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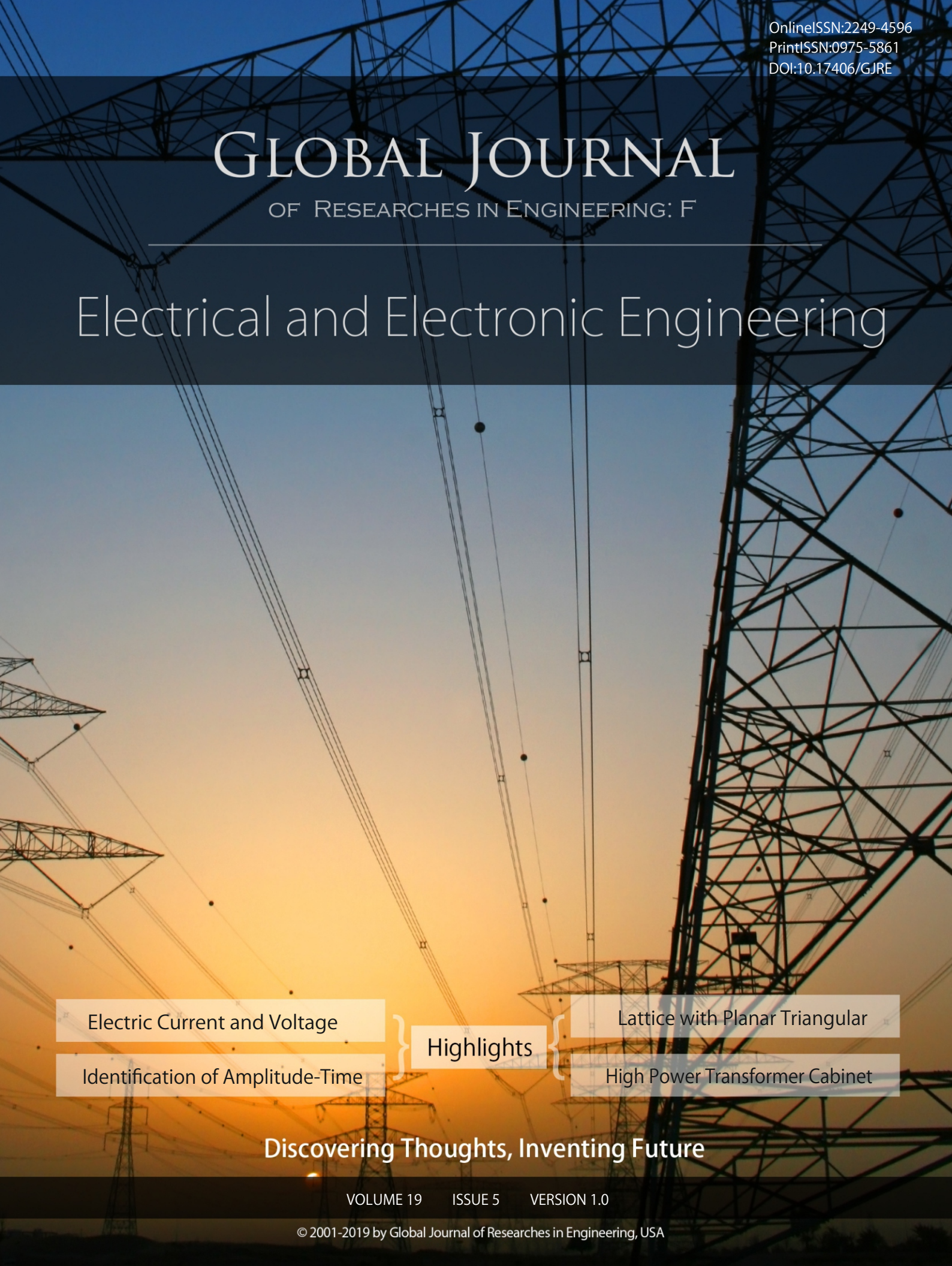

Highlights

- Electric Current and Voltage
- Identification of Amplitude-Time
- Lattice with Planar Triangular
- High Power Transformer Cabinet

Discovering Thoughts, Inventing Future

VOLUME 19 ISSUE 5 VERSION 1.0

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Research on Conducted Electromagnetic Interference Mechanism based on High Power Transformer Cabinet

By Lingxiang Deng, Yongan Wang, Xudong Zhao & Shijinli

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Abstract- The problem of conducted electromagnetic interference generated by high-power transformer cabinets is analyzed. Firstly, the equivalent model of the high-frequency circuit of conduction noise is established. The calculation method of noise current and voltage is described. Then the joint mode and differential mode conduction noise are analyzed. I am modeling as a theoretical basis for subsequent conduction noise extraction and separation. The method of suppressing conducted noise is studied, and the suppression effect of the filter on the noise of the AC output of the high-power transformer cabinet is analyzed, which provides a theoretical basis for the actual engineering rectification.

Keywords: *high-power transformer cabinet, conducted electromagnetic interference noise, theoretical noise model, noise suppression.*

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Lingxiang Deng[α], Yongan Wang[σ], Xudong Zhao[ρ] & Shijin li[ω]

Abstract- The problem of conducted electromagnetic interference generated by high-power transformer cabinets is analyzed. Firstly, the equivalent model of the high-frequency circuit of conduction noise is established. The calculation method of noise current and voltage is described. Then the joint mode and differential mode conduction noise are analyzed. I am modeling as a theoretical basis for subsequent conduction noise extraction and separation. The method of suppressing conducted noise is studied, and the suppression effect of the filter on the noise of the AC output of the high-power transformer cabinet is analyzed, which provides a theoretical basis for the actual engineering rectification.

Keywords: high-power transformer cabinet, conducted electromagnetic interference noise, theoretical noise model, noise suppression.

I. Introduction

With the increasing use of high-power transformer cabinets, there is a more complex electromagnetic compatibility problem. The power density continues to increase, and the electromagnetic environment inside the system is more complicated. A large number of electromagnetic interferences will bring a series of problems, such as equipment malfunction, motor rotor heating, communication system collapse, transformer life reduction, etc. The question poses a threat to the reliability of itself and other surrounding equipment, and also exacerbates the electromagnetic environment pollution problem and high-frequency impact [1-5]. Therefore, it is extremely urgent to study the modeling problem of conducted electromagnetic interference for high-power transformer cabinets and the method of conducting EMI noise suppression.

The schematic diagram of the high-power transformer cabinet system is shown in Figure 1.

The transmission path of the electromagnetic emission can be seen by the arrow in the figure. Generally, the high-frequency noise generated by the high-power inverter is transmitted through the cable, with common-mode and difference. The form of the mode is propagated out [6-10]. This paper will analyze the conduction noise model and the conducted noise suppression method of a certain type of high-power transformer cabinet.

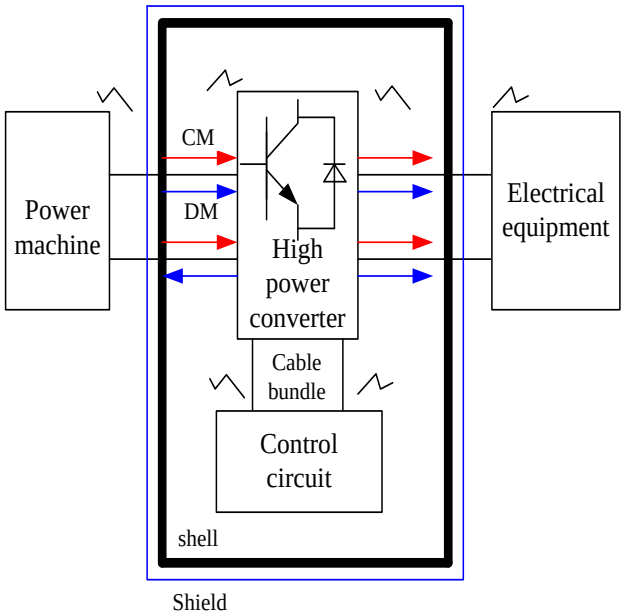

Fig. 1: Transmission control system electromagnetic transmission path

The conducted electromagnetic interference problem seriously affects the working state of the load and reduces its use efficiency. It also causes a harmful shadow on the working state of the inverter power supply. Therefore, it is necessary to analyze and suppress the conducted noise of the inverter circuit [11-14].

II. Analysis of Conducted EMI Noise in High Power Transformer Cabinet

a) Analysis of common mode EMI noise

For the conducted EMI mechanism of the inverter, in our electromagnetic compatibility laboratory, an artificial power network and a receiving device are used to extract the conducted noise of the equipment under test.

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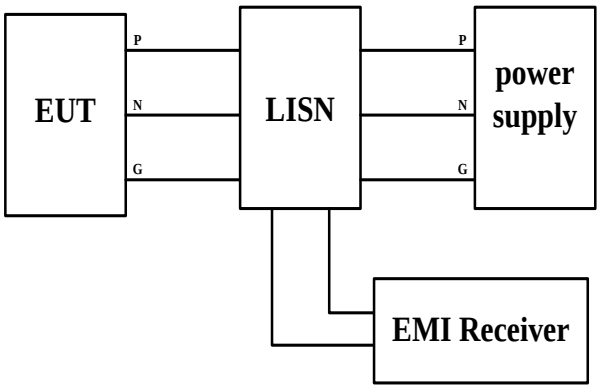

Fig. 2: Conducted noise test schematic

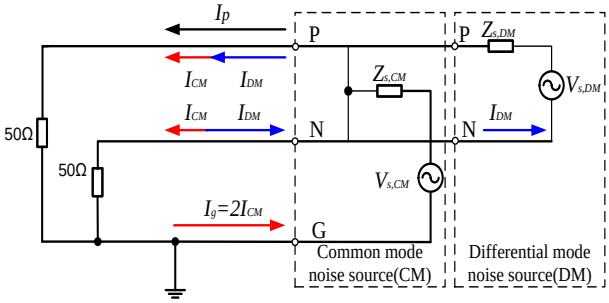

Fig. 3: Conducted noise high frequency equivalent circuit model

Figure 2 is a schematic diagram of the conducted noise test. In this figure, the G point of the P point and the N point represent the fire line, the neutral line/the neutral line, and the ground line. Figure 3 shows the high-frequency equivalent circuit diagram of the conducted noise. The block diagram illustrates that the common mode noise source and the differential mode noise source are separate parts. Assuming that ICM is a common mode current, IDM is a differential mode current, and in and Ip are the noise currents flowing through the live and neutral lines, respectively, then.

$$I_p = I_{CM} + I_{DM} \tag{1}$$

$$I_n = I_{CM} - I_{DM} \tag{2}$$

Those equations give the relationship between ICM and power line current.

$$I_{CM} = (I_p + I_n)/2 \tag{3}$$

The common-mode current in the circuit includes the live-ground, neutral, and ground lines, and the values are the same, and the directions are the same. Assume that the line impedance stabilization network is the same for the live and neutral lines, and then connect the impedance to the ground in the circuit, and its value is 50Ω. From the above study of the common-mode current, it can be seen from Fig. 4 that the relationship between the ground current Ig and the common-mode current ICM is as follows:

$$I_g = I_p + I_n = 2I_{CM} \tag{4}$$

Assume that VN and VP are respectively zero line and live line conducting noise voltage, and the common-mode voltage is defined as

$$V_{CM} = I_{CM} \times 50\Omega = \frac{I_p \times 50\Omega + I_N \times 50\Omega}{2} = \frac{V_p + V_N}{2} \tag{5}$$

It can be seen from equations (4) and (5) that the voltage value across the resistor is the common-mode voltage, and the common-mode current value is equal to the current noise value of the live line plus the noise current value of the neutral line.

$$I_{CM} = I_p + I_n \tag{6}$$

Comparing equations (4) with (6), it can be obtained that the values of ICM and Ig are equal. The common-mode current is not equal to the live and neutral currents in all cases. The ICM forms a loop with the parasitic capacitance in the circuit to generate current. Equation (7) shows the current pulse size ic caused by the rapid change of the parasitic capacitance Cp.

$$i_c = C_p \frac{dV_c}{dt} \tag{7}$$

When the load connection-mode is Y-type connection, the common-mode voltage refers to the voltage of the neutral points to the zero potential point. Set the voltage midpoint O point to the reference ground, and divide the DC side voltage into two parts, one part is Vdc/2, and the other part is -Vdc/2, then the DV/dt condition can be directly observed, and it can be clear Indicates the common-mode voltage. The schematic diagram of the three-phase inverter circuit is shown in Figure 5.

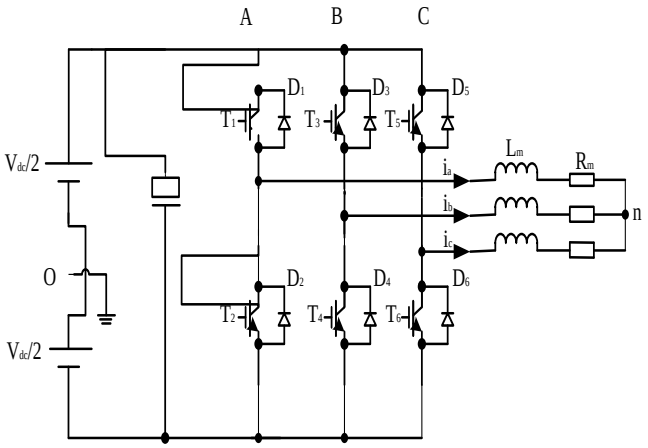

Fig. 4: Three-phase inverter circuit diagram

As shown in Figure 4, with zero point zero reference point, there are

$$\begin{cases} V_a - V_{cm} = R_m i_a + L_m \dfrac{di_a}{dt} \\ V_b - V_{cm} = R_m i_b + L_m \dfrac{di_b}{dt} \\ V_c - V_{cm} = R_m i_c + L_m \dfrac{di_c}{dt} \end{cases} \quad (8)$$

In the above formula, Va, Vb, and Vc are the phase voltages of each phase; ia, ib, and ic are the current outputs of each phase; and Vcm refers to the common-mode noise voltage. deformation of equation (8).

$$V_a + V_b + V_c - 3V_{cm} = R_m(i_a + i_b + i_c) + L_m \frac{d(i_a + i_b + i_c)}{dt} \quad (9)$$

According to Kirchhoff's current law KCL, ia+ib+ic=0, the simplified common-mode noise voltage is obtained by (9).

$$V_{cm} = \frac{V_a + V_b + V_c}{3} \quad (10)$$

Similarly, the common-mode noise value of a single-phase inverter can be obtained.

$$V_{cm} = \frac{V_a + V_b}{2} \quad (11)$$

It can be seen that the common-mode noise of the inverter can be represented by the line voltage, and the common-mode voltage noise must exist in the inverter system, but the common-mode current noise interference is not reflected, only when the current flows through the parasitic capacitance. In the ground, then the common-mode current noise interference is generated by the loop. Also, if the circuit is symmetrical, the common-mode current flowing through the neutral line and flowing through the live line is the same, and the value flowing through the ground line is twice the common-mode current.

b) Analysis of differential mode EMI noise

The relationship between the differential mode current IDM and the power supply current can be obtained by the equations (1) and (2).

$$I_{DM} = (I_p - I_n)/2 \quad (12)$$

The differential mode current IDM flowing through the live line and flowing through the neutral line is large and reverse. Based on the definition of the differential mode current IDM in the above equation, the differential mode voltage is defined as

$$V_{DM} = i_{DM} \times 50\Omega = \frac{i_p \times 50\Omega - i_N \times 50\Omega}{2} = \frac{V_p - V_N}{2} \quad (13)$$

Modulate the pulse width of the PWM, so that the inverter produces the sine wave we need, and also accumulates many high-order harmonics. The function of the filter is to weaken the harmonics. Different filters have different filter bands due to the difference in parameters. The upper limit of the frequency of the insulated gate bipolar transistor is very high, about 10khz to 20khz, the LC filter cannot be completely filtered out, which makes some high-frequency harmonics still exist, which acts on the output side of the circuit to generate differential mode noise.

Due to the existence of distributed capacitance, inductive load, and inductance, the differential mode EMI noise of high-frequency oscillation will inevitably occur in the breaking of the switching tube. If it is not suppressed, it will affect the DC power supply measurement and the load side, making the abnormal load jobs.

III. Application of Filter in Suppressing Conducted Noise of High Power Transformer Cabinet

Two important characteristics based on the filter: common-mode rejection ratio and differential mode rejection ratio. There is also a feature that the differential mode insertion loss is small in the common mode filter, and the common-mode insertion loss is small in the differential mode filter. Therefore, in the design circuit, it is necessary to give priority to the parameters of the filter to enable it to exert the best noise suppression capability and highlight the common-mode rejection ratio.

In this paper, the simulation model of the common-mode filter of the inverter circuit shown in the following figure is used. The noise source impedance Zs can be replaced by the parallel connection of the current source Iscm and the high impedance Zp. According to practical experience, it is known that Rs = 0.15Ω, Lp = 15 NH, RL = 10 mΩ, Cp = 5 pF, and Zp = 10 kΩ.

$$I(Z_{LISN}/2) = (Z_{2Cy}//Z_P)I_{scm}/(Z_{Lc} + Z_{LISN}/2 + Z_{2Cy}//Z_P) \quad (14)$$

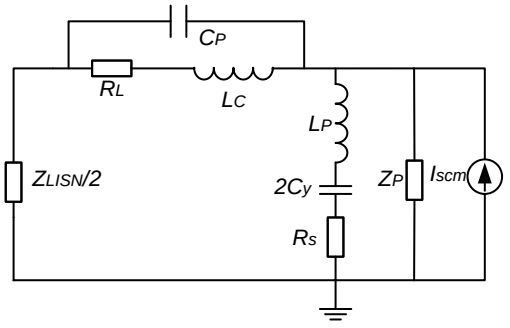

Fig. 5: Common mode filter circuit model

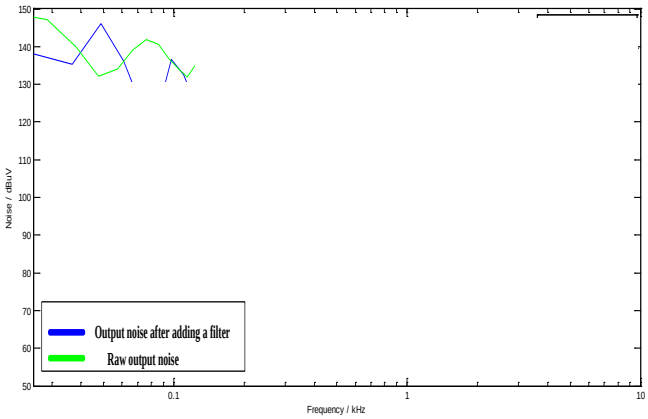

Fig. 6: The effect of the output filter added on CE101

In Figure 6 and Figure 7, we built the filter and set the parameters in the Simulink simulation software to extract the voltage at the input. As can be seen from the figure, compared with the previous circuit, the addition of the filter makes the conduction noise greatly reduced. The result of this simulation proves that the filter can reduce the conduction noise in the high-power transformer cabinet circuit, and It has practical significance.

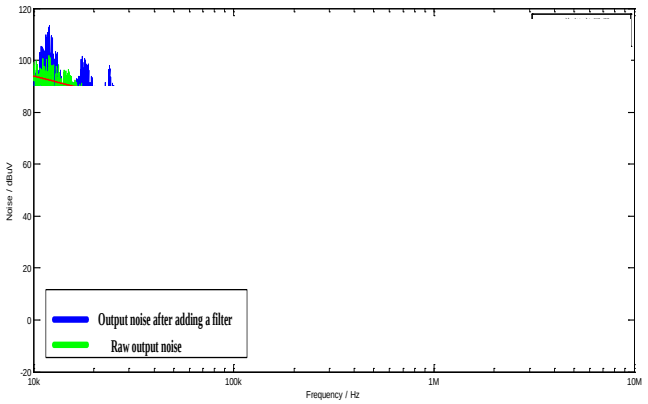

Fig. 7: The effect of the output filter added on CE102

IV. Conclusion

This paper mainly studies the mechanism of conducted noise and models, separates and suppresses noise. In the first step, based on the high-frequency equivalent circuit topology, the conduction noise current and voltage were successfully extracted, and the generation mechanism of the common-mode conduction noise was summarized. In the second step, a noise conduction equivalent circuit model based on this mechanism is built-in Simulink. The above work provides a theoretical basis for the following discussion to discuss the extraction and separation of conducted noise. In the third step, simulation experiments show that adding a filter to the simulation circuit can greatly reduce the conduction noise at the AC output, which provides a theoretical basis for our future practical application.

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Electric Current and Voltage Behaviour for a Perturbed Capacitor Lattice with Planar Triangular Design

By Noemen Ammar
University of Tunis el Manar

Abstract- The wave concept iterative process (WCIP) method is introduced in the goal to study the electric voltage and current distribution for a planar capacitor circuit with equilateral triangular architecture, excited by a vertical lumped source. The grid is governed by three planar directional vectors phase shifted the one to the other to 60 degree. The formulation employ the definition of the auxiliary sources for modelling the electrical components of the circuit (resistor and capacitor). Simulation results consider the current distribution on an RC circuit network with equilateral triangular lattice for both regular and perturbed design.

Keywords: *capacitor circuit, equilateral triangular lattice, wcip method, current and voltage distribution.*

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I. Introduction

Recently, interconnect circuit attract increasing attracting in a wide area of scientist researchers such as circuit theory design, microwave application, integrated circuit and physical model. The circuit networks analysis and design have been addressed by many research's regarding several architectures with finite or infinite size [1-4]. Many competitive methods have been developed to improving the design and modelling of the several lattice. Among them we cited, the Green function lattice [5], the Laplacian matrix [6] and the Recursion Transform method [7].

However, despite the accuracy and efficiency of these methods, there are limited to the analysis of the equivalent resistance or impedance for homogenous circuits excited an exterior source.

Latterly, a new approach of the Wave Concept Iterative Process method (WCIP) [8] is for computing the effective impedance and the current distribution of an RLC electrical circuit with triangular or hexagonal lattice.

The WCIP method is successfully used, near two decades, in the analysis of planar micro strip microwave circuits [9], [10] and it is demonstrating its power for solving the radiation and scattering electromagnetic problems [11-13]. The method is also reformulated to *analyze quasi-periodic lumped circuits with rectangular grid [14].These periodic lumped circuits can be considered as good equivalent representations to* accurately model continuous mediums if the cell's length is much smaller than the lattice.

The main keys of the proposed method was summarised as follows: (1) the incoming and outgoing wave's concept definition from the electrical entities (voltage and current).

(2) The introduction of the auxiliary sources techniques instead of the circuit components. (3) the use of the Fourier transforms appropriate to hexagonal and triangular lattice named HFFT (hexagonal fast Fourier Transform) and the resolution of the alternative (spectral-spatial) equations by an iterative process.

Therefore, the mathematical formulation is developed into two definition domains; a spectral-domain in which periodicity and coupling between components of the circuit was defined and a spatial one describing the topology and values of network elements, and imposing the continuities conditions (Kirchhoff's laws). The above relations represent a recursive system, which is resolved by an iterative process; the transition between one domain to another is guaranteed by the HFFT and its inverse.

In the first part of this paper, we develop the mathematical formalism describing the new WCIP method approach. In the second part, we show the design of the proposed circuit results, such as the spatial variation of the electric field inside the resonator and the frequency response of the transmission coefficient.

II. Theoretical Formulation

a) Waves definition

The WCIP principle is described in many papers; it is founded on the introduction of the incident (A) and reflected (B) waves tangential to each edge of the network. These waves are defined from the voltage and the current by the following equation:

$$\begin{cases} A = \frac{1}{\sqrt{Z_0}}(V + Z_0 I) \\ B = \frac{1}{\sqrt{Z_0}}(V - Z_0 I) \end{cases} \quad (1)$$

Where, Z_0 is an arbitrary chosen impedance.

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The electric current (I) and the voltage (V) can be calculated as follows (6):

$$\begin{cases} V = \sqrt{Z_0}(A+B) \\ I = \dfrac{1}{\sqrt{Z_0}}(A-B) \end{cases} \quad (2)$$

b) Spectral-domain analysis

This domain characterizes the physical relations (periodicity and Kirchhoff laws) established between the electrical components and written in waves term.

Fig.1 shows an electrical circuit network, the electrical schema considers a capacitor connected to a resistor and distributed according to an equilateral triangular grid. The circuit is excited by a lumped source located in the center (n=0, m=0) at a vertical edge.

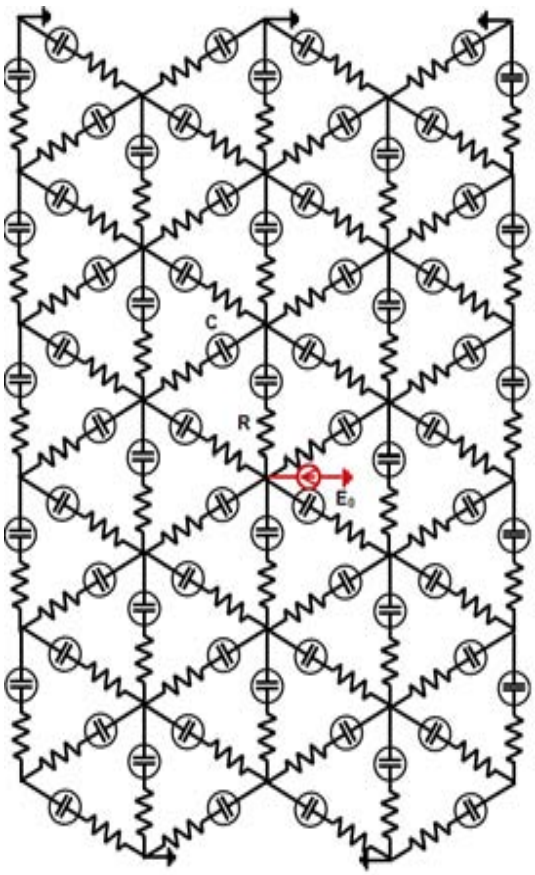


Fig. 1: A capacitor triangular circuit lattice

The potential difference across each lumped components of the circuits (capacitor, open circuit, shorted circuit and, source) is represented by an auxiliary sources.

The unit cell of the studied network is represented by the Fig.2; it considers three horizontal branches connected to a vertical one at the nodes. The shift phased the one to the other to 60 degrees. The electrical lattice is generated from the translation of the unit cell according to two of the three directional vectors ($\vec{e}_\alpha$, $\vec{e}_\beta$ and $\vec{e}_\gamma$) collinear to the horizontal branches.

We denote by (E_α, E_β, E_γ and E_z)the auxiliary sources representing the potential difference across the electrical components.

For ensuring the unit cells periodicity, periodic walls are placed perpendicular to the three directional vectors.

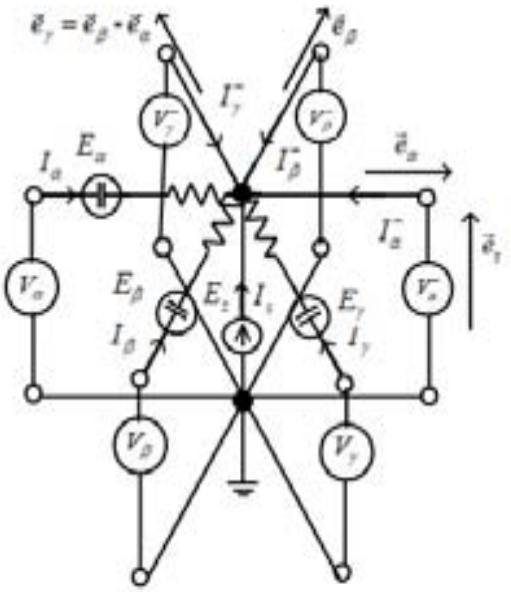


Fig. 2: Triangular unit cell

From Fig. 2, the periodicity laws permit to write

$$\begin{cases} E_z = V_\alpha e^{j\alpha} = V_\beta e^{j\beta} = V_\gamma e^{j\gamma} \\ \begin{pmatrix} I_\alpha^- \\ I_\beta^- \\ I_\gamma^- \end{pmatrix} = \begin{pmatrix} e^{j\alpha} & 0 & 0 \\ 0 & e^{j\beta} & 0 \\ 0 & 0 & e^{j\gamma} \end{pmatrix} \begin{pmatrix} I_\alpha \\ I_\beta \\ I_\gamma \end{pmatrix} \end{cases} \quad (3)$$

Establishing the Kirchhoff's laws to the unit cell, in considering relations given by Eq. 3, we obtain a spectral equation relating the electric current to the voltage

$$\begin{pmatrix} \tilde{I}_\alpha(n,m) \\ \tilde{I}_\beta(n,m) \\ \tilde{I}_\gamma(n,m) \\ \tilde{I}_z(n,m) \end{pmatrix} = \tilde{Y}_{n.m} \begin{pmatrix} \tilde{E}_\alpha(n,m) \\ \tilde{E}_\beta(n,m) \\ \tilde{E}_\gamma(n,m) \\ \tilde{E}_z(n,m) \end{pmatrix} \quad (4)$$

With

$$\tilde{\tilde{Y}}_{n.m} = \frac{1}{R}\begin{pmatrix} 1 & 0 & 0 & a_n \\ 0 & 1 & 0 & b_m \\ 0 & 0 & 1 & c_{n.m} \\ a_n^* & b_m^* & c_{n.m}^* & d_{n.m} \end{pmatrix} \quad (5)$$

Where $a_n = \left(1 + e^{-j\alpha_n}\right), b_n = \left(1 + e^{-j\beta_n}\right)$, $c_{n.m} = \left(1 + e^{-j\gamma_{n.m}}\right)$, $d_{n.m} = \left(|a_n|^2 + |b_m|^2 + |c_{n.m}|^2\right)$ and

$$\begin{cases} \alpha_n = \dfrac{2\pi m}{N} \\ \beta_m = \dfrac{2\pi m}{M} \\ \gamma_{n.m} = \beta_m - \alpha_n \end{cases} \quad (6)$$

The subscript (*) denote the conjugate of a complex number.

Substituting Eq. (2) in Eq. (3), a spectral equation relating the incident to the reflected wave is

$$\begin{pmatrix} \tilde{\tilde{B}}_\alpha(n,m) \\ \tilde{\tilde{B}}_\beta(n,m) \\ \tilde{\tilde{B}}_\gamma(n,m) \\ \tilde{\tilde{B}}_z(n,m) \end{pmatrix} = \tilde{\tilde{\Gamma}}_{n.m} \begin{pmatrix} \tilde{\tilde{A}}_\alpha(n,m) \\ \tilde{\tilde{A}}_\beta(n,m) \\ \tilde{\tilde{A}}_\gamma(n,m) \\ \tilde{\tilde{A}}_z(n,m) \end{pmatrix} \quad (7)$$

With $\tilde{\tilde{\Gamma}}_{n.m} = (II - Z_0 Y_{n.m})(II + Z_0 Y_{n.m})^{-1}$

c) Spatial domain analysis

In the spatial domain, every auxiliary source replace by its corresponding impedance (capacitor, inductor or resistor), then the spatial reflexion operator is given by

$$S = (Z - Z_0)(Z + Z_0)^{-1} \quad (8)$$

For the open and shorted circuit, the spatial reflexion operator is given by

$$S = \begin{cases} -1 \ For\ the\ short\ circuit \\ 1 \ For\ the\ open\ circuit \end{cases} \quad (9)$$

In considering the excitation source, the reflected waves are related to the incidents ones by the following relationship

$$A = SB + A_0 \quad (10)$$

With A_0 represents the feeding source in wave term.

d) Iterative process

Collecting (7) and (10), the iterative process is governed by a set of two equations describing, the boundaries condition (Kirchhoff's laws) in the spatial-domain and the periodicity laws in the spectral-domain. The Hexagonal Fast Fourier Transform (HFFT) and its inverse $(HFFT)^{-1}$, ensure the transition between the two domains (Fig.3)[8]. Electrical quantities: current and voltage are determined from the incident and reflected waves at each iteration. The iterative process is halted when the voltage (or current) converges.

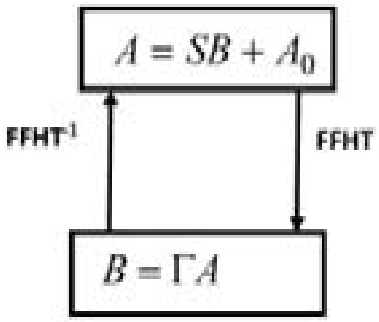


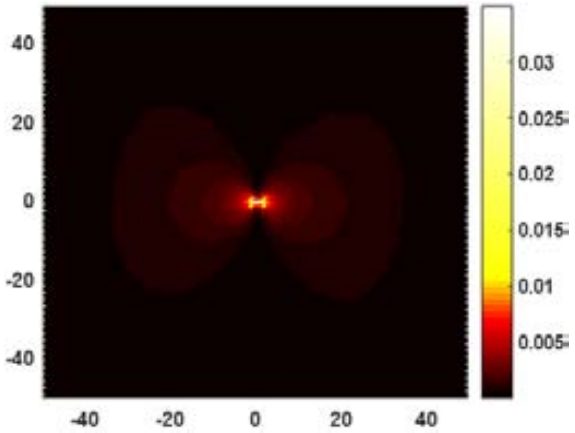
Fig. 3: Principle of the iterative scheme

III. Numerical Results

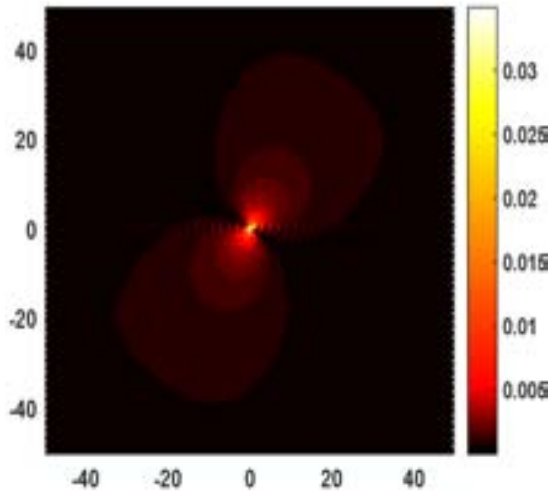
The above formulation is employed for calculated the electrical current components on the horizontal edges of the lattice and the potential difference between the nodes and ground in a first step, then the method is also used to investigating the so-called perturbed lattice.

In the numerical example, the total cells number are fixed to N= 100 and M=116, and we take C=2.3pF and R=0.4 **Ω**. The circuit is excited by a voltage source E_0= 1V, the source is located at the middle of the circuit in (N =0, M =0).

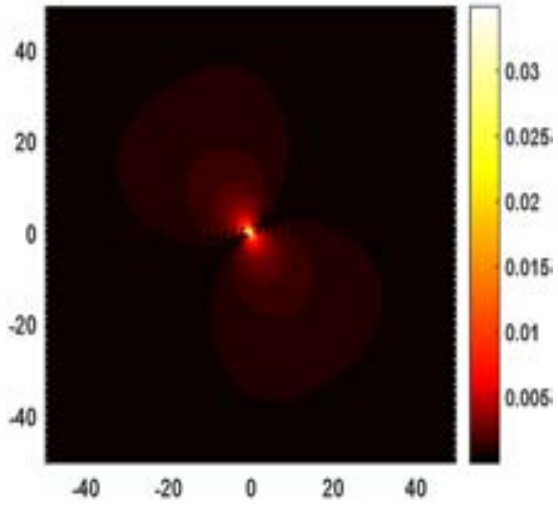
Fig.4 shows the electrical current propagation for the three horizontal components I_α, I_β and I_γ. It is observed that the distributions of each current component is oriented according its principal axis.



a) I_α component



b) I_β component



c) I_γ component

Fig. 4: Electric currents components distribution

We can also see that the components present a rotational symmetry of angle of 60 degrees. The currents figures display that the intensities are maximum at the lattice center and show a central and axial symmetry.

Fig. 5 shows the vertical voltage propagation; we note that the dispersion is considerable in the proximity of the feeding source.

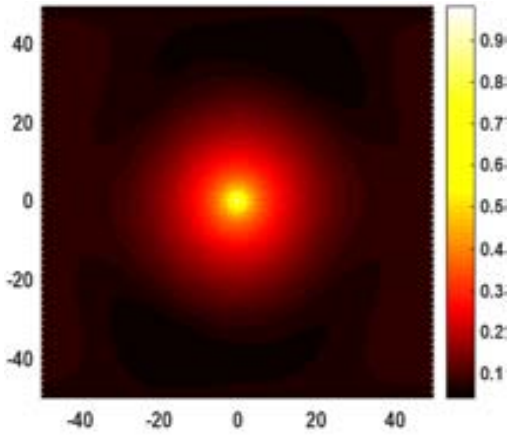


Fig. 5: Vertical voltage repartition

In the next, we analysis the so called perturbed lattice. A perturbed lattice is defined, in many types of research that interested in computing the equivalent resistance or impedance between two arbitrary nodes, by the network wherein we remove one or two bonds from the regular circuit. Herein, we extend this description and we define a perturbed architecture by the lattice that we remove one or many arbitrary part.

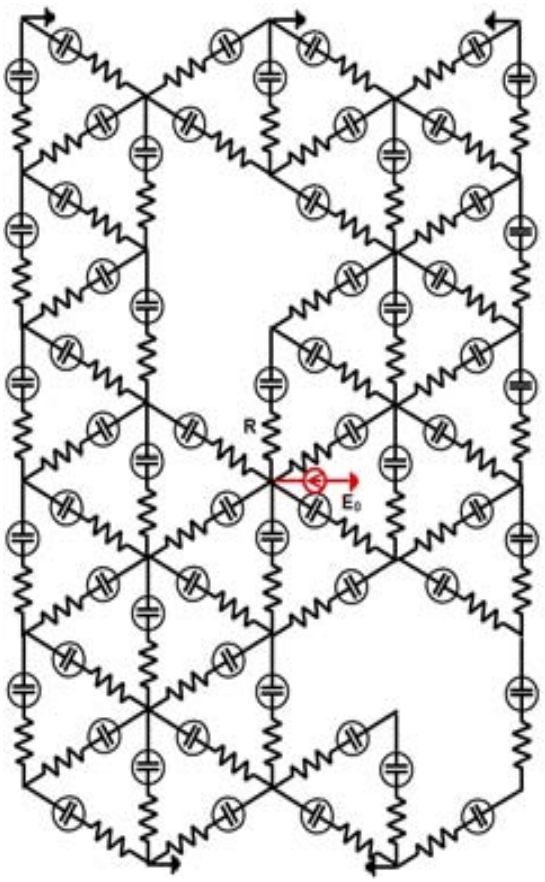
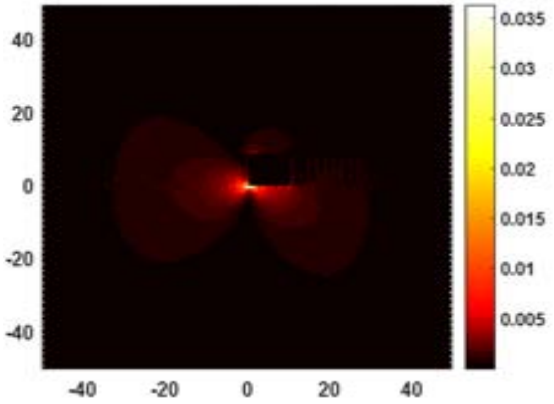
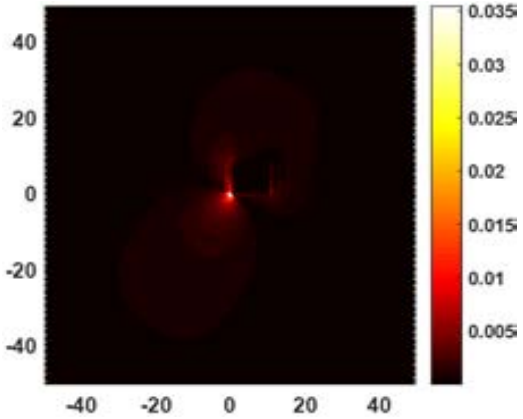


Fig. 6: Example of perturbed circuit with triangular lattice

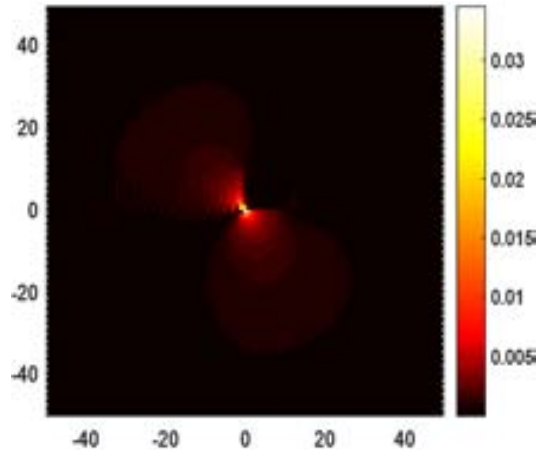
The figures (7) and (8) display the current and vertical voltage distributions for a removed band located for (1≤n≤10) and (1≤m≤10) . With n and m represent the cell numbers according $\vec{e}_\alpha$ and $\vec{e}_\beta$ directions, respectively.



a) Perturbed Iα component



b) Perturbed I_β component



c) Perturbed $I_\gamma$component

Fig. 7: Electric currents components distribution for a perturbed triangular lattice: one band removed

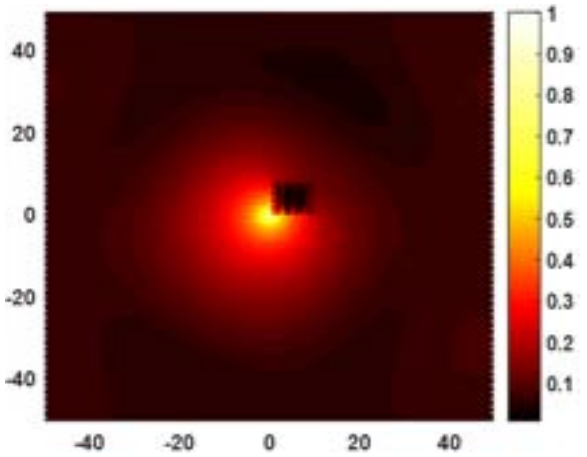
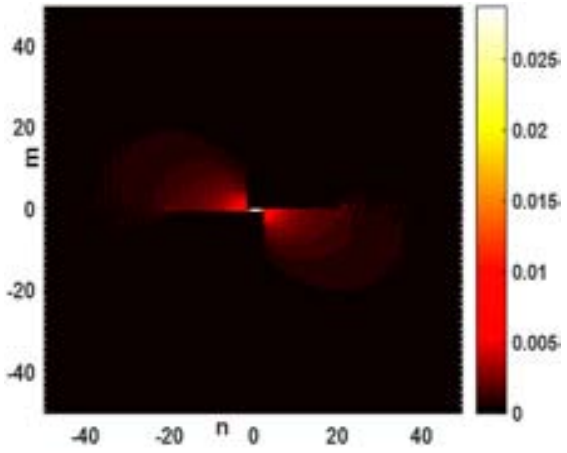


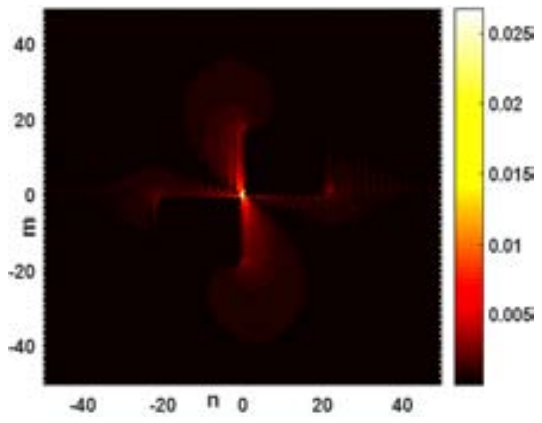
Fig. 8: Vertical electric voltage distribution for a perturbed triangular lattice

We clearly observe the perturbation effecton the graph, infact, the currents and voltage are null in the removed bands and in the irproximities.

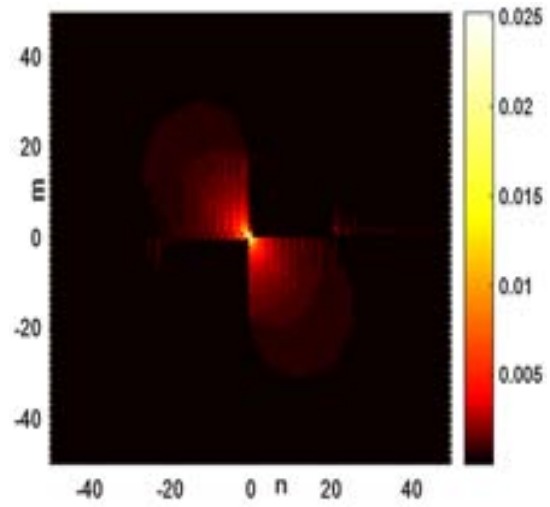
In the next example, we remove two electrical bands for a wide eliminated area. The suppressed surfaces are situated on (1≤n≤20), (1≤m≤20) and (-20≤n≤-1),(-20≤m≤-1).



a) Perturbed I_α component for two removed bands



b) Perturbed I_β comonent for two removed bands



c) Perturbed I_γ component for two removed bands

Fig. 9: Electrical current components for two removed bands

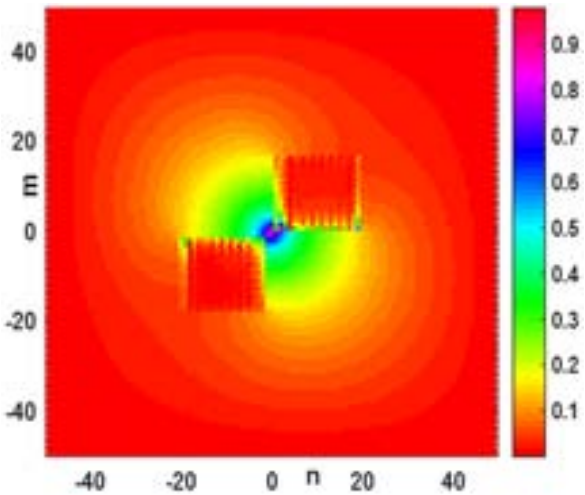


Fig. 10: Perturbed vertical voltage for two removed bands

The visualization of the electrical current and voltage depicted by figures (9) and (10) demonstrates that the propagation becomes more degenerate when the surfaces and number of the removed bans increases. It is worth noting that the problems of the electrical perturbed circuits become more interesting for several physical difficulties analysis, notably for in the modelling of semiconductors with electrical default.

IV. Conclusion

In this paper, a full-wave concept was formulated to investigate an RC circuit with triangular lattice. The method is defined in two definition domains: a spectral-domain describing the periodicity laws and a spatial-domain in the design of the circuit is defined and the Kirchhoff's laws are imposed. The auxiliary sources was introduced for characterizing the potential difference across each electrical element.

In numerical results, the electrical current and vertical potential difference distribution are visualized for a planar capacitor-resistor circuit with triangular architecture. The perturbed RC circuit is also defined and investigated, we observe a deformation of the electrical current and voltage.

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Complex Analysis of Human Movements based on the Identification of Amplitude-Time Characteristics of Electromyographic Patterns

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Abstract- The task of a complex biomechanical and electrophysiological analysis of human movements is actual for medicine, sports and special work. The article describes an algorithm for creation of electromyographic patterns of human movements. The method of complex estimation of human movements based on the identification of the amplitude-time characteristics of electromyographic patterns is presented. Research of the electromyographic pattern of the test movement "jump up"is described. The classification of motion skills types by the energy contribution of muscles during the movement and by the distribution of muscle efforts in the movement phases is detected.

Keywords: digital signal processing, amplitude-time analysis, human movements, multi-channel electromyography, podography, electromyographic motion pattern.

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Nadezhda Davydova [α], Maksim Davydov [σ], Anatoly Osipov [ρ] & Marina Mezhennaya [ω]

Abstract- The task of a complex biomechanical and electrophysiological analysis of human movements is actual for medicine, sports and special work. The article describes an algorithm for creation of electromyographic patterns of human movements. The method of complex estimation of human movements based on the identification of the amplitude-time characteristics of electromyographic patterns is presented. Research of the electromyographic pattern of the test movement "jump up"is described. The classification of motion skills types by the energy contribution of muscles during the movement and by the distribution of muscle efforts in the movement phases is detected. The research of the energy contribution of the muscles during the test motion allowed to identify three types of motion skills: 1) the muscles *m. gastrocnemius lateralis* and *m. soleus* mainly provide test motion (40.48% of all subjects); the muscles *m. rectus femoris, m. gastrocnemius lateralis* and *m. soleus* are equal in the degree of involvement in the process of motion (50% of all subjects); the muscle *m. rectus femoris* dominates in the process of the motion (9.52% of all subjects).The research of the distribution of muscle efforts in the phases of the test motion allowed to identify three types of motion skills: the maximum muscle effort is performed in the push phase (54,76% of all subjects);the maximum muscle effort is performed in the squatting phase (14,29% of all subjects); the muscle efforts are equally distributed between squatting and push phases (30,95% of all subjects).The research results demonstrate the effectiveness of the proposed complex analysis of human movements.

Keywords: digital signal processing, amplitude-time analysis, human movements, multi-channel electromyography, podography, electromyographic motion pattern.

I. Introduction

Human movements are the result of the coordinated work of functional mechanisms and processes. Such coordinated work develops during and as a result of constructing an action with the leading role of the higher parts of the central nervous system and ensures the consolidation of all body systems involved in its implementation [1-2].This complicated organization of the human motion system determines the demand of integrated analysis of movements based on the interpretation of both biomechanical and electrophysiological motion parameters. Biomechanical parameters describe the external spatio-temporal components, and electrophysiological parameters describe internal control mechanisms [3-4].

Existing methods and technical solutions for the study of human movements based on electrophysiological signals are used primarily in clinical practice to diagnose the functional state and diseases of the human musculoskeletal system [5-6]. Moreover, the list of movements in clinical practice is limited to simple and working movements (walking, grabbing, cyclic motion acts) [7-10]. In the field of sports, the use of biomechanical methods for analyzing human movements predominates. Such methods allow to estimate the technique of implementation sports exercises, but do not provide information about the physiological mechanisms of the motion act [11-13].Electrophysiological methods in sports are still not enough used, because they are mainly intended for laboratory use of rather complex and expensive neurophysiological systems, require highly qualified personnel and special methods for analyzing the obtained data [14-17].Diagnostic systems for the study of sports movements must have certain design and technical features: multichannel, compact, autonomous power, wireless data transfer[18-20]. In addition, the sport movements are characterized by a complicated structural and functional organization [21], which requires the development of new algorithms for the complex processing of biomechanical and electrophysiological data.

Each human movement corresponds to a certain spatio-temporal pattern, which characterize the direction, power and sequence of inclusion of muscles involved in performing the movement. Automated movements (walking, running, cycling, special and sports movements) are motion skills. They have a

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constant pattern of muscle involvement not only when the movement is repeated by one person, but also in different people. Selection from the aggregate of the muscles electrical activity data such combinations, which characterize a specific movement, make it possible to create the electromyographic pattern of human movement [22-24].

In this work, we propose the complex analysis of human movements based on the identification of amplitude-time characteristics of electromyographic patterns, and describe studies that confirm the effectiveness of the proposed approach.

II. Research Methods and Data Processing

a) Subjects

The study was carried out among participations of the basketball team at the Sports Complex of the Belarusian State University of Informatics and Radio Electronics (Minsk, Belarus). The study involved 42 people (7 women, 35 men) aged 17 to 25 years, of which 8 people are the professional sportsmen. The essence of the research were previously explained for all subjects. The subjects were in full health and did not report any feelings of pain when performing the tests.

The movement "jump up" was selected as a test for the study of person motion skills. This movement is a speed-strength exercise, andit' sused as a test movement for estimation of motion abilities in high-speed power sports, or as a training exercise to develop a muscle strength of legs, jumping ability and the ability to concentrate muscle efforts combining strength with speed [25-26].

The main muscles of the legs (*m. rectus femoris, m. biceps femoris, m. gastrocnemius lateralis, m. soleus*) were studied [27] (table 1) due to the specificity of the test movement.

Table1: The studied muscles and their functions

Musclename	Locationandfunction
m.rectusfemoris	It is located on the front of the thigh. Unbends the leg in the knee joint, flexes the hip in the hip joint.
m. bicepsfemoris	It is located on the back of the thigh. Flexes the leg in the knee joint, unbends the leg in the hip joint.
m. gastrocnemiuslateralis	It is located on the back of the shin. Flexes the foot, helps in the flexing of the leg in the knee joint.
m. soleus	It is located deep in the shin. Flexes the foot.

b) Methods

The method of multichannel interference electromyography was chosen for creation of the motion innervation structure. The method of podography was chosen for creation of the motion spatio-temporal structure.

The methods, which are used to create the motion innervation structure, should be associated with the registration of muscles control signals in the process of motion activity. The most convenient, simple and painless of these methods is multichannel interference electromyography, which allows studying the bioelectric activity of several muscles at the same time. The summary electromyogram (EMG) is formed as a result of interference of many motion unit signals located in the area of recording. The method of multichannel interference electromyography allows to estimate the participation of muscles in various movements, the sequence of their on and off, the integrated level of muscle activation, the correlation of muscle activity in different periods of motion skills formation [28-30].

Thus, the motion innervation structure can be represented by multichannel electromyographic signals of the studied muscles.

The spatio-temporal structure of movement allows to divide the motion activity into separate phases and then to research it in parts. In the presented paper, the method of podography was chosen for creation of the motion spatio-temporal structure. The method of podography (PDG) allows to record the time moments of contact of various parts of the foot with the ground, and to identifymotion phases [31-32].

Thus, the motion spatio-temporal structure can be represented by multichannel podographic signals of the studied movement.

The complex application of these methods (multichannel interference electromyography and podography) allows to create an electromyographic pattern of motion, which is an electrophysiological analogue of motion and is a combination of time, spatial and amplitude electromyographic characteristics of motion.

c) Data collection

Registration of electrophysiological and biomechanical signals were realized by the proprietary system "Mio Sport" [33]. The developed device includes a multi-channel electromyography system with synchronous registration multi-channel podographic signals, and a software for visualization and analysis of the results (Figure 1). The system allows real-time recording of 4EMG channels (minimum detection limit of 30 μ V, frequency range of 0.1–800 Hz), 4 PDG channels

(time resolution of 3,125 ms), and data transmission via a wireless interface to a distance of up to 100 m [34–35].

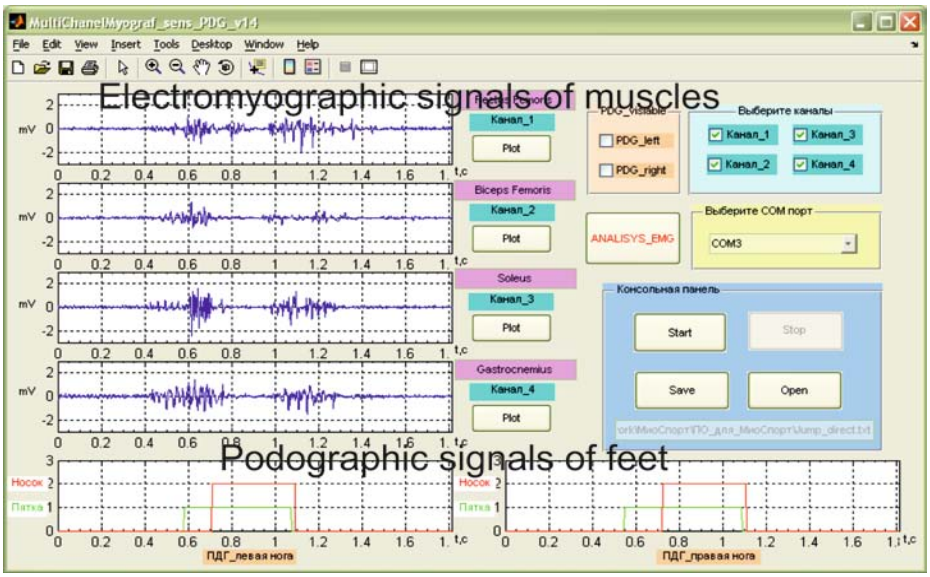


Figure 1: The software of the system "Mio Sport"

The registration of summary bioelectric activity of the muscles (electromyograms) was carried out using specialized surface medical adhesive electrodes. Fixation and positioning of electrodes on the studied muscles, orientation relative to motor fibers, the quality of skin surface preparation for recording of surface EMG were carried out in accordance with the recommendations of SENIAM [36].

The multi-channel podographic signals were recorded synchronously with EMG using the developed sensor electrodes [33–34] located on the soles of both feet. The dimensions of the podographic electrodes are small and do not disturb with the acting of exercises. The sensory manufacturing technology of PDG electrodes allows to study motions on the floor with any coating. The PDG electrodes are fixed to the heel and toe of each foot. Thus, it is possible to record the moments of separation and touching the ground by the heel and toe of each leg.

Figure 2 shows an example of the signals registration: the muscle electromyogram of *m. rectus femoris* of the right leg and two channels of the right foot podograms for the test move "jump up". The podograms of each leg are presented as two curves: with a smaller amplitude - the reaction of the heel, with a larger amplitude -the reaction of the toe. In this case, the zero level of the curves matches to the touching of the foot part with the ground, and the maximum amplitude of the curves matches to the lack of touching (Figure 2).

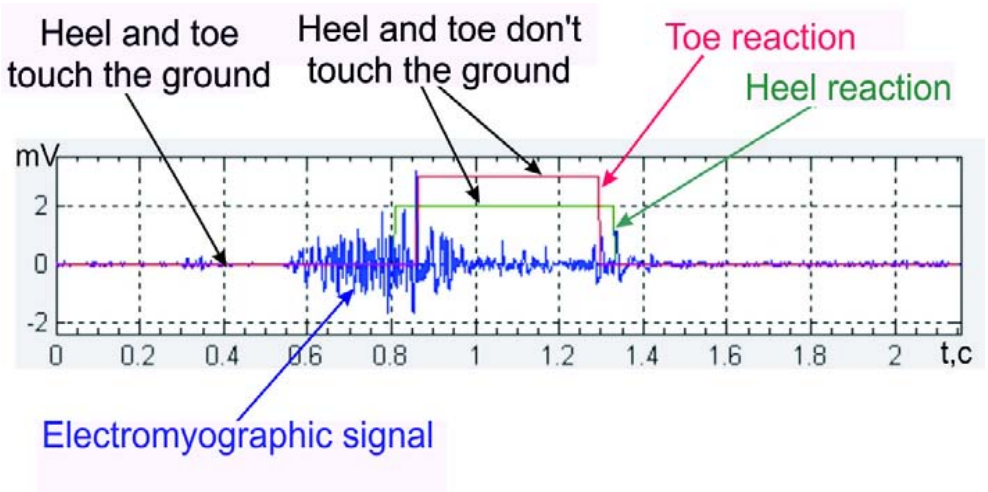


Figure 2: View of synchronously recorded EMG and PDG signals during the test movement

d) Data processing

The multichannel electrophysiological and biomechanical signals recorded during the motion are processed to create the electromyographic motion pattern according to the following algorithm:

1. The overlay of electrophysiological and biomechanical signals in the time domain.

The overlay of electrophysiological and biomechanical signals in the time domain is necessary for cooperative studying of the motion innervation and spatio-temporal structure. The time scales of signals are converted to a common basis according to their sampling frequencies, and then the signals are drawn in one graphic window.

In the presented work, the sampling frequency of the electromyographic signals is 1600 Hz for, and the sampling frequency of the podographic signals is 320 Hz. Accordingly, the minimum sampling recovery time interval for the correct displaying of electrophysiological and biomechanical signals is selected as 0.625 ms for the EMG signal, and 3.125 ms- for the PDG signal.

2. The filtration of multichannel electrophysiological signals.

As a result of the electrode system movement during the motion test, low-frequency components (motion artifacts) appear in the spectrum of the EMG signal, which leads to incorrect analysis of the EMG signal [37]. In the presented work, EMG signals are filtered using a fourth-order Chebyshev digital high-pass filter for removing of the motion artifacts from the useful signal spectrum. The cutoff frequency of the filter is 10 Hz.

3. Time rationing of multichannel electromyographic signals.

Time rationing of signals of multichannel electromyograms is necessary for unification of the EMG pattern of the same movement in different people.

The creation of a time motion structure using the method of podography is possible for such locomotion as walking, running, jumping. Thus, any such exercise will contain phases of movement, when one or both legs do not touch the ground. Those phases are chosen as the norm. Further, the signals of multichannel EMG are normalized according to the selected norm.

In the work, “jump up” was selected as a test motion. For this exercise, the phase of flight (Δt_flight) is taken as the norm. The time interval corresponding to the two phases of flight (2Δt_flight) is captured to the left of the moment the toe separate from the ground and to the right of the moment the toe touch with the ground (Figure 3).

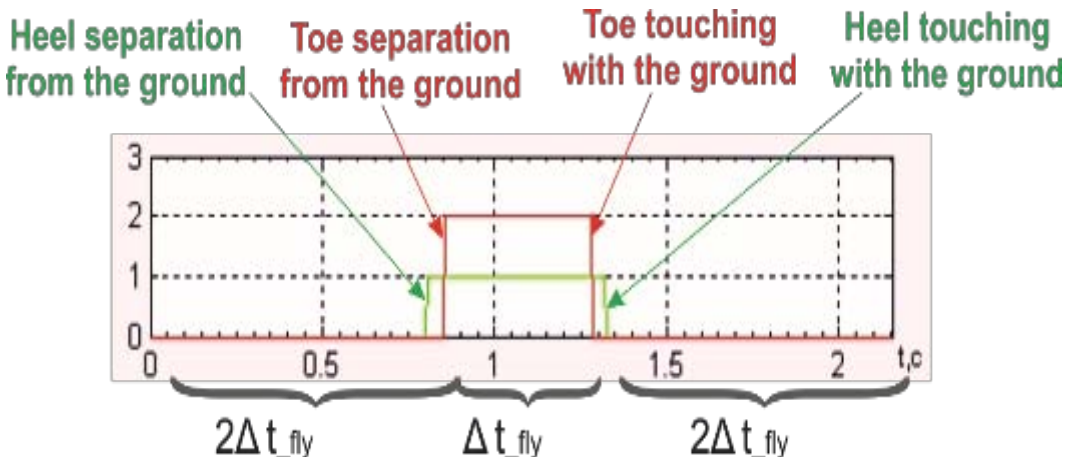


Figure 3: The time structure of the motion "jump up"

1. The detection of motion phases.

The phases of movement are detectedbased on the obtained time structure of the studied motion activity. The beginning and end of the movement can be determined based on the detection of the time interval of concentration of the EMG signal energy of the studied muscles. The detection criterion of this time interval is the concentration of the EMG signal energy of the studied muscles more than 95% of the initial EMG signals energy:

$$\sum_{m=1}^{M} E_{m,T} \geq 0{,}95 \sum_{m=1}^{M} E_m^{init} \qquad (1)$$

Where T – the time interval from the beginning to the end of the movement;

M – the number of studied muscles;

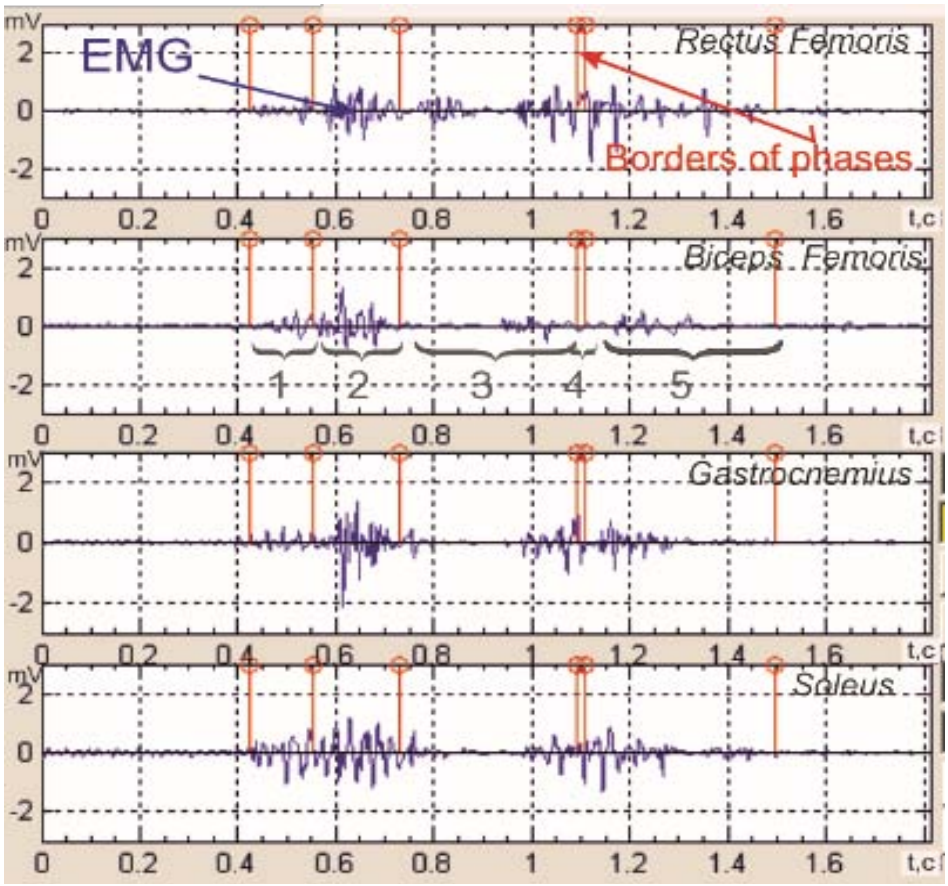
m – the muscle number;

$E_{m,T}$ - the EMG signal energy of the muscle $m$in the time interval T;

E_m^{init} - the initial EMG signal energy of the muscle m.

Thus, after processing of the multichannel electrophysiological and biomechanical signals in accordance with the described algorithm, the obtained data are the EMG pattern of the studied movement [38].

Figure 4 shows an example of the EMG pattern of the motion "jump up". The figure shows the normalized electromyograms of muscles *m. rectus femoris*, *m. biceps femoris*, *m. gastrocnemius lateralis* and *m. soleus* of the right leg, and markers of the movement phases borders corresponding to the time moments "start of the movement ", "heel separation from the ground", "toe separation from the ground", "toe touching with the ground", "heel touching with the ground", "heel touching with the ground" and "end of the movement". The following phases were detected for the test movement: the squatting phase (1) - from the motion beginning to the heel separation from the ground, the push phase (2) - from the heel separation from the ground to toe separation from the ground, the flight phase (3) - from toe separation from the ground to the toe touching with the ground, the touchdown phase (4) - from the toe touching with the ground to the heel touching with the ground, the rise phase (5) - from the heel touching with the ground to the movement end.



1 – the squatting phase, 2 – the push phase, 3 – the flight phase, 4 – the touchdown phase, 5 – the rise phase

Figure 4: The EMG pattern of the movement "jump up"

2. The amplitude-time analysis of electromyographic motion patterns.

The processing of registered electromyographic signals of muscles is carried out in the digital form. The initial analog electrical EMG signal of muscles is sampled in time and quantized in amplitude.

In the theory of digital signal processing, the energy of a digital signal is considered not as a physical quantity but as a means of comparing different signals. So, for the initial electrical signal, the load resistance is assumed R=1 [39]. Accordingly, the dimension of the received energy of the digital signal is not measured in Joules. However, the energy of the digital signal can be recalculated to a physical value if the load resistance is known [40].

The EMG signal energy E_m is calculated for each muscle *m*:

$$E_m = \sum_{i=1}^{n} E_{m,i} = \sum_{i=1}^{n} \frac{(x_{m,i})^2}{n}, \quad (2)$$

where $E_{m,i}$ - *i*-th discrete sample of the EMG signal energy of the muscle *m*;

$x_{m,i}$ - the amplitude of *i*- th discrete sample of the EMG signal of the muscle *m*;

n – the number of discrete samples of the EMG signal.

Similarly, the energy of the EMG signal of muscle *m* is calculated for each phase *f* of the studied motion $E_{m,f}$.

The using of the average, not summary energy of the EMG signal of muscles allows to take account of the frequency of sampling of the initial electromyographic signal, and, accordingly, to standardize the proposed method of integrated analysis of human motions in case of using technical systems of multichannel electromyography with different parameters of the sampling frequency of EMG signals.

In each phase of motion *f* for all muscles *m*, the fraction of the EMG signal energy $E^{\%}_{m,f}$ is calculated as a percentage of the total signal energy:

$$E^{\%}_{m,f} = \frac{E_{m,f}}{E_m} * 100\%, (\%) \quad (3)$$

Where *f*– the number of the motion phase;

$E_{m,f}$ - the energy of the EMG signal of the muscle *m* in the phase *f*.

III. Results

The estimation of energy contribution of the muscles in the process of motion.

In order to identify types of motion skills, the estimation of the energy contribution of muscles during the motion "jump up" was carried out according to the following algorithm:

1. For each subject, the EMG pattern of the test motion was created in accordance with the above method.
2. The summary energy of the EMG motion pattern E_{Σ} was calculated as the sum of the EMG signal energies of all studied muscles:

$$E_{\Sigma} = \sum_{m=1}^{M} E_m, \quad (4)$$

3. For each muscle, the percentage of energy from the summary EMG energy of the motion pattern $E^{\%}_m$ was determined:

$$E^{\%}_m = \frac{E_m}{E_{\Sigma}} * 100\%, \quad (5)$$

4. For each muscle, the mean value and standard deviation (RMS) of the energy fraction from the summary EMG energy of the motion pattern were calculated.

The percentage of the energy from the summary EMG energy of the motion pattern for each muscle is presented in Table 2.

Table 2: The percentage of the energy from the summary EMG energy of the motion pattern for the studied muscles

	m.rectusfemoris	m. bicepsfemoris	m. gastrocnemiuslateralis	m. soleus	m. gastrocnemius + m. soleus
Meanvalue of $E^{\%}_m$, %	38,82	4,33	28,62	28,23	56,85
RMS of $E^{\%}_m$, %	14,75	2,86	12,33	13,43	14,22

It was found out that among the studied muscles the following muscles mainly provide for the test movement: *m. rectus femoris muscles* (the share of EMG energy of the motion pattern is 38.82%±14.75%), *m. gastrocnemius lateralis* and *m. soleus* (the share of EMG energy of the motion pattern is 28.62%±12.33% and 28.23%±13.43%). The level of involvement of the muscle *m. biceps femoris* in the motion is not significant (the share of EMG energy of the motion pattern is 4.33%±2.86%).

In addition, the largest variation of the EMG energy fraction of the motion pattern is observed for the muscles *m. rectus femoris, m. gastrocnemius lateralis* and *m. soleus* (*m. rectus femoris* - ±14.75%, *m. gastrocnemius lateralis* - ±12.33%, *m. soleus* - ±13.43%).

Thus, the muscles *m. rectus femoris, m. gastrocnemius lateralis* and *m. soleus* are the leaders in the formation of the test motion and were chosen as the basis for the detection of jump types. The muscles *m. gastrocnemius lateralis* and *m. soleus* belong to the triceps of the shin and perform the same functions (shin and foot bending/unbending, shin rotation). Accordingly, they can be combined into one group for consideration of energy contribution of the muscles in the process of motion. For this muscle group (*m. gastrocnemius lateralis* + *m. soleus*), the share of EMG energy of the motion pattern is 56.85%±14.22% (see Table 2).

The point diagram of the percentage proportion of the EMG energy share of the test motion pattern for the muscle *m. rectus femoris* and the muscle group *m. gastrocnemius lateralis* + *m. soleus* was drawn (Fig. 5).

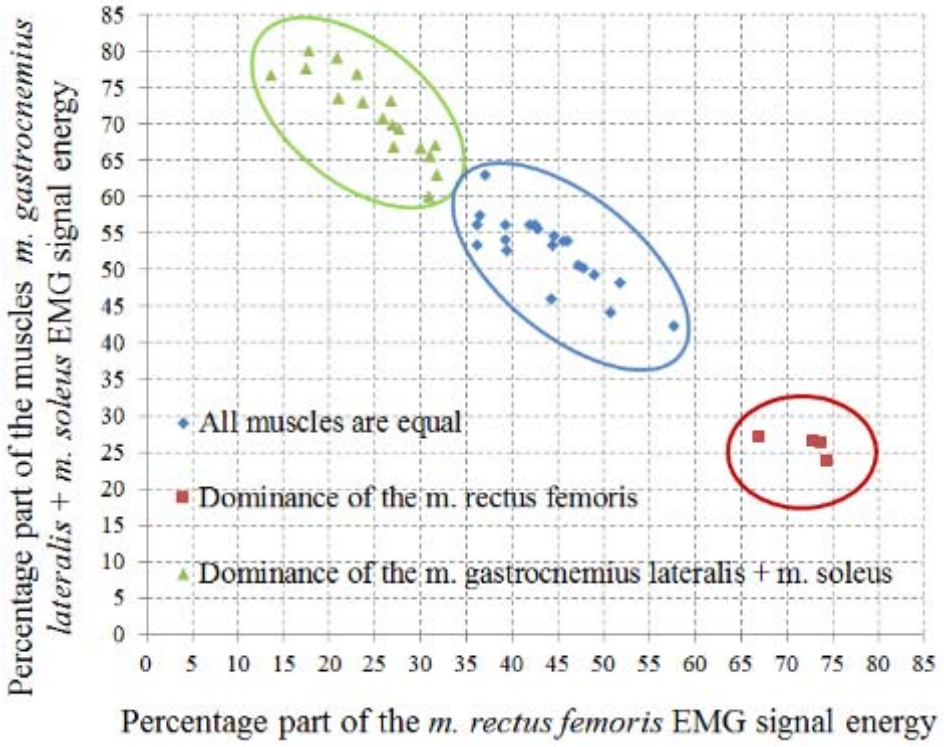


Figure 5: The point diagram of the percentage proportion of the EMG energy share of the test motion pattern for the muscle *m. rectus femoris* and the muscle group *m. gastrocnemius lateralis + m. soleus*

It was found that the data are clustered into 3 groups:

1. The group (17 people - 40.48% of the whole group), for which the muscles that mainly provide test motion are *m. gastrocnemius lateralis* and *m. soleus*. The share of EMG energy of the motion pattern for the muscular group *m. gastrocnemius lateralis + m. soleus* is 71.17%± 5.63%, for the muscle *m. rectus femoris* - 25.09%± 5.30%.
2. The group (21 persons - 50% of the whole group), for which the muscles *m. rectus femoris*, *m. gastrocnemius lateralis* and *m. soleus* are equal in the degree of involvement in the process of motion. The share of EMG energy of the motion pattern for the muscular group *m. gastrocnemius lateralis + m. soleus* is 52.78%± 4.69%, for the muscle *m. rectus femoris* - 43.81%± 5.58%.
3. The group (4 persons - 9.52% of the whole group), for which the muscle *m. rectus femoris* dominates in the process of the movement. The energy share of the EMG motion patternfor muscle group*m. gastrocnemius lateralis + m. soleus* is 25.79%±1.32%, for the muscle *m. rectus femoris* - 72.07%±2.94%.

Figure 6 shows the histograms of the percentage ratio of the EMG energy shares of the motion pattern for the studied muscles, corresponding to the above groups.

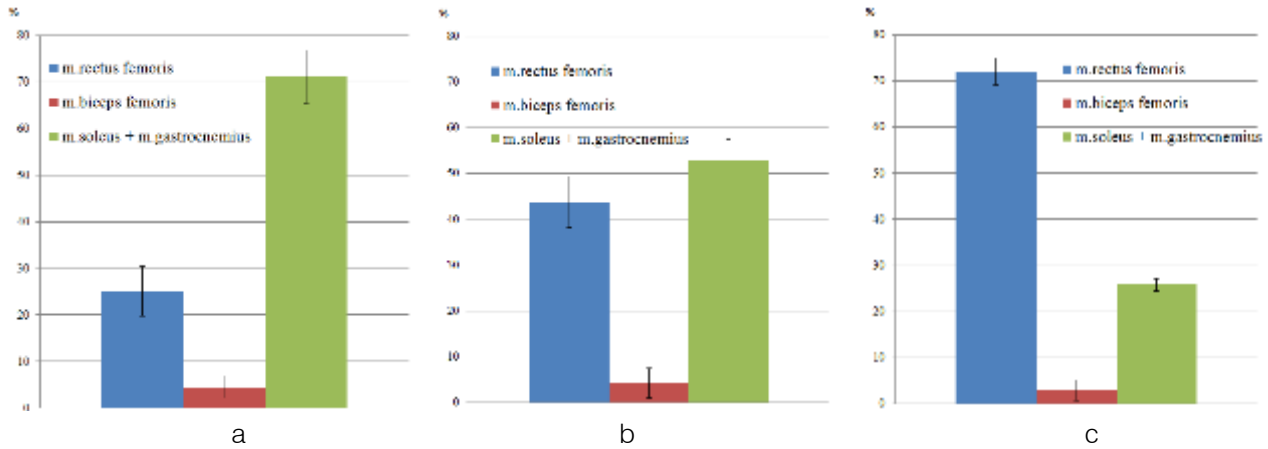


Figure 6: The histograms of the percentage ratio of the EMG energy shares of the motion pattern for the studied muscles: the muscles *m. gastrocnemius lateralis* and *m. soleus* mainly provide test motion (a); the muscles *m. rectus femoris, m. gastrocnemius lateralis* and *m. soleus* are equal in the degree of involvement in the process of motion (b); the muscle *m. rectus femoris* dominates in the process of the motion (c)

Thus, the percentage ratio of the EMG energy shares of the motion pattern for the studied muscles is different and allows to identify three types of motion skills for the jump: a) the muscles *m. gastrocnemius lateralis* and *m. soleus* mainly provide test motion (Fig. 6 a); b) the muscles *m. rectus femoris, m. gastrocnemius lateralis* and *m. soleus* are equal in the degree of involvement in the process of motion (Fig. 6 b); c) the muscle *m. rectus femoris* dominates in the process of the motion (Fig. 6 c). The EMG energy share of the motion pattern for the muscle *m. biceps femoris* does not exceed 5%.

The estimation of distribution of muscle efforts in the phases of motion.

The analysis of the distribution of muscle efforts in the phases of the test motion was carried out in order to identify the types of motion skills.

1. The analysis of the distribution of muscle efforts in the motion phases was carried out according to the following algorithm:
2. For each subject, the EMG pattern of the test motion was created in accordance with the above method.
3. The summary energy of the EMG motion pattern E_{Σ} was calculated as the sum of the EMG signal energies of all studied muscles (see formula 4).
4. The summary energy of the EMG signals of each phase E_f was calculated as the sum of the EMG signal energies of the muscles, concentrated in the phase *f*:

$$E_f = \sum_{m=1}^{M} E_{m,f}\ , \qquad (6)$$

5. For each phase, the percentage of energy from the summary EMG energy of the motion pattern $E_f^{\%}$ was determined:

$$E_f^{\%} = \frac{E_f}{E_{\Sigma}} * 100\%\ , \qquad (7)$$

6. For each phase, theme an value and standard deviation (RMS) of the energy fraction from the summary EMG energy of the motion pattern were calculated.

The percentage of the energy from the summary EMG energy of the motion pattern for each phase is presented in Table 3.

Table 3: The percentage of the energy from the summary EMG energy of the motion pattern for each phase

	The squatting phase	The pushphase	The flight phase	The touchdown phase	The risephase
Meanvalue of $E_f^{\%}$, %	20,20	50,94	15,91	4,14	8,81
RMS of $E_f^{\%}$, %	18,15	19,80	6,00	3,05	4,70

It was found that the largest variation of the EMG energy share of the test motion pattern is observed in the squatting phase and the push phase. The deviation of the EMG energy share of the motion pattern for the squatting phase is ±18.15%, for the push phase - ±19.80%. For the other phases (flight,

touchdown and rise), this parameter does not exceed 6% of the summary EMG energy of the motion pattern. In addition, the sum of the EMG energy of the test motion pattern for the squatting and push phases is 71.14%±7.95%. Thus, these phases are determinative in the formation of test motion. Based on the above, the squatting and push phases were chosen as the basis for the identification of jump motion types.

The point diagram of the percentage proportion of the EMG energy share of the test motion pattern in the squatting phase and the push phase was drawn (Fig. 7).

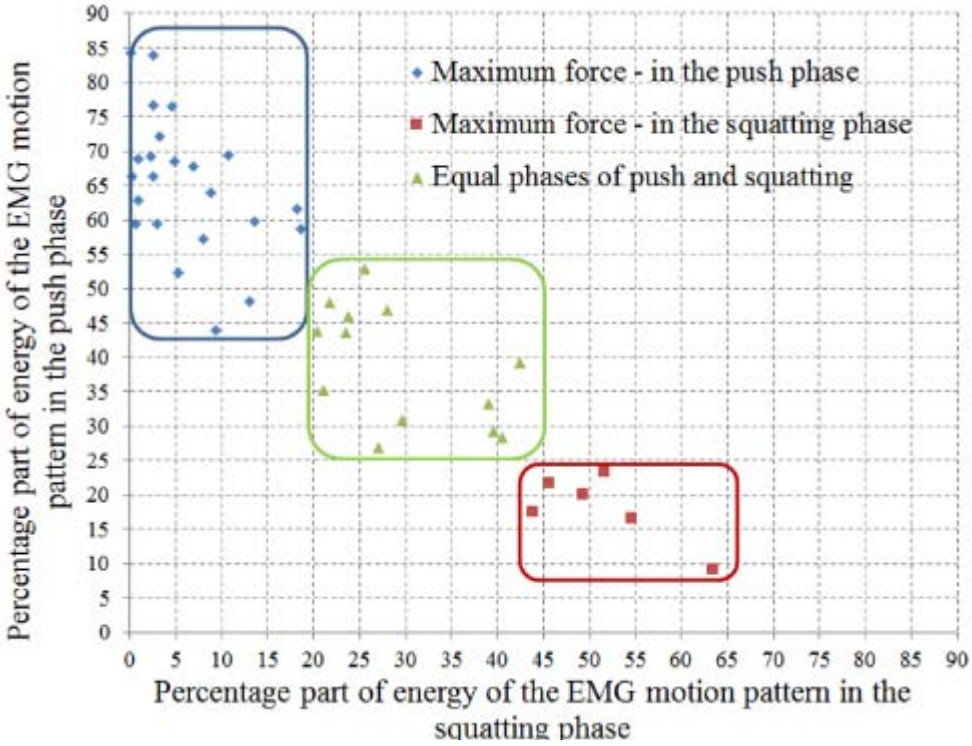


Figure 7: The point diagram of the percentage proportion of the EMG energy share of the test motion pattern inthe squatting phase and the push phase

It was found that the data are grouped into 3 groups (Figure 7):

1. The group (23 people - 54. 76% of the whole group), for which the maximum muscle effort is performed in the push phase: the share of EMG energy of the motion pattern in the squatting phase is 6.12%± 5. 45%, in the push phase - 65. 07%± 9. 82%.
2. The group (6 people - 14. 29% of the whole sampling), for which the maximum muscle effort is performed in the squatting phase: the share of EMG energy of the motion pattern in the squatting phase is 51. 47%± 6. 44%, in the push phase - 17. 90%± 4. 59%.
3. The group (13 people - 30, 95% of the whole group), for which the muscle efforts are equally distributed between squatting and push phases: the share of EMG energy of the motion pattern in the squatting phase is 29, 40%±7, 78%, in the push phase - 38, 74%±8, 29%.
4. Figure 8 shows the histograms of the percentage ratio of the EMG energy shares of the motion pattern by the phases, corresponding to the above groups.

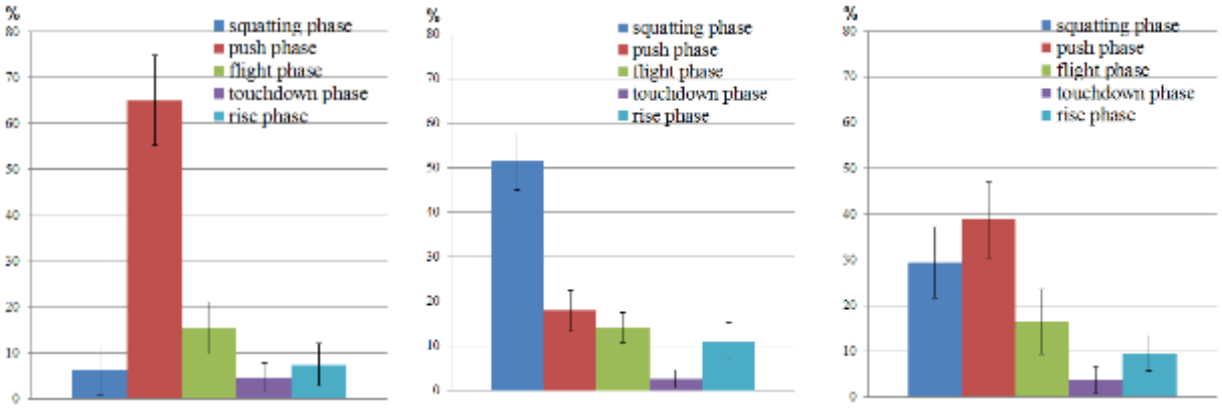


Figure 8: The histograms of the percentage ratio of the EMG energy shares of the motion pattern by the phases: the maximum muscle effort is performed in the push phase (a); the maximum muscle effort is performed in the squatting phase (b); the muscle efforts are equally distributed between squatting and push phases (c)

Thus, the percentage ratio of the EMG energy shares of the motion pattern for the squatting and push phase is different and allows to identify three types of motion skills for the jump: a) the maximum muscle effort is in the push phase (Figure 8 a); b) the maximum muscle effort is in the squatting phase (Figure 8 b); c) the muscle efforts are equally distributed between squatting and push phases (Figure 8 c). The distribution of muscle efforts in the flight, touch-down, and rise phases does not change (the deviation of the EMG energy share of the motion pattern for these phases is less than 6%).

IV. Discussing

The results of the research prove the effectiveness of the proposed complex analysis of human motion, which allows to classify the types of motion skills of the subjects on the following bases:

- by the energy contribution of the muscles in the process of motion;
- by the distribution of muscle efforts in the phases of motion.

The research of the energy contribution of the studied muscles during the test motion "jump up" was carried out. As a result of the analysis of the percentage ratio of EMG signal energy of the muscles during the test movement, three types of motion skills were identified:

a) 40.48% of all subjects: the muscles *m. gastrocnemius lateralis* and *m. soleus* mainly provide test motion (the share of EMG energy of the motion pattern for the muscular group *m. gastrocnemius lateralis* + *m. soleus* is 71.17%± 5.63%);
b) 50% of all subjects: the muscles *m. rectus femoris, m. gastrocnemius lateralis* and *m. soleus* are equal in the degree of involvement in the process of motion (the share of EMG energy of the motion pattern for the muscular group *m. gastrocnemius lateralis* + *m. soleus* is 52.78%± 4.69%, for the muscle *m. rectus femoris* - 43.81%± 5.58%);
c) 9.52% of all subjects: the muscle *m. rectus femoris* dominates in the process of the motion (the energy share of the EMG motion pattern for the muscle *m. rectus femoris* - 72.07%±2.94%).

The research of the distribution of muscle efforts in the phases of the test motion "jump up" was carried out. The percentage ratio of EMG energy of the motion pattern in the squatting and push phases is different and allows to identify three types of motion skills:

a) 54, 76% of all subjects: the maximum muscle effort is performed in the push phase (the share of EMG energy of the motion pattern in the push phase - 65. 07%± 9. 82%);
b) 14, 29% of all subjects: the maximum muscle effort is performed in the squatting phase (the share of EMG energy of the motion pattern in the squatting phase is 51. 47%± 6.44%,);
c) 30, 95% of all subjects: the muscle efforts are equally distributed between squatting and push phases (the share of EMG energy of the motion pattern in the squatting phase is 29, 40%±7, 78%, in the push phase - 38, 74%±8, 29%).

V. Conclusion

In the paper, the method of multichannel interference electromyography was chosen as a method of investigation of electrophysiological parameters of motion. The method of multichannel interference electromyography allows to estimate the participation of muscles in various movements, the sequence of their on and off, the integrated level of muscle activation, the correlation of muscle activity in different periods of motion skills formation. The method of podography was chosen to study the biomechanical motion parameters. The method of podography (PDG) allows to record the

time moments of contact of various parts of the foot with the ground, and to identify motion phases. The complex application of these methods (multichannel interference electromyography and podography) allows to create an electromyographic pattern of motion, which is an electrophysiological analogue of motion and is a combination of time, spatial and amplitude electromyographic characteristics of motion.

In the paper, the algorithm of creation of an electromyographic motion pattern based on analysis of multichannel electrophysiological and biomechanical signals was proposed. The algorithm includes: 1) the overlay of electrophysiological and biomechanical signals in the time domain; 2) the filtration of multichannel electromyographic signals to remove motion artifacts and network interference from the spectrum of the useful signal; 3) the time rationing of multichannel electromyogrphic signals for unification of the EMG pattern of the same movement in different people; 4) the detection of motion phases.

In the paper, the method of complex estimation of human motion skills based on the analysis of electromyographic motion pattern was proposed. The analysis of multichannel electromyogrphic signals of muscles is made in the time domain, due to the need for comparison of the innervation motion structure with the spatial and time characteristics of the studied motion. The proposed method allows to calculate the energy contribution of the muscles in the process of motion and to calculate the distribution of muscle efforts in the phases of motion.

In the paper, the research of the motion skills was carried out on the example of the test movement "jump up". The research of the energy contribution of the muscles during the test motion allowed to identify three types of motion skills: 1) the muscles *m. gastrocnemius lateralis* and *m. soleus* mainly provide test motion (40.48% of all subjects); the muscles *m. rectus femoris, m. gastrocnemius lateralis* and *m. soleus* are equal in the degree of involvement in the process of motion (50% of all subjects); the muscle *m. rectus femoris* dominates in the process of the motion (9.52% of all subjects).The research of the distribution of muscle efforts in the phases of the test motion allowed to identify three types of motion skills: the maximum muscle effort is performed in the push phase (54,76% of all subjects);the maximum muscle effort is performed in the squatting phase (14,29% of all subjects); the muscle efforts are equally distributed between squatting and push phases (30,95% of all subjects).The results of the research demonstrate the effectiveness of the proposed complex analysis of human motion.

The proposed approach to the analysis of human movements can be used to study human motion abilities in clinical and sports medicine (motion rehabilitation, clinical and sports biomechanics, prosthetics), training process (control of the sportsman's motion stereotype, prognosis of the children's motion talent) and special activity (effective training of special skills, professional selection).

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We shall provide you intimation regarding launching of e-version of journal of your stream time to time.This may be utilized in your library for the enrichment of knowledge of your students as well as it can also be helpful for the concerned faculty members.

The MARSE member can apply for approval, grading and certification of standards of their educational and Institutional Degrees to Open Association of Research, Society U.S.A.

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The Global Journals Incorporation (USA) at its discretion can also refer double blind peer reviewed paper at their end to the board for the verification and to get recommendation for final stage of acceptance of publication.

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- • This individual has learned the basic methods of applying those concepts and techniques to common challenging situations. This individual has further demonstrated an in–depth understanding of the application of suitable techniques to a particular area of research practice.

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g) Suitable statistical data should also be given.
h) All data must have been gathered with attention to numerical detail in the planning stage.

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19. Refresh your mind after intervals: Try to give your mind a rest by listening to soft music or sleeping in intervals. This will also improve your memory. Acquire colleagues: Always try to acquire colleagues. No matter how sharp you are, if you acquire colleagues, they can give you ideas which will be helpful to your research.

20. Think technically: Always think technically. If anything happens, search for its reasons, benefits, and demerits. Think and then print: When you go to print your paper, check that tables are not split, headings are not detached from their descriptions, and page sequence is maintained.

21. Adding unnecessary information: Do not add unnecessary information like "I have used MS Excel to draw graphs." Irrelevant and inappropriate material is superfluous. Foreign terminology and phrases are not apropos. One should never take a broad view. Analogy is like feathers on a snake. Use words properly, regardless of how others use them. Remove quotations. Puns are for kids, not grunt readers. Never oversimplify: When adding material to your research paper, never go for oversimplification; this will definitely irritate the evaluator. Be specific. Never use rhythmic redundancies. Contractions shouldn't be used in a research paper. Comparisons are as terrible as clichés. Give up ampersands, abbreviations, and so on. Remove commas that are not necessary. Parenthetical words should be between brackets or commas. Understatement is always the best way to put forward earth-shaking thoughts. Give a detailed literary review.

22. Report concluded results: Use concluded results. From raw data, filter the results, and then conclude your studies based on measurements and observations taken. An appropriate number of decimal places should be used. Parenthetical remarks are prohibited here. Proofread carefully at the final stage. At the end, give an outline to your arguments. Spot perspectives of further study of the subject. Justify your conclusion at the bottom sufficiently, which will probably include examples.

23. Upon conclusion: Once you have concluded your research, the next most important step is to present your findings. Presentation is extremely important as it is the definite medium though which your research is going to be in print for the rest of the crowd. Care should be taken to categorize your thoughts well and present them in a logical and neat manner. A good quality research paper format is essential because it serves to highlight your research paper and bring to light all necessary aspects of your research.

Informal Guidelines of Research Paper Writing

Key points to remember:

- Submit all work in its final form.
- Write your paper in the form which is presented in the guidelines using the template.
- Please note the criteria peer reviewers will use for grading the final paper.

Final points:

One purpose of organizing a research paper is to let people interpret your efforts selectively. The journal requires the following sections, submitted in the order listed, with each section starting on a new page:

The introduction: This will be compiled from reference matter and reflect the design processes or outline of basis that directed you to make a study. As you carry out the process of study, the method and process section will be constructed like that. The results segment will show related statistics in nearly sequential order and direct reviewers to similar intellectual paths throughout the data that you gathered to carry out your study.

The discussion section:

This will provide understanding of the data and projections as to the implications of the results. The use of good quality references throughout the paper will give the effort trustworthiness by representing an alertness to prior workings.

Writing a research paper is not an easy job, no matter how trouble-free the actual research or concept. Practice, excellent preparation, and controlled record-keeping are the only means to make straightforward progression.

General style:

Specific editorial column necessities for compliance of a manuscript will always take over from directions in these general guidelines.

To make a paper clear: Adhere to recommended page limits.

Mistakes to avoid:

- Insertion of a title at the foot of a page with subsequent text on the next page.
- Separating a table, chart, or figure—confine each to a single page.
- Submitting a manuscript with pages out of sequence.
- In every section of your document, use standard writing style, including articles ("a" and "the").
- Keep paying attention to the topic of the paper.

- Use paragraphs to split each significant point (excluding the abstract).
- Align the primary line of each section.
- Present your points in sound order.
- Use present tense to report well-accepted matters.
- Use past tense to describe specific results.
- Do not use familiar wording; don't address the reviewer directly. Don't use slang or superlatives.
- Avoid use of extra pictures—include only those figures essential to presenting results.

Title page:

Choose a revealing title. It should be short and include the name(s) and address(es) of all authors. It should not have acronyms or abbreviations or exceed two printed lines.

Abstract: This summary should be two hundred words or less. It should clearly and briefly explain the key findings reported in the manuscript and must have precise statistics. It should not have acronyms or abbreviations. It should be logical in itself. Do not cite references at this point.

An abstract is a brief, distinct paragraph summary of finished work or work in development. In a minute or less, a reviewer can be taught the foundation behind the study, common approaches to the problem, relevant results, and significant conclusions or new questions.

Write your summary when your paper is completed because how can you write the summary of anything which is not yet written? Wealth of terminology is very essential in abstract. Use comprehensive sentences, and do not sacrifice readability for brevity; you can maintain it succinctly by phrasing sentences so that they provide more than a lone rationale. The author can at this moment go straight to shortening the outcome. Sum up the study with the subsequent elements in any summary. Try to limit the initial two items to no more than one line each.

Reason for writing the article—theory, overall issue, purpose.

- Fundamental goal.
- To-the-point depiction of the research.
- Consequences, including definite statistics—if the consequences are quantitative in nature, account for this; results of any numerical analysis should be reported. Significant conclusions or questions that emerge from the research.

Approach:

- Single section and succinct.
- An outline of the job done is always written in past tense.
- Concentrate on shortening results—limit background information to a verdict or two.
- Exact spelling, clarity of sentences and phrases, and appropriate reporting of quantities (proper units, important statistics) are just as significant in an abstract as they are anywhere else.

Introduction:

The introduction should "introduce" the manuscript. The reviewer should be presented with sufficient background information to be capable of comprehending and calculating the purpose of your study without having to refer to other works. The basis for the study should be offered. Give the most important references, but avoid making a comprehensive appraisal of the topic. Describe the problem visibly. If the problem is not acknowledged in a logical, reasonable way, the reviewer will give no attention to your results. Speak in common terms about techniques used to explain the problem, if needed, but do not present any particulars about the protocols here.

The following approach can create a valuable beginning:

- Explain the value (significance) of the study.
- Defend the model—why did you employ this particular system or method? What is its compensation? Remark upon its appropriateness from an abstract point of view as well as pointing out sensible reasons for using it.
- Present a justification. State your particular theory(-ies) or aim(s), and describe the logic that led you to choose them.
- Briefly explain the study's tentative purpose and how it meets the declared objectives.

Approach:

Use past tense except for when referring to recognized facts. After all, the manuscript will be submitted after the entire job is done. Sort out your thoughts; manufacture one key point for every section. If you make the four points listed above, you will need at least four paragraphs. Present surrounding information only when it is necessary to support a situation. The reviewer does not desire to read everything you know about a topic. Shape the theory specifically—do not take a broad view.

As always, give awareness to spelling, simplicity, and correctness of sentences and phrases.

Procedures (methods and materials):

This part is supposed to be the easiest to carve if you have good skills. A soundly written procedures segment allows a capable scientist to replicate your results. Present precise information about your supplies. The suppliers and clarity of reagents can be helpful bits of information. Present methods in sequential order, but linked methodologies can be grouped as a segment. Be concise when relating the protocols. Attempt to give the least amount of information that would permit another capable scientist to replicate your outcome, but be cautious that vital information is integrated. The use of subheadings is suggested and ought to be synchronized with the results section.

When a technique is used that has been well-described in another section, mention the specific item describing the way, but draw the basic principle while stating the situation. The purpose is to show all particular resources and broad procedures so that another person may use some or all of the methods in one more study or referee the scientific value of your work. It is not to be a step-by-step report of the whole thing you did, nor is a methods section a set of orders.

Materials:

Materials may be reported in part of a section or else they may be recognized along with your measures.

Methods:

- Report the method and not the particulars of each process that engaged the same methodology.
- Describe the method entirely.
- To be succinct, present methods under headings dedicated to specific dealings or groups of measures.
- Simplify—detail how procedures were completed, not how they were performed on a particular day.
- If well-known procedures were used, account for the procedure by name, possibly with a reference, and that's all.

Approach:

It is embarrassing to use vigorous voice when documenting methods without using first person, which would focus the reviewer's interest on the researcher rather than the job. As a result, when writing up the methods, most authors use third person passive voice.

Use standard style in this and every other part of the paper—avoid familiar lists, and use full sentences.

What to keep away from:

- Resources and methods are not a set of information.
- Skip all descriptive information and surroundings—save it for the argument.
- Leave out information that is immaterial to a third party.

Results:

The principle of a results segment is to present and demonstrate your conclusion. Create this part as entirely objective details of the outcome, and save all understanding for the discussion.

The page length of this segment is set by the sum and types of data to be reported. Use statistics and tables, if suitable, to present consequences most efficiently.

You must clearly differentiate material which would usually be incorporated in a study editorial from any unprocessed data or additional appendix matter that would not be available. In fact, such matters should not be submitted at all except if requested by the instructor.

Content:

- Sum up your conclusions in text and demonstrate them, if suitable, with figures and tables.
- In the manuscript, explain each of your consequences, and point the reader to remarks that are most appropriate.
- Present a background, such as by describing the question that was addressed by creation of an exacting study.
- Explain results of control experiments and give remarks that are not accessible in a prescribed figure or table, if appropriate.
- Examine your data, then prepare the analyzed (transformed) data in the form of a figure (graph), table, or manuscript.

What to stay away from:

- Do not discuss or infer your outcome, report surrounding information, or try to explain anything.
- Do not include raw data or intermediate calculations in a research manuscript.
- Do not present similar data more than once.
- A manuscript should complement any figures or tables, not duplicate information.
- Never confuse figures with tables—there is a difference.

Approach:

As always, use past tense when you submit your results, and put the whole thing in a reasonable order.

Put figures and tables, appropriately numbered, in order at the end of the report.

If you desire, you may place your figures and tables properly within the text of your results section.

Figures and tables:

If you put figures and tables at the end of some details, make certain that they are visibly distinguished from any attached appendix materials, such as raw facts. Whatever the position, each table must be titled, numbered one after the other, and include a heading. All figures and tables must be divided from the text.

Discussion:

The discussion is expected to be the trickiest segment to write. A lot of papers submitted to the journal are discarded based on problems with the discussion. There is no rule for how long an argument should be.

Position your understanding of the outcome visibly to lead the reviewer through your conclusions, and then finish the paper with a summing up of the implications of the study. The purpose here is to offer an understanding of your results and support all of your conclusions, using facts from your research and generally accepted information, if suitable. The implication of results should be fully described.

Infer your data in the conversation in suitable depth. This means that when you clarify an observable fact, you must explain mechanisms that may account for the observation. If your results vary from your prospect, make clear why that may have happened. If your results agree, then explain the theory that the proof supported. It is never suitable to just state that the data approved the prospect, and let it drop at that. Make a decision as to whether each premise is supported or discarded or if you cannot make a conclusion with assurance. Do not just dismiss a study or part of a study as "uncertain."

Research papers are not acknowledged if the work is imperfect. Draw what conclusions you can based upon the results that you have, and take care of the study as a finished work.

- You may propose future guidelines, such as how an experiment might be personalized to accomplish a new idea.
- Give details of all of your remarks as much as possible, focusing on mechanisms.
- Make a decision as to whether the tentative design sufficiently addressed the theory and whether or not it was correctly restricted. Try to present substitute explanations if they are sensible alternatives.
- One piece of research will not counter an overall question, so maintain the large picture in mind. Where do you go next? The best studies unlock new avenues of study. What questions remain?
- Recommendations for detailed papers will offer supplementary suggestions.

Approach:

When you refer to information, differentiate data generated by your own studies from other available information. Present work done by specific persons (including you) in past tense.

Describe generally acknowledged facts and main beliefs in present tense.

The Administration Rules

Administration Rules to Be Strictly Followed before Submitting Your Research Paper to Global Journals Inc.

Please read the following rules and regulations carefully before submitting your research paper to Global Journals Inc. to avoid rejection.

Segment draft and final research paper: You have to strictly follow the template of a research paper, failing which your paper may get rejected. You are expected to write each part of the paper wholly on your own. The peer reviewers need to identify your own perspective of the concepts in your own terms. Please do not extract straight from any other source, and do not rephrase someone else's analysis. Do not allow anyone else to proofread your manuscript.

Written material: You may discuss this with your guides and key sources. Do not copy anyone else's paper, even if this is only imitation, otherwise it will be rejected on the grounds of plagiarism, which is illegal. Various methods to avoid plagiarism are strictly applied by us to every paper, and, if found guilty, you may be blacklisted, which could affect your career adversely. To guard yourself and others from possible illegal use, please do not permit anyone to use or even read your paper and file.

Criterion for Grading a Research Paper (Compilation) by Global Journals

Please note that following table is only a Grading of "Paper Compilation" and not on "Performed/Stated Research" whose grading solely depends on Individual Assigned Peer Reviewer and Editorial Board Member. These can be available only on request and after decision of Paper. This report will be the property of Global Journals.

Topics	Grades		
	A-B	**C-D**	**E-F**
Abstract	Clear and concise with appropriate content, Correct format. 200 words or below	Unclear summary and no specific data, Incorrect form Above 200 words	No specific data with ambiguous information Above 250 words
Introduction	Containing all background details with clear goal and appropriate details, flow specification, no grammar and spelling mistake, well organized sentence and paragraph, reference cited	Unclear and confusing data, appropriate format, grammar and spelling errors with unorganized matter	Out of place depth and content, hazy format
Methods and Procedures	Clear and to the point with well arranged paragraph, precision and accuracy of facts and figures, well organized subheads	Difficult to comprehend with embarrassed text, too much explanation but completed	Incorrect and unorganized structure with hazy meaning
Result	Well organized, Clear and specific, Correct units with precision, correct data, well structuring of paragraph, no grammar and spelling mistake	Complete and embarrassed text, difficult to comprehend	Irregular format with wrong facts and figures
Discussion	Well organized, meaningful specification, sound conclusion, logical and concise explanation, highly structured paragraph reference cited	Wordy, unclear conclusion, spurious	Conclusion is not cited, unorganized, difficult to comprehend
References	Complete and correct format, well organized	Beside the point, Incomplete	Wrong format and structuring

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