Chairside Treatment Planning
- Human Resource Solutions - Track payroll, time-off, benefits, and performance
- Scheduling Simplified - Actively fill empty slots
- Online Payments - Patients can pay online, with a credit card, anytime
- Customized Reminders - Allow patients to choose; phone, text, or email [10]

Fig. 3 Patient profile – X-Ray (www.umbiedentalcare.com)



DENTRIX ASCEND

Dentrix Ascend is a brand new practice management software, designed to work on the web. It is created by the same company that developed the original Dentrix—the most popular practice management system in North America

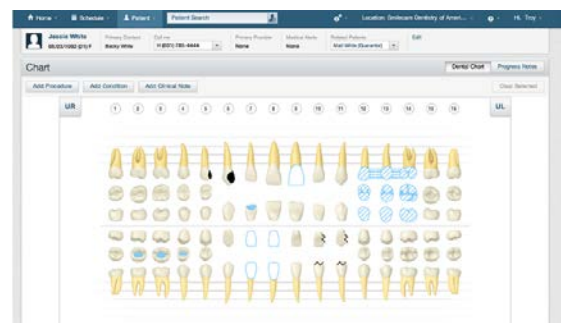


Fig. 4 Patient profile – dental chart

Dentrix Ascend uses new technology to erase old limitations. With its innovative cloud-based architecture, Dentrix Ascend gives new flexibility and freedom to:

- More flexibility – access your practice from any computer with an Internet connection; move beyond traditional PCs; Solve the multioffice dilemma;
- Smarter workflow – boost efficiency with a smart, simple workflow-based user experience; find patient information faster with one click access; streamline your business operations; focus on patients instead of technology; get a comprehensive solution for one low price; enjoy the freedom and convenience of pay – as - you – go;

- Continuous improvement – close collaboration; rigorous pre-release testing; active ongoing notifications and training; [11](www.dentrixascend.com)

4. Results

After detailed analysis, literature reviews and practical experiments with demo version of foreign developments, we decided to invest in Bulgarian solution, which fully satisfies both the requirements according to the regulations and legislation in Bulgaria and on the basis of consultations with a number of specialists in the field

DENS CLOUD is entirely online, cloud-based application for managing dental practice seeking to streamline processes in management and greater accessibility. The service is accessible via any internet-enabled devices - PC, laptop, tablet, smartphone. Within DENS CLOUD, dentists have all the tools they need for seamless management practice - multifunctional calendar, files of patients, drafting a plan for treatment, the possibility of reference and viewing

images and pictures of imaging in dedicated galleries. Moreover, the application is designed with user-friendly interface for ease of use and efficient for users.

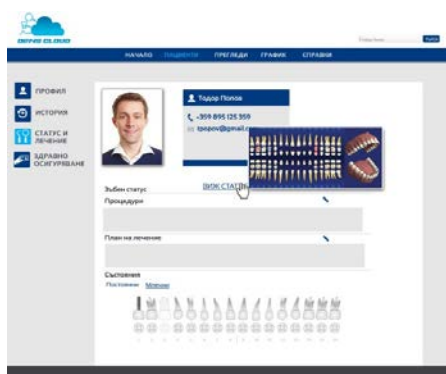


Fig.5. Form for the teeth status and treatment plan of the patient (DENS CLOUD – authors' solution)

SYSTEM/PARAMETER	DENS Cloud	Practice Dent	DENTSIO	Umbie Dental Care	Dentrix Ascend
Login with username and password	3	3	2	2	2
Color signal	3	2	2	2	2
Schedule	3	3	0	2	3
Patient profile	3	3	3	3	3
EHR	3	3	2	2	3
Dental chart	3	3	3	3	3
Periodontal chart	3	3	3	3	3
Teeth status	3	2	3	3	3
Dental specialist data - organization	2	3	3	3	3
Document manager	2	2	2	2	2
Imaging and X-ray	3	2	3	3	3
Treatment plan	2	2	2	2	2
User Interface	3	2	3	2	2
Adaptability of the application	3	3	3	3	3
Access from different mobile devices	3	3	3	3	3
Edit options	3	1	2	1	1
Total:	47	40	39	39	41

Legend: 0 – missing; 1 – existing; 2 – good organization; 3 – excellent organization

Table 2. Comparative analysis of cloud-based dental applications

The selected 15 parameters and assessment scale, prove the benefits of the author's solution. Analysis and evaluation of the results of the comparative analysis with other software, confirm the quality of the cloud-based application. The maximum result of the 15 parameters analysis is 47. The minimum result is 39. All of the presented available in the web applications, including the authors model, have login with username and password. Except DENTSIO, the other 4 software solutions have excellent organized schedules and good organization about patient data. The cloud-based systems are available from different mobile devices – tablets, smartphones,

laptops, etc. All of the solutions are adaptive and have user-friendly interfaces.

5. Conclusion

Through the implementation of a cloud model, all IT processes will be migrated to a remote cloud infrastructure, where all processes will be stored and carried out. The new "pay as you go" model allows healthcare organizations to pay only for what they use. Therefore there is no reason for acquisition of expensive hardware infrastructure, software licenses or maintenance personnel, security, applications, because providers of cloud services take care of all that.

Human life is priceless, and medical resources are limited (Wang, 2010), because the cloud-based health services, combine cost-effective concept, where patients and healthcare organizations benefit from this new technology by improving the quality of services to patients through highly integrated platform (Wang, 2010), coordination of the medical process and reduce IT infrastructure costs for investment or maintenance, which leads to better health. [1]

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AN OPPORTUNITY FOR IMPROVED MODELING AND INFORMATION ANALYSIS IN ISAR SYSTEMS

ЕДНА ВЪЗМОЖНОСТ ЗА ПОДОБРЕНО МОДЕЛИРАНЕ И ИНФОРМАЦИОНЕН АНАЛИЗ В ISAR СИСТЕМИ

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Abstract: This article offers a new geometry model of ISAR image reconstruction procedure. Improved modeling and information analysis of ISAR systems are developed by implementation of detail 3D model of observed flying object. Simulation experiments are executed in MATLAB environment.

Keywords: ISAR, ISOMETRIC PROJECTION, IMAGE RECONSTRUCTION

1. Introduction.

For all ISAR systems high performance and better image reconstruction technologies are needed. An opportunity for improved modeling and information analysis in that area is suggested to be the development of better recognition of the various flying objects. The simulation needed for better image reconstruction and subsequent recognition can be developed only if the model is more similar to the real flying object and has a detailed 3D structure.

A 2-D range/cross-range radar image of a target is always sparse since only a few strong scattering centers occupy the whole image plane, and thus, it can be suitable to apply the compressive sensing (CS) theory to obtain inverse synthetic aperture radar (ISAR) images. It generates fully polarimetric ISAR images with the number and the positions of the scattering centers aligned in polarimetric channels, which allows for further polarimetric scattering characteristic analysis [1].

Another technique based on image segmentation, local polynomial Fourier transform (LPFT), and image contrast (IC) maximisation is used in order to extract the scattering centres and estimate their chirp rate [2].

A 3-D interferometric ISAR altitude image can be derived from two 2-D images reconstructed from the measurements by antennas at different altitudes [3]. A bistatic interferometric radar image is a sheared version of the projection of the target on the range-Doppler plane. Its configuration is developed to correct this distortion and to form 3-D image [4]. There are methods for accurate determination of the position of important radio-frequency scatterers by combining accurate knowledge of target position and orientation with specialized signal processing. For each type of ISAR plot technique, a corresponding interferometric ISAR (InSAR) technique is provided [5].

The feature space and the visual perception theory also can achieve an accurate and robust classification of ISAR images [6].

The 3D image can be considered as a set of 2D images retrieved from the 2D ISAR signal projections if the complex ISAR signal, reflected from the 3D target is obtained by four receivers, placed on the axes and origin of the coordinate system of observation. The image reconstruction procedure includes both range and azimuth compression [7].

In the inverse synthetic aperture radar (ISAR) autofocus signal processing linear frequency modulation (LFM) signals are used for image retrieving. The procedure is composed by range compression and azimuth compression using Fast Fourier Transform (FFT) [8].

2. Preconditions and means for resolving the problem.

The signal processing is performed assuming arbitrary rectilinear movement of a target in the 3D coordinate system. The image processing is accomplished over the time record of ISAR signal returns. It can be summarized that the ISAR signal

processing of LFM signal returns, reflected by the object with complicated form are implicitly based on the assumption of availability of well-isolated dominant scatterers and cannot work effectively in most practical case when these scatterers are missing [8]. The common 2D model of the aircraft will never be detailed enough for real analytic geometric approach. The experiment compares the difference in the images of the target retrieved from the ISAR signal return from 2D (figure 1) and 3D aircraft model (figure 2). The aircraft model and its arbitrary position in the local 3D Cartesian coordinate system placed and the coordinate system of the ISAR system are shown on figure 3.

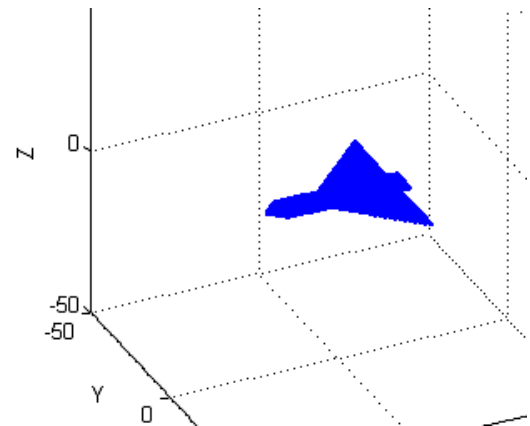


Fig.1 2D model of an aircraft.

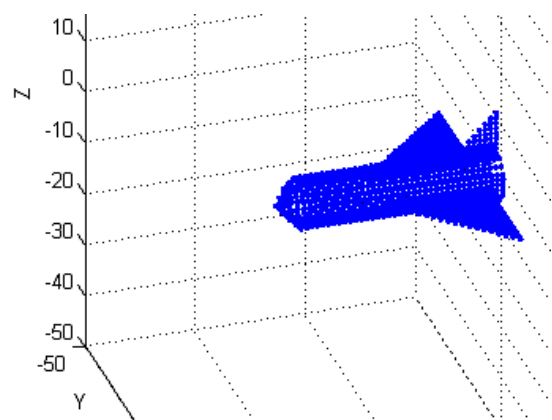


Fig.2 3D model of an aircraft.

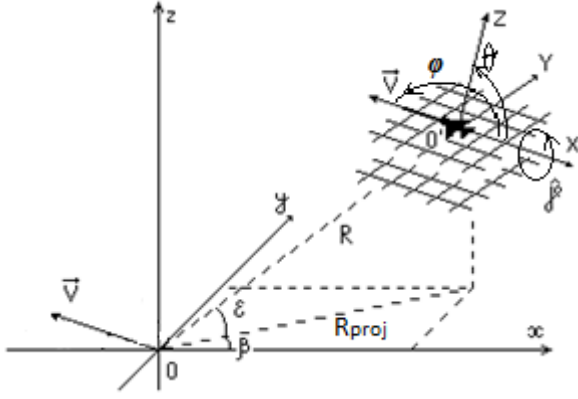


Fig. 3. ISAR 3-D observation coordinate system geometry and 3-D model coordinate system geometry.

R is the latitude to the middle of the trajectory in the space, $R_{proj} = \sqrt{R^2 - H^2}$ is the distance to the middle of the trajectory projection on Oxy, H is the altitude of the target, β is the azimuth angle of the target in Oxyz in $\left(\frac{Np}{2}\right)$ moment, ϵ is the elevation angle of the target in $\left(\frac{Np}{2}\right)$ moment, γ is the bank angle of the target in the Oxyz. The object's space is moving rectilinearly with a constant vector velocity $\vec{V}$ in the 3D Cartesian coordinate system Oxyz where φ is the Ox - direction angle of velocity vector $\vec{V}$, ϑ - Oz - elevation angle of velocity vector $\vec{V}$, ρ is the Oy - bank angle of the velocity vector $\vec{V}$, point O'(O) is the location of the coordinate system O'xyz at the moment $\left(p = \frac{Np}{2}\right)$, which corresponds to the middle of the ISAR length; point O'(p) is the location of the coordinate system at the p -th moment.

The components of the velocity vector $\vec{V}$ are:

$$(1) \begin{aligned} V_x &= V \cdot \cos \vartheta \cdot \cos \varphi; \\ V_y &= V \cdot \cos \vartheta \cdot \sin \varphi; \\ V_z &= V \cdot \sin \vartheta; \end{aligned}$$

The initial trajectory parameters of the target flight are:

$$(2) \begin{aligned} x_0 &= -\frac{N_p}{2} \cdot T_p \cdot V; \\ y_0 &= R; \\ z_0 &= H; \end{aligned}$$

The transformation between the target and ISAR separate coordinate systems are determined by the transformation matrix coefficients:

$$(3) \begin{bmatrix} X \\ Y \\ Z \end{bmatrix} = \begin{bmatrix} x_0 \\ y_0 \\ z_0 \end{bmatrix} + T_p p \begin{bmatrix} V_x \\ V_y \\ V_z \end{bmatrix} + \begin{bmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{bmatrix} \begin{bmatrix} X \\ Y \\ Z \end{bmatrix}$$

where X_0, Y_0, Z_0 are the coordinates of the mass center of the object in the moment $p = 1$. The components of the transformation matrix are presumed to be:

$$(4) \begin{aligned} a_{11} &= \cos \varphi \cos \rho - \sin \varphi \cos \theta \sin \rho; \\ a_{12} &= -\cos \varphi \sin \rho - \sin \varphi \cos \theta \cos \rho; \\ a_{13} &= \sin \varphi \sin \theta; \\ a_{21} &= \sin \varphi \cos \rho + \cos \varphi \cos \theta \sin \rho; \\ a_{22} &= -\sin \varphi \sin \rho + \cos \varphi \cos \theta \cos \rho; \\ a_{23} &= -\cos \varphi \sin \theta; \\ a_{31} &= \sin \theta \cos \rho; \\ a_{32} &= \sin \theta \sin \rho; \\ a_{33} &= \cos \theta. \end{aligned}$$

The ISAR signal is a sum of $p = \overline{1, N_p}$ LFM impulses: $s(t) = A_s \exp[j(\omega t + bt^2)]$, where A_s is the ISAR signal's amplitude. The sensitivity as a function of distance is determined by $\Delta R = \frac{c}{2(2\Delta F)}$ where c is the electromagnetic waves speed.

Each (m, n, h) point scatterer reflects the ISAR signal as

$$(5) \hat{s}_{mnh} = A_{mnh} \exp[j(\omega(t - \tau_{mnh}) + b(t - \tau_{mnh})^2)]$$

and A_{mnh} is the amplitude of the signal reflected by (m, n, h) target point scatterer.

For each transmitted impulse p the time dwell t of the ISAR signal return are retrieved values in the interval: $\tau_{min} \leq t \leq \tau_{max} + T$. The complex trajectory signal is formed in discrete function as $t = \tau_{min} + k\Delta T + l\Delta T$ where $k = \overline{1, N_k}$, $l = \overline{1, L(p)}$.

Matrix of the complex trajectory signal is:

$$(6) S(\bar{k}, p) = \sum_{m=1}^M \sum_{n=1}^N \sum_{h=1}^H \left(A_{mnh} \text{rect}[t - \tau_{mnh}(p)] \cdot \exp \left\{ j \left[\omega(\tau_{min}(p) + \bar{k}\Delta T - \tau_{mnh}(p)) + b(\tau_{min}(p) + \bar{k}\Delta T - \tau_{mnh}(p))^2 \right] \right\} \right)$$

where $\bar{k} = \overline{1, N_k + L(p)}$; $p = \overline{1, N_p}$.

It is assumed that the reflected signal is received and intensified, furthermore transformed on intermediate frequency, discretized and finally reorganized in digital. For every impulse reflected next step is multiplication of the elements of the complex matrix $S(\bar{k}, p)$ by the ISAR signal:

$$(7) \dot{S}(k, p) = S(\bar{k}, p) \exp[-j(\omega t + bt^2)], \text{ where:}$$

$$t = k\Delta T; k = \overline{1, N_k}; \bar{k} = \overline{1, (N_k + L)}; p = \overline{1, N_p}$$

The physical interpretation of that equation is linear frequency demodulation (LFDM).

The frequencies f_{mnh} for the p -th impulse are in dependence to the difference in time delay of the nearest point of the object and the time delay of the corresponding point (m, n, h) in the function:

$$(8) f_{mnh} = \frac{2\Delta F}{N_k} (\tau_{mnh}(p) - \tau_{min}(p)), \text{ where } \frac{2\Delta F}{N_k} \text{ is constant.}$$

$$(9) \tau_{mnh}(p) = \frac{2R_{mnh}(p)}{c}$$

$\tau_{mnh}(p)$ is the reflected signal by the scatterer (m, n, h) .

After implementation of discrete Fourier transform to the sum of harmonic signals $\dot{S}(k)$ a result in the frequency area is produced. By this procedure a range compression of the trajectory signal is

executed. The Fast Fourier Transformation (FFT) results are shown on figure 4.

Every column of the demodulated complex signal matrix is processed by compressing discrete Fast Fourier Transform:

$$(10) \quad \tilde{S}(i, p) = \sum_{k=1}^{N_k} \dot{S}(k, p) \exp \left[\frac{-j2\pi(i-1)(k-1)}{N_k} \right],$$

where $k = \overline{1, N_k}$, $p = \overline{1, N_p}$.

For the object's geometry reconstruction a compression of the trajectory signal by cross-range is needed. For trajectory signal azimuth discretion and complete image reconstruction the discrete Fast Fourier transform is used to the other dimension of $\tilde{S}(k, p)$ matrix:

$$(11) \quad \tilde{\tilde{S}}(k, i) = \sum_{p=1}^{N_p} \tilde{S}(k, p) \exp \left[\frac{-j2\pi(i-1)(p-1)}{N_p} \right],$$

The isometric projection of each $\tilde{\tilde{S}}(k, p)$ element's absolute value reproduces the location and intensity of corresponding scatterer.

3. Results and discussion.

The models and simulation experiments presented in the paper are accomplished in MATLAB environment.

The initial trajectory parameters of the flying object are:

$$V = 600 [m/s], \quad \varepsilon = \arccos \left(\frac{R_{proj}}{R} \right), \quad H = 5000 [m], \quad R = 50000$$

[m], $\beta = \frac{\pi}{2}$, $\gamma = 0$, $f = 10^{10}$ [Hz] is the carrier frequency,

$T = 10^{-6}$ [s] is the time duration of every impulse in sequence.

The process of trajectory evaluation is shown on figure 4.

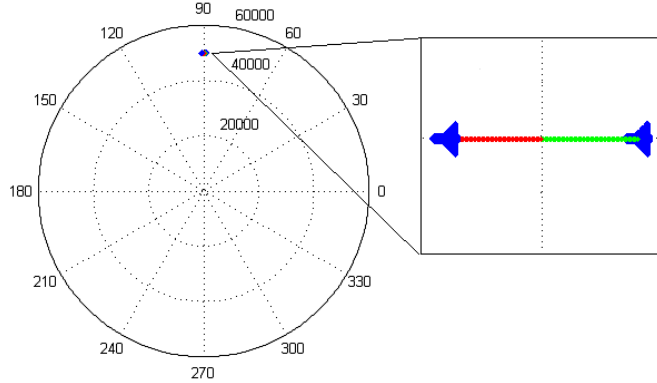


Fig. 4. Process of target trajectory simulation.

During the first experiment a 2D target model is used. The real and imaginary components of the $S(k, p)$ matrix of received echo signal are shown on figure 5a, 5b. The real and imaginary components of matrix $\dot{S}(k, p)$ of demodulated values are displayed on figure 5c, 5d.

The absolute values of the First and Second Fast Fourier Transforms are shown on figure 5e, 5f.

The final reconstructed image is presented on figure 5g (isometric projection), 5h (pseudo-color map).

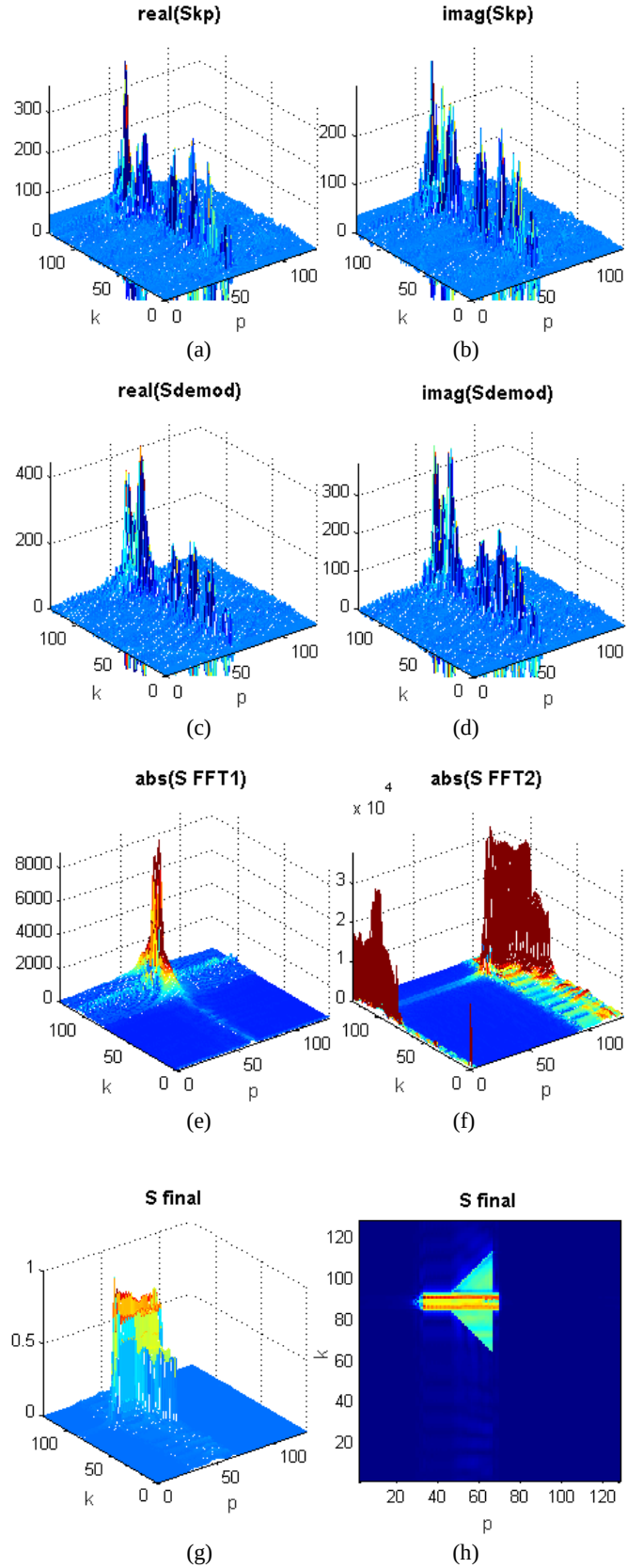


Fig. 5. Image reconstruction process of 2D target model.

During the second experiment a 3D target model is used. The real and imaginary components of the $S(k, p)$ matrix of received echo signal are shown on figure 6a, 6b. The real and imaginary components of matrix $\dot{S}(k, p)$ of demodulated values are displayed on figure 6c, 6d.

The absolute values of the First and Second Fast Fourier Transforms are shown on figure 6e, 6f.

The final reconstructed image is presented on figure 6g (isometric projection), 6h (pseudo-color map).

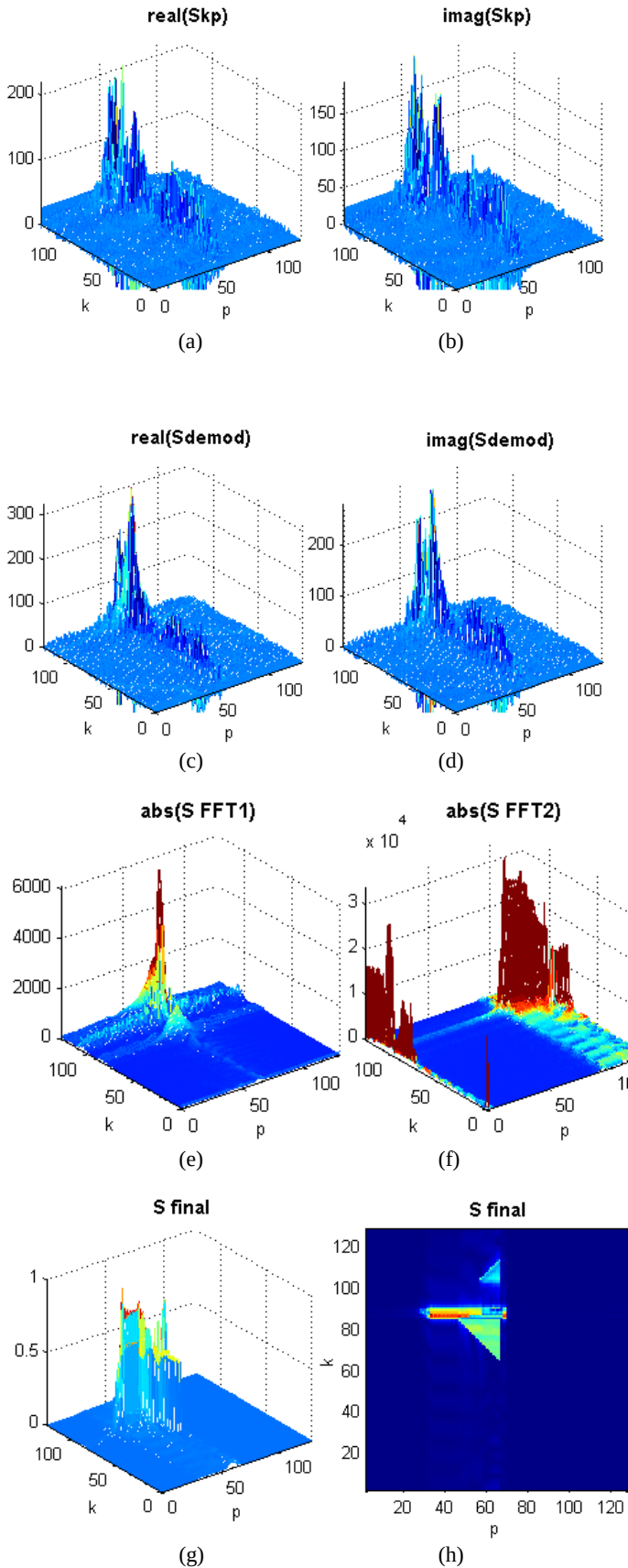


Fig. 6. Image reconstruction process of 3D target model.

4. Conclusion.

Some of the 3D target model's point scatterers are positioned to generate shadowing effect for another point scatterers situated after them for the ISAR system's transmitted signal. The shadowing effect is presented on figure 7 as missing details of the target's wing.

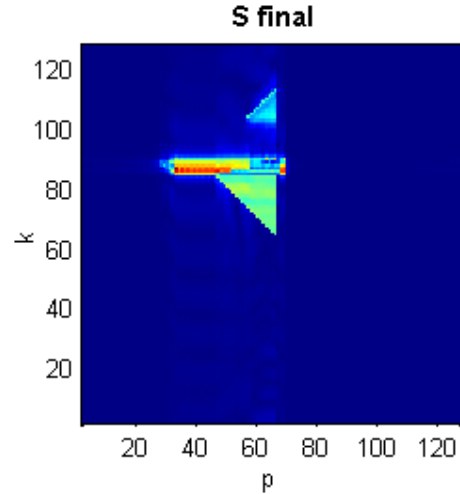


Fig. 7. The image retrieved by observation and analysis of a target with 3D geometry.

Point scatterer's shadowing effect during simulation with 3D model geometry is the reason more accurate and detailed image to be presented according both the ISAR system location and the space position of the flying object.

The results of 3D target model ISAR observation can be used for subsequent image recognition implementations.

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PROCESSING OF INTERFERENCE-CORRUPTED SIGNALS IN CELLULAR RADIO SYSTEMS

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Abstract: Cellular radio communications operate in a severe radio environment. Multipath propagation, inter-channel, inter-symbol and Multiple Access interference, frequency selective fading and many others, contribute to system performance degradation. Contemporary techniques, such as zero-forcing equalization and sophisticated signal filtering, are used for interference cancellation. To observe the system performance, BER analysis is made in this paper.

Keywords: INTERFERENCE CANCELLATION, ZERO FORCING, MMSE, DECISION FEEDBACK FILTERING, BER

1. Introduction.

Cellular networks operate in different geographical areas. Crowded cities differ from plain fields as a matter of radio propagation. Multipath, high speed movement of terminals, close radio resource allocations and noise, are one of the causes for bad signal reception. In real cellular radio systems, the communication channel is with Additive White Gaussian noise and has time-varying characteristics [1]. Multiple subscribers and multiple channels, operating simultaneously, cause Multiple-Access Interference (MAI), which is the limiting feature, downgrading the overall system capacity. Moreover, the distortive character of the radio environment spreads the transmitted data symbols in time, interfering with each other. This phenomenon is called Inter-Symbol Interference (ISI). Changes in the propagation environment, e.g., due to mobility in wireless communications, introduce channel time variation, which could be very harmful [6]. Code division multiple access (CDMA) systems lead the popular multiple access schemes mainly due to their better multiple access characteristics, fading robustness and anti-interference capability.

For increasing the data rate, in 3G and 4G the traffic is distributed among multiple orthogonal subcarriers and channel signals are divided by orthogonal variable functions (OVFs). The receiving signal consists of many fingers (up to 6), which typically have phase differences. This is the cause of errors in the received data. All the added components to the originally transmitted signal can be assumed as noise. The noise figure is statistically explored before the deployment of the system equipment.

Communication engineers face the challenge of finding techniques for improving the error rate. Adaptive equalizers bring beneficial results to the signal processing at the radio receiver. Enhanced Rake-receivers are also in favor of multipath signal extractions.

2. Mathematical models and equalization.

Exploring the radio environment is the first step when deploying communication equipment. In the base station and the terminals, multi-user receivers are utilized. They require knowledge either of the dispersion of the mostly used user's data sequence, or of a previously negotiated preparation (pilot) sequence. When neither exists, the extracting of information is called "blind multiuser detection" [3]. Channel Impulse and Frequency responses are the main characteristics of interest.

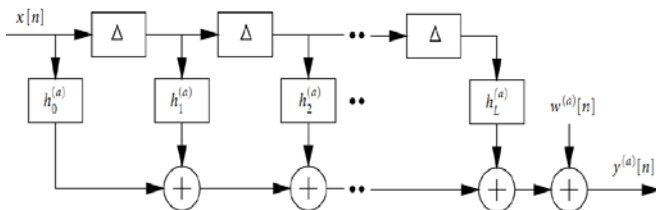


Fig. 1 - Model of a time-invariant impulse response.

Looking at a fixed time, one can distinguish between time-invariant (TIV) and time-variant (TV) channels. It can be said that circumstances in a manner of movement (speed) of terminals, crowded RF spectrum usage, etc., imply time variation or non-variation.

The TIV channel is modeled by a finite impulse response (FIR) (see Fig. 1). The TV channel is modeled with a basis expansion model (BEM) (see Fig. 2), creating a BEM FIR channel.

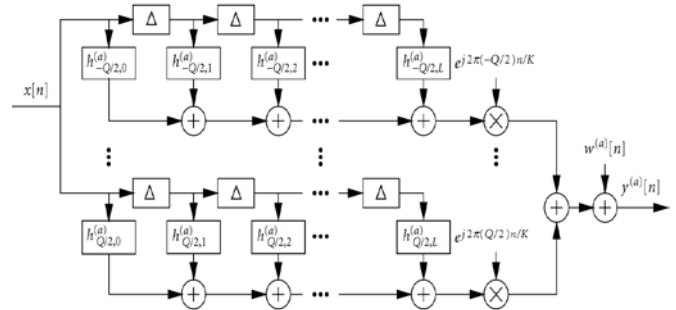


Fig. 2 - Model of a time-variant impulse response.

In Figure 1, the transmitted signal $x[n]$ (sampled at time n) is received as $y^{(a)}[n]$ with interference through the channel with L multiple delays (Δ). The index term (a) here represents one of the $A-1$ possible transmitted signals. This is a representation of the multipath propagation and interference insertion. Each path has transfer characteristic $h^{(a)}$ and for the signal $y^{(a)}$ we have the mathematical model as follows:

$$y^{(a)}[n] = \sum_{l=0}^L h_l^{(a)} \cdot x[n-l] + w^{(a)}[n] \quad (1)$$

Multiple paths interfere with the adjacent symbols and cause fading. More signal paths with time delay $\Delta=L$ cause more interference. In (1) $w^{(a)}[n]$ represents the added White Gaussian noise with power spectral density $\sigma=N_0/2$.

To fight against interference, equalization is performed at the receiver side. The optimum receivers employ Maximum Likelihood (ML) sequence estimation, Maximum A-posteriori Probability (MAP) rule for detection of symbols [1], or Zero-Forcing algorithm (ZF). The suboptimum receivers use the following major equalization techniques:

- Block Linear Equalization (BLE);
- Block Decision Feedback Equalization (BDFE);
- Serial Linear Equalization (SLE);
- Serial Decision Feedback Equalization (SDFE);
- Frequency-Domain Linear EQ (FDLE);
- Frequency-Domain Decision Feedback EQ (FDDFE).

Block and serial equalization have decision feedback schemes described below.

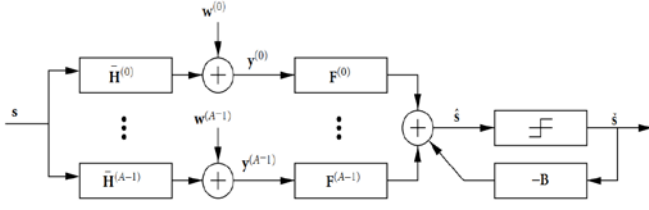


Fig. 3 - Block decision feedback equalization.

Here, in Fig. 3, $\bar{H}^{(0)}$ to $\bar{H}^{(A-1)}$ represents different symbols in a predefined block set from particular alphabet. H is the data symbol matrix with full column rank. After the noise insertion (w), $y^{(0)}$ to $y^{(A-1)}$ appear as interference-corrupted signals. And $F^{(0)}$ to $F^{(A-1)}$ appear as noise corrupted received symbols from the predefined set. If noise (or interference) has caused the symbols chosen to be erroneous, a symbol error occurs. The number of occurred errors is estimated by the Bit Error Rate (BER). The BER characteristic describes system performance. For signal symbol error correction, different actions are taken [5]. One of it is to utilize a threshold and a feedback decision device ($-B$). The feedback algorithm equalizes erroneous amplitudes in the frequency spectrum, thereby the name Equalizer. The equalized and estimated symbol $\hat{s}$ is mathematically represented as [6]:

$$\hat{s} = \sum_{a=0}^{A-1} F^{(a)} \cdot y^{(a)} - B \cdot \hat{s} = \left(\sum_{a=0}^{A-1} F^{(a)} \cdot \bar{H}^{(a)} \right) \cdot s - B \cdot \hat{s} + \sum_{a=0}^{A-1} F^{(a)} \cdot w^{(a)} \quad (2)$$

Figure 4 presents a serial decision feedback equalizer consisting of a serial feedforward filters $f^{(a)}[n;v]$ for the a^{th} output and a serial feedback filter $b[n;v]$, in order to find an estimate of $\hat{x}[n-d]$.

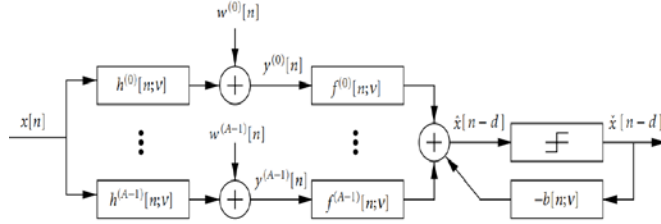


Fig. 4 - Serial decision feedback equalization.

The so presented equalizer minimizes the Mean Square Error (MSE). The minimum mean square error (MMSE) solutions offer optimal balance between removing the ISI and noise enhancement, and computational complexity. On Figure 5 MMSE adaptive line enhancement is shown. The adaptive filtering is used to overcome the added unwanted noise.

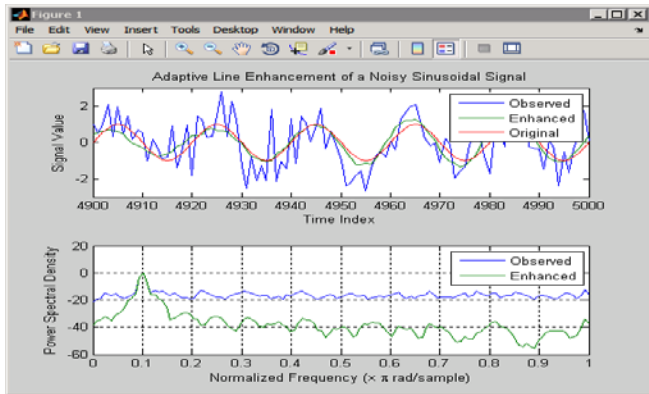


Fig. 5 - Noise corrupted signal enhancement.

Peak signal distortion is also minimized with equalization techniques. Another of it is the Zero-Forcing Algorithm. The ZF solution is achieved by forcing the cross-correlation, between an error sequence and a desired information sequence, to be zero for shifts in the range of sample duration within symbol duration ($0 \leq n \leq K$). Comparing the MMSE with the Zero Forcing (ZF) solution, the MMSE solution always leads to a better performance than the ZF solution. However, the existence of the ZF solution generally gives a good indication of the performance at high SNR.

3. Interfered signals processing.

A comparative study of interference cancellation algorithms (ICA) for DS-CDMA cellular systems shows that the Fast ICA algorithm is the best in extracting the unknown symbols, but it requires high computational complexity and exhibits slow convergence.

In constant multipath signal delays, the Rake-receiver is employed. Rake-ICA is proposed, but this method relies on multipath delay time information of the desired user, which sometimes is difficult to be estimated.

The interference corruption of the signal results in data transfer session rate degradation, or loss of voice communication for small amount of time. Using a signal spectrum analyzer, the interference in a TETRA radio signal is shown in Figure 6:



Fig. 6 Left: interfered radio signal; right: non-interfered signal.

The left side shows massive signal corruption, and the right side shows the same signal (in a different time, a few seconds late) affected only by several amount of AWG noise. If the presented interference is short and appear pretty occasionally (very rare), the channel is modeled as time-invariant and error correcting codes and bit interleaving schemes provide uninterrupted information flow. If such interference changes the radio environment constantly in a random manner, the channel is modeled as time-variant and receiver filter equalizers are used.

The Recursive Least Squares (RLS) algorithm adaptive filter uses a reference signal for input and a desired signal on one port to automatically match the filter response in a Noise Filter block. As it converges to the correct filter, the filtered noise should be completely subtracted from the "Signal+Noise" signal, and the "Error Signal" should contain only the original signal.

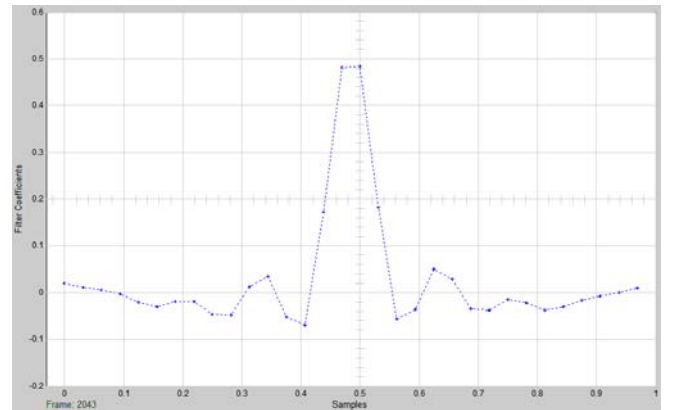


Fig. 7 – Filter tap coefficients.

In Figure 7, simulation results for filter tap coefficients, with respect to time delay samples, are depicted. While on Figure 8, simulation results for noise interference cancellation, after several training sequences, is shown.

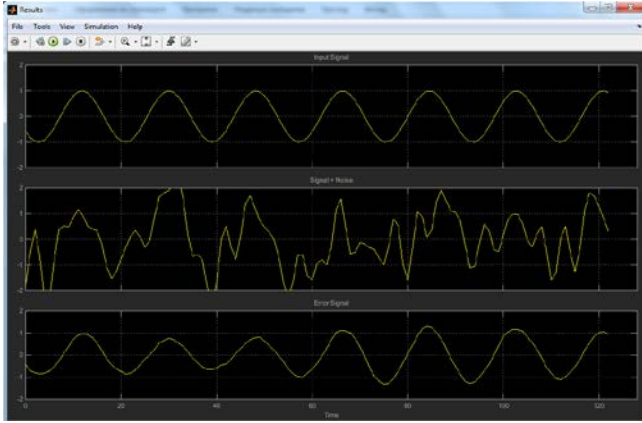


Fig. 8 – Interference cancellation.

An advanced technique in contrast with Least Mean Square (LMS) and Recursive Least Square (RLS) seems to be the proposed Laguerre Filter [4]. This algorithm performs well in the *blind* symbol estimation in DS-CDMA systems and outperforms other leading detectors. Results also show that Multiple Access Interference (MAI) can be mitigated well by the proposed method, thus improving the performance over conventional detection. Furthermore, the results show the proposed detector maintains the consistent improvement in the performance even though the number of symbols is decreased.

Another contemporary technique is antenna diversity in receivers. The larger the number of receive antennas M , the smaller the probability that at some time all M channels are in a deep fade.

4. Symbol processing and BER analysis.

In the case of time-invariant channel, the frequency shift is accepted to be zero ($f_{max}=0$), and the equalizer taps are assumed to be three ($L=3$). A data bit block size of 64 is considered ($N=64$). This block size is large enough such for *blind* channel estimation and the overhead of the training symbols for training-based channel estimation does not decrease the data transmission rate. It is also the block size for the IEEE 802.11a and HIPERLAN/2 WLAN standards. On Figure 9 and 10 a comparison of block equalizers (BLE, BDFE) with frequency-domain equalizers (FDLE, FDDFE) for TIV channels is shown.

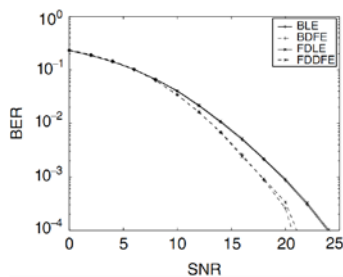


Fig. 9 – Bit Error Rate for $M=1$ and $P=1$.

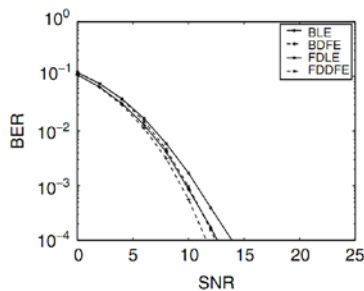


Fig. 10 – Bit Error Rate for $M=2$ and $P=2$.

On the figures, M is the number of transmission channels, and P is the number of parameters included in the channel characteristic. On Figure 11 and 12 a comparison of block and serial (SLE, SDFE) equalizers for TIV channels is shown.

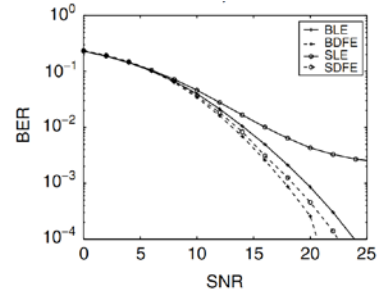


Fig. 11 - Bit Error Rate for $M=1$ and $P=1$.

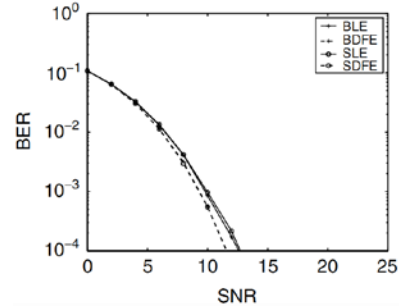


Fig. 12 - Bit Error Rate for $M=2$ and $P=2$.

5. Conclusion.

In the severe noisy radio environment advanced techniques help for the correct receiving of data while signals are interference-corrupted. The studied serial and block filters achieve efficiency with low computational complexity, operating under multipath channel. It is shown that the effect of AWGN, ISI and MAI is best eliminated with linear equalization. Implementing these equalizers in cellular systems seems to be an efficient alternative for the mobile cellular systems and for the evolutionary future generations.

Channel estimation training sequences bring knowledge of the current channel condition, which enables the receiver to adjust the equalizer coefficients, enhancing the signal recognition and decision making. It can also be concluded that better the performance is achieved by utilizing large number (M) of transmit/receive antennas. On the other hand, Pre-Rake transmission leaves the processing power to base station rather than to the terminal.

The automatic match to frequency response is not immediate after symbols signal reception, but after a small period of convergence time, the interference is shown to be cancelled.

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A SURVEY ON THE QUALITY OF DIGITAL IMAGES

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Abstract: The survey of the digital image quality appears to pass through a man's perception. This leads to a one's own personal decision. To bring tests on the quality of video information, methods for digital image processing analyses are utilized. Correlation between subjective and objective assessment is explored in this paper. A special video sequences are projected and the subjective influence is compared with a well-founded image quality metrics.

KEYWORDS: CORRELATION METRICS, IMAGE ACQUISITION, IMAGE ESTIMATION, VIDEO PROCESSING

1. Introduction.

Data transfer systems nowadays process high definition (HD) pictures and 4K high quality video images. Different TV and monitor manufacturers offer extreme video experience. New light emitting displays allow users to view bright and contrast pictures like never before. Nevertheless, different people see different colors in their own way. And as a matter of video performance and image estimation, an allied quality metric should be applied.

Before any video or image processing can commence, an image must be captured by a camera and converted into a manageable entity. This is the process known as image acquisition [7]. The image acquisition process consists of three steps; energy reflected from the object of interest, an optical system which focuses the energy and finally a sensor which measures the amount of energy.

In the methodology of the experimental studies of the quality of digitally processed images, the conducting of the subjective analysis on these images is inseparable part of the developing of objective value for this rating. Multiscale analysis tools underlie many recent advances in key areas of signal and image processing, namely, approximation/representation, estimation, and compression.

2. Image quality estimation.

Image quality estimation in image processing can be broadly defined as the action of retrieving an image from some source, usually a hardware-based source, so it can be passed through whatever processes need to occur afterward [6]. Performing image acquisition in image processing is always the first step in the workflow sequence because, without an image, no processing is possible. The image that is acquired is completely unprocessed and is the result of whatever hardware was used to generate it, which can be very important in some fields to have a consistent baseline from which to work. One of the ultimate goals of this process is to have a source of input that operates within such controlled and measured guidelines that the same image can, if necessary, be nearly perfectly reproduced under the same conditions so anomalous factors are easier to locate and eliminate.

Some of the explored video images in this research are suggested by the Video Quality Experts Group (VQEG). Others are taken by digital video camera and the rest are generated by software. Their origins cover almost all possible sources - referenced studio tests, animated video images, videos taken with amateur cameras, etc.

On Figure 1 additions of subjective evaluation of test sequences of projections on objective metrics are shown.

For all test sequences involved in subjective assessment, image quality is calculated, with few metrics: MOS (mean opinion score); PSNR (no relation between signal - noise); MSU-BM (MSU – Blocking Measure – assessment of blocking artifacts in MPEG); VQM (Video Quality Measure) and SSM (Structural Similarity Metric). This is necessary to determine the accuracy of the results.

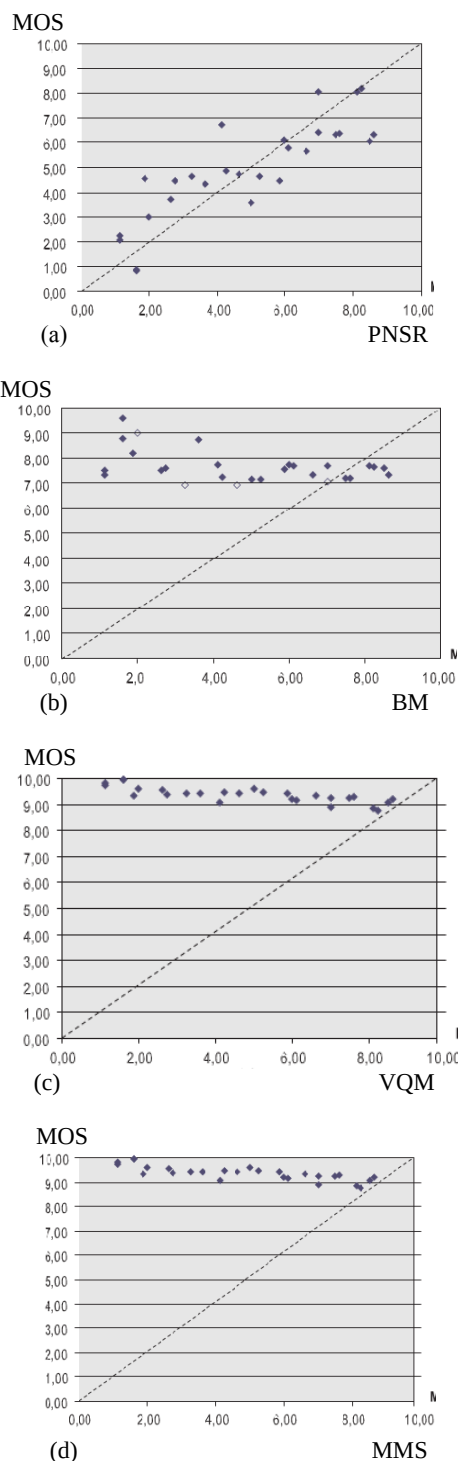


Fig 1. Objective metrics vs. subjective evaluations

In Figure 1, a) is dependence of MOS from PSNR, b) is dependence of MOS from BM, c) is dependence of MOS from VQM and d) is dependence of MOS from SSM

Depending on subjective assessment is appropriate to consider these comparisons separately for each identity video image, but for convenience, here are presented on graphic.

As seen in the graphs BM and VQM don't accurately reflect subjective human perception. There are values with high level subjective quality, rated lower, than them and back. (Are shown dotted ellipses on fig 1).

Although, PSNR, is statistical metric, gives better prediction of the subjective rate, although not achieved the required accuracy. Most objectively reflects the visual quality of the image compression SSM metrics, based on the structural similarity between the original and restored after compression picture.

The most important thing to study the connection between the results of an objective rating of the deformation during compression [1] of the images and their perception of human sight is defining their correlation. This is done with the help approximating functions. For the values of the objective rating to be compared correctly, their results are brought to aggregate scale. According to the described procedure in (1.3), the data is brought to the range of results of the visual study by an approximating function of the form:

$$O_{apr.} = 1 / (1 + e^{g \cdot O + d}) \quad (1)$$

Where:

O - outcome results of objective rating;

$O_{apr.}$ - objective data brought down to subjective results;

g, d - parameters for setting of the approximating

function;

The params g and α are taken in a way that they minimize the sum of the root mean square error between subjective results and $O_{apr.}$

$$g, d : \sum (O_{apr.} - S)^2 \rightarrow \min \quad (2)$$

Where:

S - data from subjective tests.

The received brought down objective results can be deemed as foretold subjective opinion provided by objective values.

On Figure 2, the dependences of the values of the subjective ratings, foretold by the viewed objective values, from the real subjective rating are displayed. The foretold rating is obtained with the help of the approximating function (1), and for the optimizing was used the software package "Statgraphics".

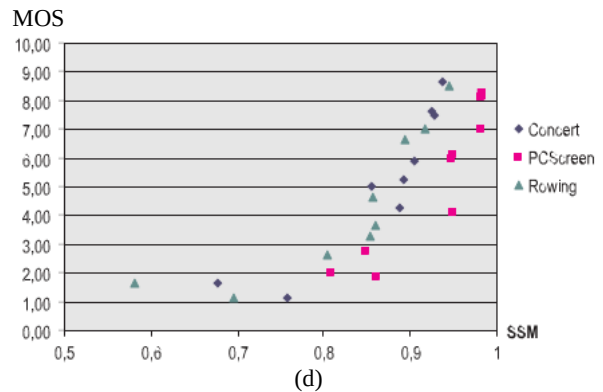
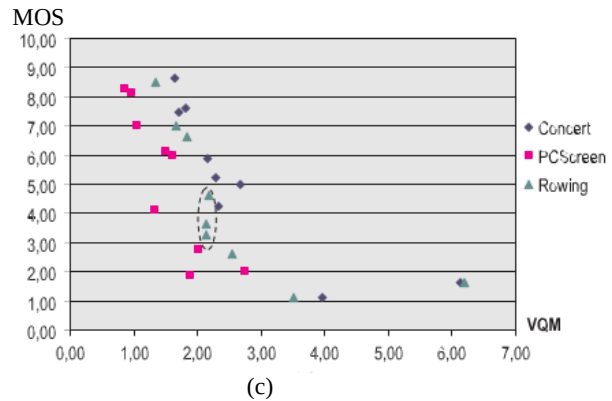
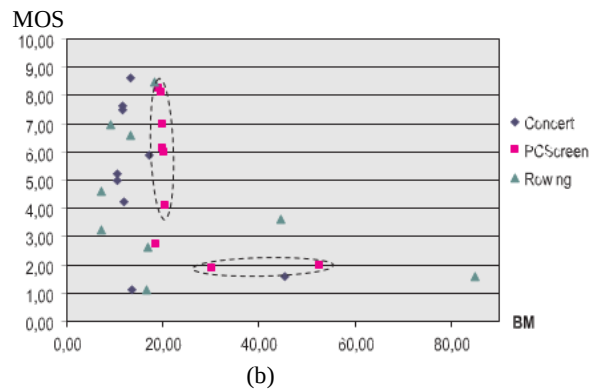
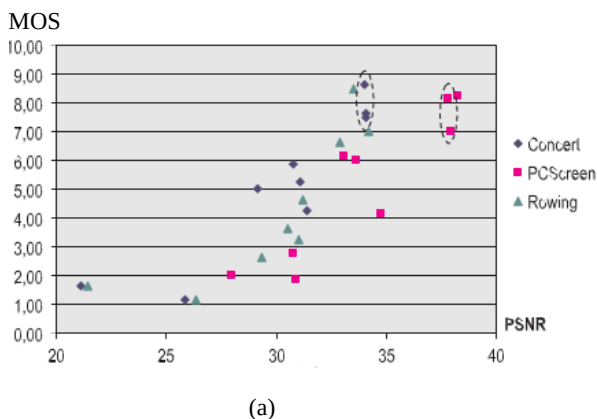


Fig 2. Evaluation ratings ratio.

Dependence on the subjective evaluation of objective metrics from actually subjective assessment:
(a) Dependence on PSNR from MOS; (b) dependence on BM from MOS; (c) dependence on VQM from MOS;
(d) dependence on SSM from MOS

These graphics allow visual rating of the quality of a foretelling of subjective rating or the work of the objective values.

The closer to the diagonal are the dots placed, the more the correlation between the objective values and the visual quality is higher.

3. Image quality results.

As can be seen from the results shown graphically, in Fig. 2, assessment of the artifacts (BM) and VQM is not very effective in predicting subjective opinion. PSNR cope with this task fairly well, having in mind that a purely statistical methodology, unreported peculiarities of human vision.

The most accurate metric to assess the quality of compressed followers proved SSM, which has been shown and statistical, calculated correlation coefficients between each objective metrics (after implementation of the approximated function) and subjective data. Value of the differences and the mean square error are given in Table 1.

Table 1. Values of correlation and the mean square error for various objective metrics.

Metrics	Correlation	$\sigma = (O-S)$	$\sigma = (O-S)^2$
PSNR	0,814	-1,03	46,41
BM	-0,447	-75,42	421,1
VQM	-0,719	-120,8	735,27
SSM	0,921	-2,66	27,29

The numbers in the table demonstrate convincingly, that the results obtained by SSM metrics, have the highest correlation coefficient with the subjective results, obtained from visual tests. Respectively mean square error between objective and subjective results is the lowest in SSM. This proves once again, that the method of objective assessment of image quality, based on the structural deformations of compression, reflects full subjective perception.

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SURFACE ACTIVITY OF SOLUTIONS FOR ELIMINATING RADIOACTIVE CONTAMINATION

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Abstract: Surface activity of water solutions, surfactants, has been calculated on the base of concentration dependence of surface tension. Compounds for deactivation, based on synthetic detergents in different concentration scales have been offered.

Keywords: SURFACE TENSION, SURFACTANTS

1. Introduction

The deactivating solutions, applicable to eliminate radioactive contamination are mainly required to have enough wettability for the processed surfaces. Surface activity is quantitative and qualitative criterion of deactivation solutions wettability and it is also a temperature dependent quantity. It has been defined by Gibbs absorption isotherm.

$$(1) \quad \alpha = -\frac{C}{RT} \left(\frac{\partial \sigma}{\partial C} \right)_A,$$

where: α is surface adsorption concentration, mol/g; C – concentration of solution, mol/l; R – universal gas constant, J/mol.K, $R=8,3$ J/mol.K; A – surface of processed area, m²; $g = \left(\frac{\partial \sigma}{\partial C} \right)_A$ – surface/ capillary/ activity.

The quantity $\left(\frac{\partial \sigma}{\partial C} \right)$ can have different signs. For surfactants $\left(\frac{\partial \sigma}{\partial C} \right)_A$ it is minus sign, hence for surfactants $\alpha > 0$ the adsorption on the surface of the solution is positive.

Water solutions of surfactants are used for conducting deactivation. In the Bulgarian Army the composition DV-2 is in use, it contains alkylphenolpolyglycol ethers, sodium threepolyphosphate and sodium sulphate.

The objective of this research is to be carried out comparative analysis on the wettability of two kinds of solutions: on the one hand - water solutions, containing DV-2, and on the other hand water solutions on synthetic detergents, which can be used for deactivation in different temperature and concentration interval.

2. Measurement Methodology and Research Object

Objects of the research are water solutions DV-2, water solutions of SHTAMEX, or powder-like synthetic detergents on the base of sodium salt of alkyl derivatives of benzene sulphaicid (containing 10-16 carbon atoms). The names – synthetic detergents SD „T” [4] and SD „B” [5] are introduced figuratively. Their components are given in Table1. Shtamex is a composition which is applicable in extinguishing fires by Fire Security and population protection.

Table 1: Synthetic detergents components.

Ingredients of SD „B”	Ingredients of SD „T”
- 5÷15% sodium salt of alkyl derivatives of benzene sulphaicid (containing C ₁₀₋₁₆)	- 5÷15% sodium salt of alkyl derivatives of benzene sulphaicid (containing C ₁₀₋₁₃);
- 10÷20% sodium carbonate	- 5÷15% sodium carbonate;
- 1÷ 5% C ₆ H ₅ O ₇ /CH ₂ COOH-C(OH)COOH-CH ₂ COOH	- <5% polyacrylic acid;
5 ÷ 15% sodium silicate	- 5÷15% sodium silicate.

The research has been conducted in a concentration range from 0,1% to 0,35%. To calculate the surface activity it is necessary to be aware of the correlation $\sigma = f(C)$, which can be received experimentally.

Defining surface tension is completed through the method of maximum pressure while blowing a bubble from the capillary. [1,2,3]. The correlation between surface activity and temperature is fixed indirectly using the data of surface tension dependence on temperature. Heating the samples of experimental solutions is realized indirectly with heated in thermostat water, used as heat carrier. [1, 2]

The amounts of studied objects’ surface activity are defined with graphic differentiation of $\sigma = f(C)$ correlation, applying computer platform [6]. Figure 2 is a chart of example correlation $\sigma = f(C)$, showing:

$$(2) \quad \operatorname{tg} \varphi = \frac{\partial \sigma}{\partial C} = g,$$

where: g – surface activity; $\partial \sigma$ – infinitely small change in surface tension, ∂C – infinitely small change in concentration.

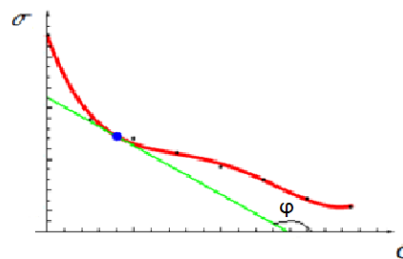


Fig. 1 Graphic chart $\sigma = f(c)$ for defining surface activity of solutions.

3. Results and discussion

Fig. 2 illustrates correlations $\sigma = f(c)$ for DV-2, SD „T”, SD „B” and „SHTAMEX” at temperature of 20°C. Statistically processed data of correlations $\sigma = f(c)$ [6] respectively for DV-2, SD „T”, SD „B” and „SHTAMEX” at (3), (4), (5) and (6) are given with regression equations:

$$(3) \quad \sigma = 0,073 - 0,072.C + 0,539.C^2 - 2,842.C^3 + 3,849.C^4$$

$$(4) \quad \sigma = 0,073 - 0,215.C + 1,061.C^2 - 3,389.C^3 + 4,153.C^4$$

$$(5) \quad \sigma = 0,072 - 0,449.C + 3,457.C^2 - 12,776.C^3 + 16,849.C^4$$

$$(6) \quad \sigma = 0,072 - 0,027.C - 0,010.C^2 - 0,001.C^3$$

where: σ – surface tension, N/m; C – concentration, %.

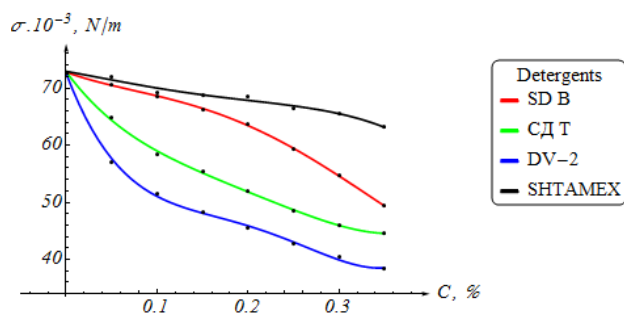


Fig. 2 Dependence of surface tension on detergent concentration in deactivating solutions.

The results, received after graphic differentiation of dependences Fig.2, give the amounts of surface activity, shown in Table2.

Table 2. Surface activity of detergent solutions

detergent t, °C	DV-2	SD „T“	SD „B“
10°C	-81,0171	-64,8325	-50,494
20°C	-82,5559	-64,8457	-56,38
30°C	-82,6505	-65,8962	-60,4664
40°C	-83,8558	-66,8449	-66,6501

Experiments have been conducted in temperature interval from 10°C to 40°C, which is the most suitable for eliminating consequences caused by radioactive contamination. Figure 3 shows the correlation between surface activity and the temperature of synthetic detergents SD„T“, SD„B“ compared to DV-2.

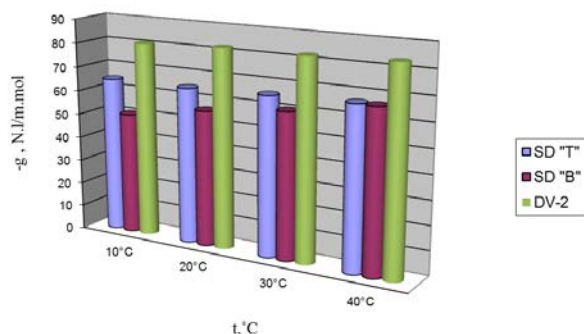


Fig. 3 Dependence of surface activity on temperature of different synthetic detergent solutions.

It is clear from table 2 and fig.3, that the surface activity is lower than that of DV-2, which means that their concentration in deactivating solutions is to be increased in relation to that of DV-2. When temperature is 40°C it does not influence the detergents significantly.

It is obvious from the histogram fig.3, that surface activity of DV-2 has the highest absolute value in comparison to synthetic detergents, object of the research. SD „T“ is adsorbed on the surface 18,9% less than DV-2 at 20°C surface activity of SD „B“ is 45 % lower than that of DV-2.

4. Conclusion:

1. With the usage of graphic differentiation of correlation between concentration and surface tension and the help of applied software product numerical values of deactivating

solutions surface activity have been received which also serve as a base for quantitative and qualitative evaluation of their wettability.

2. It has been determined that water solutions of detergents based on sodium salt of alkyl derivatives (with 10-16 carbon atoms) of benzene sulphotoacid with concentration 0,2 % ÷ 0,35 %. Are applicable for deactivation.
3. The above stated empiric correlations of surface tension and concentration can be applied after statistic processing of experimental results.

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ИЗВЛИЧАНЕ НА ИНФОРМАЦИЯ ОТ РАДИО СЕНКИ НА GPS СИГНАЛИ

EXTRACTING OF INFORMATION FROM THE RADIO SHADOW OF GPS SIGNALS

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Резюме: Радио сянката е физическо явление която може да се използва за извличане на полезната информация за обектите които я порождават. Резултатите в статията показват, че от GPS радио сенките на различни обекти може да бъде извлечена информация относно параметрите на обекта (размер, скорост и направление на движение, дистанция до приемника и др). Получената информация може да се използва за радио бариери, охрана, класификация и идентификация на подвижни и неподвижни обекти.

КЛЮЧОВИ ДУМИ: GPS, РАДИО СЯНКА, ОТКРИВАНЕ И ОЦЕНЯВАНЕ НА СИГНАЛИ.

Abstract: Radio shadow is essential physical phenomenon, which can be used to extract some useful information about the objects that generate it. The results presented in this article show that from GPS radio shadows of different objects can be extracted information about the parameters of the object (size, speed and direction of movement, distance to the receiver). The information obtained can be used in various applications like those in classic radar, including radio barriers, security, classification and identification of moving and stationary objects.

KEYWORDS: GPS, RADIO SHADOW, SIGNAL DETECTION AND ESTIMATION

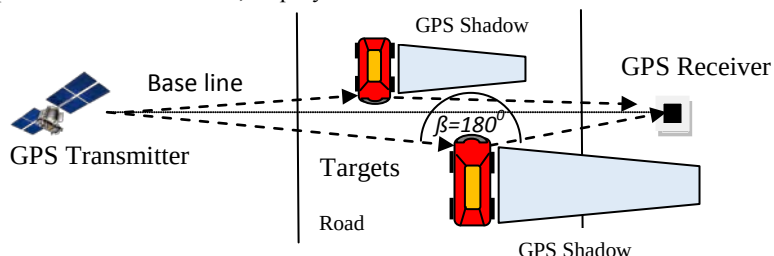
Въведение.

Регистрирането и оценяването параметрите на радио сянката от подвижен или неподвижен обект носи информация, която може да се използва за определяне на размера, скоростта, посоката на движение на обекта и др. Радио сенките са носител на ценна информация, която може да бъде използвана за вторично приложение на безжичните технологии (SAWT), като бистатични пасивни пеленгационни системи базирани на радио комуникационни или на радио навигационните системи.

Изборът на GPS като система за източник на сигнал е продиктуван от непрекъснатото наличие на GPS спътници на различни позиции спрямо приемника и наличие на евтини, конвенционални GPS приемници. За получаване на радио сянка и измерване на параметрите ѝ се използват принципите на пряко разпространение на сигналите.

Основното явление, използвано в настоящето изследване, е дифракцията на GPS сигнала [1], което се появява когато вълна срещне препятствие на пътя си, в резултат на

което тя променя праволинейното си разпространение в пространството. Районът зад препятствието, в който не стига вълната, се нарича сянка. Размерът на сянката зависи от размера на препятствието и дължината на вълната на сигнала. Според принципа Babinet, дифракционната картина на непрозрачен обект е идентична с дифракционната картина на отвор с една и съща форма и размер, но с реципрочна интензивност [1, 2]. В бистатичните радар един от факторите, които влияят на електромагнитната напрегнатост на полето и модела на приемника, е ъгълът, образуван между предавател, цел и приемник. Този ъгъл се нарича бистатичен ъгъл, β . Когато бистатичният ъгъл е равен или близък до 180° ($\beta \approx 180^\circ$), радарната система е с пряко разсейване на сигнала, както е показано на фигура 1. Наличието на препятствие в зоната на разпространение на радиовълната в този случай, частично ще блокира разпространението на вълната на сигнала от предавателя (радио сянка на целта).



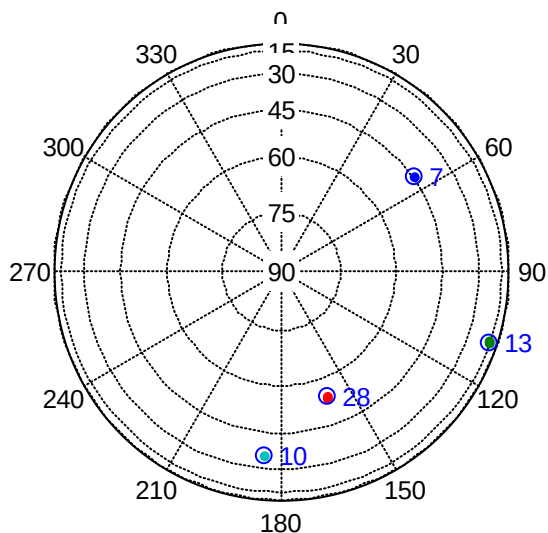
Фиг. 1: GPS радио система

Експериментални резултати: По време на експериментите е използвана комерсиална не насочена GPS антена, GPS приемник и видео камера показани на фигура 2.



Фиг. 2 Експериментална апаратура за регистрация на GPS сенките

GPS антенната е закрепена неподвижно на 1 метър над земята и се намира на края на улично платно. Заедно с антенната е използвана и видео камера за заснемане на експеримента. Платното се състои от четири ленти, по две във всяка посока (3 метра всяка лента), и движещи се превозни средства в двете посоки. По време на експеримента са видими четири сателити, един от които с номер 13 отговаря най-много на условията на пряко разпространение на сигнала. Този спътник е ниско над хоризонта и бистатичният ъгъл е близо до 180 градуса (фиг. 3). Сигнала от този спътник е използван за откриване на GPS радио сенките. Сигнала от сателит 13 е интегриран



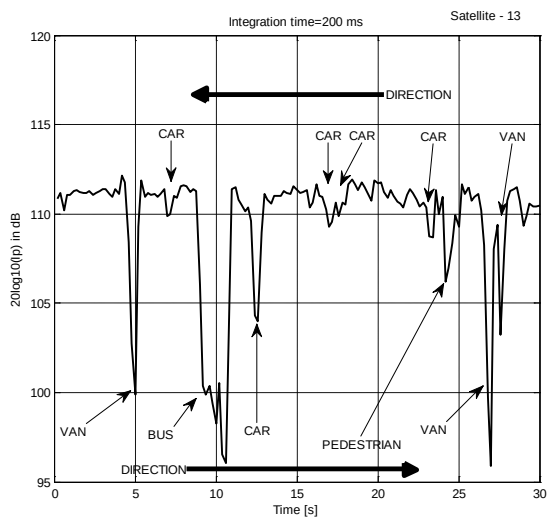
Фиг. 3 Видими сателити

Заклучение:

GPS радио сянката може да предостави информация за параметрите на обекта (размер, скорост и посока на движение, разстояние до приемника). Получената информация може да се използва в различни приложения като тези в класическите радари, включително радио бариери, сигурност, класификация и идентификация на движещи се и неподвижни обекти.

Благодарност: Изследването е проведено с подкрепата на проект ДФНИ-Т 02/3/2014.

посредством осредняващ филтър с продължителност 200 ms (фиг. 4). От фиг. 4 се виждат радио сенките на коли, бусове, автобус и пешеходец. Видът на тези сенки може да се използва за класификация на целите. Широчината на радио сянката е пропорционална на дължината на автомобила и неговата скорост на движение. Амплитудата на интегрирания сигнал е пропорционална на разстоянието до приемника. Колкото по-малко е това разстояние, толкова по-голяма е амплитудата на сянката и обратно. Мощността на сигнала във всяко следващо платно се различава с около 2 dB.



Фиг. 4 Интегриран сигнал от сателит 13

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OPTICAL GUIDE FOR BLIND PEOPLE

ОПТИЧЕН ПЪТЕВОДИТЕЛ ЗА НЕЗРЯЩИ

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Abstract: The article presents principles, methods and circuits to measure surface topography based on distance measurement. It is realized electronic optical system, registering roughness in the road on the blind people and sound signaling incase of dangers. It is used available electronic components. The development is able to be adapted to an existing system designed for people with special needs.

Keywords: ELECTRONIC OPTICAL SYSTEM, BLIND PEOPLE, IR LED, UNSEEING, SECURITY SYSTEM

1. Researched problem

The first Institute of blind people in Europe is found in 1774 in Paris from Valentine Хаюи. During eighteen century go to the path of recognition and equality. The white cane is used as an instrument of mobility for people with disabilities in sight just after WWI. As a result of the fast development of science and technologies, particularly electronics, are developed devices for easing people's lives in wide range of areas. Electrical devices for blind people are oriented to adjustment of text reading for their specific needs. There are possibilities for reading of text, electronic voting, electronic signature, writing text. There are created sensors systems, which necessitate using helmets, earphones or other external accessories that are inconvenient for users. Some of the are large, heavy, impractical and others are usable only with other tools as tactile band, colour lines and other mounted on public places. All these make the equipment more expensive and complex for fabrication.

Independent moving of blind people in urban areas is still a problem. Sensor auxiliary devices which are nom market are not mass produced, because they are too expensive for the average citizen of our country. Until his moment there is not presented a device in Bulgaria which alerts blind people for holes in the pavement. With the white cane these people successfully find roughness which may lead to stumbling and in case of hole deeper than 4cm – falling and hurting. There emerges a necessity of methods and devices that alert if risk of falling.

The main objective of this work if to formulate algorithm that meets the requirements for well-timed signalization in case of roughness on the pavement, to illustrate the main functional blocks of the device in a block diagram and to develop a model of the optical guide which helps blind people to walk safely in urban areas.

Requirements to the device:

1. To be compact and light;
2. To be low price that more people to be able to afford it;
3. To be user friendly;
4. To give in-time signalization for roughness on the road so the user to have enough time to react properly;
5. Do not require usage of auxiliary devices placed on public places.

When all requirements are met, the likelihood of finding investor for the production of optical guide is much greater. Every investment is based over the plan of a good result. Every business organization's building and management is run with the thought of its prosperity. The aspirations are generally orientated to usher in new and innovation actions, enter into new markets, cope with

competitors. At this time in Bulgaria is not known analogue of the presented appliance.

2. Illustrated material

The device is activated with little electrical switch in the grip of the white cane. There is installed the circuit of the optical guide.

On fig.1 is presented the algorithm of optical guide for blind people.

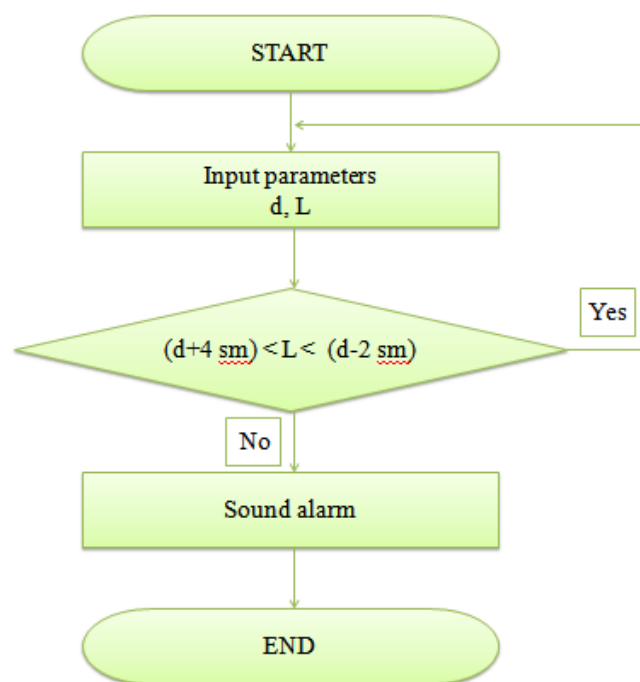


Fig.1 Algorithm of optical guide for blind people

Work of the algorithm:

Block 1 – turning on the power;

Block 2 – defining the input parameters L and d.

d is the distance from the sensor to the surface of the pavement. It is defined in advance depending on where in the cane is mounted the device.

$d = \text{const.}$

L is the measured distance in during usage. L changes depending on the roughness ahead of the user;

Block 3 – defines the condition in which the sound alarm activates.

If measured distance L is less than (d-2 cm), there is a high enough roughness that could stumble the user.

If the measured distance L is more than (d+4 cm), there is a low enough roughness that could cause falling of the user.

In case of these conditions the sound alarm will activate and will warn the user for the risk;

Block 4 – Sound alarm (buzzer, small speaker or other) will activate if conditions in Block 3;

Block 5 – turning off the power.

Based on the algorithm on fig. 1 is created block diagram on fig.2 of the optical device.

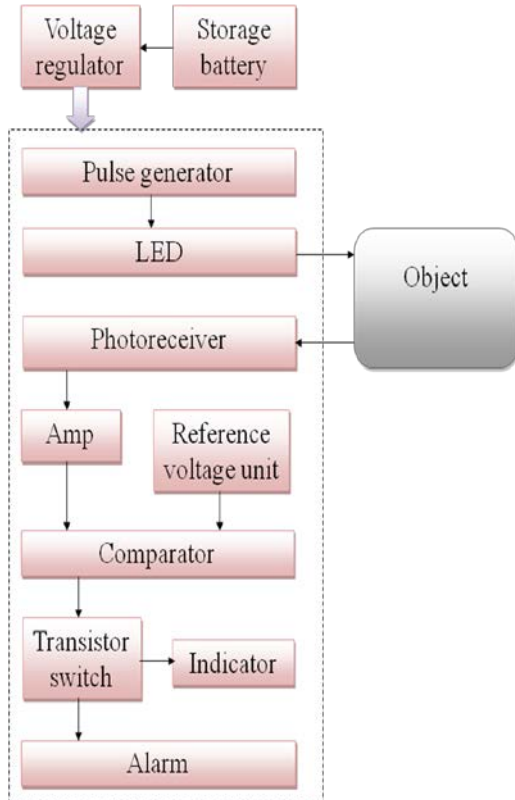


Fig.2 Flowchart of the “Optical guide for blind people”

The optical guide of blind people consists of power supply, transmitting and receiving blocks. The power supply is made with accumulator and voltage regulator. Transmitting block is made with pulse generator and IR light source – IR led. The IR beam reaches the surface is reflected and the reflected IR beam is received by the

receiver. The receiver is made with photo detector (IR photodiode that reacts on the reflected beam), amplifier of the received signal, reference voltage and comparator that compares both voltages, transistor switch, indication and alarm.

After receiving light impulses by the photodiode they go to the input of IC LM 358. it combines both the amplifier and the comparator in common case. Reference voltage is given by potentiometer RV1 (fig.3). It depends on the distance between the sensor and the surface (d the algorithm on fig.1). The transistor switch is made with PNP transistor BC 558 (fig.3).

The alarm is not shown on the circuit.

Based on the block diagram on fig.2, is shown circuit of the device on fig.3.

The pulse generator is realized with Timer 555, and the optical transmitter is IR LED. For receiver is chosen IR photodiode. The transmitter and the receiver are mounted next to each other with optical insulation between.

The pulse (high output level of terminal 3) of the timer 555 is:

$$t_1 = 0.7(R_3 + R_1)C_2 \quad (1)$$

$$t_1 = 0.7(10 \cdot 10^3 + 1 \cdot 10^3)100 \cdot 10^{-9}$$

$$t_1 = 770 \mu s$$

The pause between pulses (low output level of terminal 3) is:

$$t_p = 0.7 R_1 C_2 \quad (2)$$

$$t_p = 1 \cdot 10^3 \cdot 100 \cdot 10^{-9}$$

$$t_p = 70 \mu s$$

The period of the pulses:

$$T = t_1 + t_p \quad (3)$$

$$T = 840 \mu s$$

The maximum pulse frequency is:

$$f = 1/T \quad (4)$$

$$f = 1 \text{ kHz}$$

Duty cycle is:

$$K_F = t_1/T \quad (5)$$

$$K_F = 0.92$$

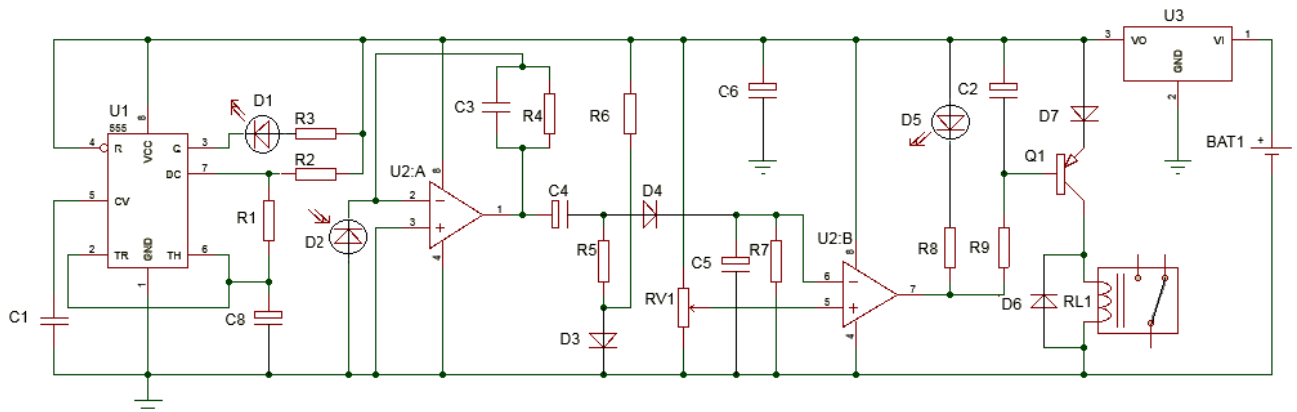


Fig.3 Circuit to Optical guide for blind people

3. Conclusion

The article presents principle, method and circuit to measure surface topography based on distance measurement. It is realized electronic optical system, registering roughness in the road on the blind people and sound signaling incase of dangers. It is used available electronic components. The development is able to be adapted to an existing system designed for people with special needs.

Developed circuit has the following advantages:

- low cost;
- ease of use and maintenance by the user (the blind person);
- easy installation to another existing system, designed for blind people;
- low power consumption
- continuous operation with one battery;
- sound signaling is individual and does not bring unnecessary confusion to people nearby.

In the purpose of regulating pulse sequence in the optical transmitter, the resistor R_1 may be replaced with a potentiometer.

For improvement the device it is needed to be made on PCB with SMD elements. Reducing the volume of the device, it is able to be worn on the neck as a medallion.

For improving the reliability it is needed to improve the temperature stability of the device and to decrease the influence from surrounding external light.

Proposed devise is actual and is connected with existing needs of specific group of the society and could be of interest for investors to finance production of the device and project that help blind people.

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