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Dynamics of Imperial Invasion

Synthesis of Thermodynamics

Highlights

The Universal Gravitational Constant

Higher Order Conditional Probability

Discovering Thoughts, Inventing Future

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Synthesis of Thermodynamics and Continuum Mechanics

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Abstract- On the basis of a unified theory of the processes of transfer and transformation of any form of energy, called "energy dynamics" by the author, the possibility of synthesizing the methods of non equilibrium thermodynamics and continuum mechanics is shown. A unified substantiation of the main provisions of both the theory of irreversible processes and classical mechanics, free from postulates and hypotheses, is given. At the same time, a new method for studying real processes is proposed, which does not exclude from consideration any (reversible or irreversible) part of them. This made it possible to generalize all three Newton's principles, to find a short-range form of his law of gravity, and for the first time to substantiate the principle of least action, which mutually enriches both thermodynamics and mechanics.

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SYNTHESISOFTHERMODYNAMICSANDCONTINUUMMECHANICS

Strictly as per the compliance and regulations of:

Synthesis of Thermodynamics and Continuum Mechanics

Valery Abramovich Etkin

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Keywords: mechanics and thermodynamics, principles of inertia, force and least action, generalized laws of gravity and transfer, superposition effects and methods for finding them.

I. Introduction

The development of physics in the twentieth century is characterized by the emergence of three new theories of a revolutionary nature. The first two of them are well known: they are quantum mechanics (QM) and the theory of relativity (SRT and GRT) [1]. Meanwhile, along with them in the first third of the same century, another no less revolutionary theory arose - the thermodynamics of irreversible processes (TIP), whose contribution to the theoretical thought of the twentieth century was marked with two Nobel prizes. This theory arose on the basis of the pioneering works of Lars Onsager as a theory of the rate of relaxation processes, which he called "quasithermodynamics" [2]. She returned to thermodynamics the concepts of the driving force and speed of the process, and thereby gave thermodynamics the ability to find the causes of the occurrence of a particular process, to identify the direction and speed of its flow, to identify the sources of dissipative losses and their magnitude. This theory explained a number of processes that contradict classical thermodynamics such as "active transport" of substances in biological systems and "ascending diffusion" in alloys (transfer of matter in the direction of increasing its concentration, as well as the emergence of "conjugated" cyclic Belousov-Zhabotinsky reactions and processes of "self-organization" systems far from equilibrium [3] All this made it possible to consider TIP a theory no less revolutionary than QM and RT.

Each of the named theories had its own conceptual system, its own mathematical apparatus and its own model ideas about the object of research. Each was based on a number of additional hypotheses and postulates, some of which, in principle, could not be confirmed by experience with the existing level of experimental and observational tools. Therefore, they developed independently, having practically no points of contact. The disagreements between them were so great that the synthesis of at least the first two of them - QM and RT - was assessed by A. Einstein as "Great Unification".

In this regard, it is of interest to study mechanics and other fundamental disciplines from the standpoint of the deductive method (from the general to the particular), especially since its most productive "principle of least action" also needs to be substantiated.

This article proposes to do this on the basis of "thermokinetics" as a unified theory of non-equilibrium processes of transfer and transformation of any forms of energy, proposed by us in our doctoral dissertation [4], and its further generalization in a new discipline, called energy dynamics for brevity [5]The main goal of this article is to show that the synthesis of the thermodynamics of irreversible processes and the mechanics of continuous media leads to their mutual enrichment and a number of non-trivial consequences of a fundamental nature.

II. Methodological Features of Energodynamics

If we adhere to the methodology of thermodynamics as a deductive and phenomenological discipline, which is alien to model concepts of the microscopic "mechanism" of processes, as well as hypotheses and postulates, then the thermodynamics of nonequilibrium (non-static) processes should be built on its own conceptual basis. Such a basis is provided by the law of conservation of the energy of the system *U*in the form proposed by the Russian professor N. Umov back in 1874 [6]:

$$dU/dt = - \oint j_e \cdot df, \qquad (1)$$

where j_e is the density of the internal energy flux through the vector element *df* of the closed surface *f* of the

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system a certain volume V in the direction of the external normal n (Figure 1).

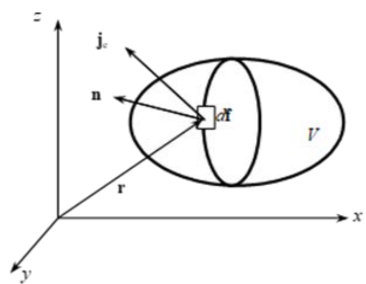

Figure 1: Energy flow across system boundaries

This form of the law of conservation of energy takes into account the kinetics of real processes, without making any assumptions about the mechanism of energy transfer and the internal structure of the system, i.e., considering it a continuous medium. According to him, the internal energy U does not just disappear at some points in space and arises at others, but is transferred by some of its carriers Θ_j through the boundaries of the system. Such "energy carriers" are moles of k-th substances N_k, their momenta P_k, charges Θ_e, entropies S_k, etc. In this case, the energy flux j_e consists of the energy flux $\boldsymbol{j}_{ej}$ of the j-th kind U_j, carried by the j-th energy carriers Θ_j. Each of these flows is expressed, as is known, by the product of the energy carrier flow $\boldsymbol{j}_j$ by its potential $\psi_j = dU_j/dM_j$(specific energy):

$$j_e = \Sigma_j j_{ej} = \Sigma_j \psi_j j_j = \Sigma_j \psi_j \rho_j \upsilon_j. \qquad (2)$$

Using the Gauss-Ostrogradskiy theorem, we transform $\oint j_e \cdot df$ into an integral over its volume $\int \nabla \cdot j_e dV$. Then, after decomposing $\nabla(\psi_j j_j)$ into independent components $\Sigma_j \psi_j \nabla \cdot j_j + \Sigma_j j_j \cdot \nabla \psi_j$, the energy conservation law (1) takes the form:

$$dU/dt + \Sigma_j \int \psi_j \nabla \cdot j_j dV - \Sigma_j \int j_j \cdot \boldsymbol{x}_j dV = 0 \text{ (Вт)}, \qquad (3)$$

where $\boldsymbol{x}_j \equiv -\nabla \psi_j$ are quantities that have the meaning of the field strength of the potential ψ_j and play the role of local thermodynamic forces in the TIP.

Taking out on the basis of the mean value theorem for the integral sign some average value Ψ_j of the potential ψ_j and the average value X_j of thermodynamic forces $\boldsymbol{x}_j$, we find:

$$dU/dt = -\Sigma_j \Psi_j J_j + \Sigma_j X_j \cdot J_j, \qquad (4)$$

Here $J_j = \int j_j dV = \Theta_j \overline{\boldsymbol{\upsilon}}_j$ is the vector flow, which has the meaning of the momentum of the energy carrier; $J_j = \int \nabla \cdot j_j dV$ is the scalar flow of the same energy carrier through the system boundaries, which has the meaning of its consumption.

This equation can be transformed to a form more familiar to mechanics, if we take out the mean value $\overline{\boldsymbol{\upsilon}}_j$ velocity $\boldsymbol{\upsilon}_j$ of the flow $j_j = \rho_j \boldsymbol{\upsilon}_j$ outside the integral sign and replace the thermodynamic force X_j with the resultant forces of the j-th kind in its general physical understanding $F_j = \int \rho_j \boldsymbol{x}_j dV = \Theta_j X_j$:

$$dU/dt = \Sigma_j F_j \cdot \overline{\boldsymbol{\upsilon}}_j - \Sigma_j \Psi_j J_j. \qquad (5)$$

This form of the law of conservation of energy makes it possible to express the strength of any force field $H_j \equiv \partial F_j/\partial V = -\nabla \rho_{uj}$ in a unified way as the density gradient of the j-th form of the "partial" energy $U_j = \int \rho_{uj} dV$. Thus, we emphasize once again that *any force fields are generated by the uneven distribution of the corresponding energy carrier in space, and are not any form of matter*.

It is easy to see that equations (4) and (5) describe the processes of both the transfer of energy (1st sum) and its transformation (2nd sum), i.e., they combine the laws of conservation of energy related to both classical thermodynamics (where $J_j = 0$ and $J_j = -d\Theta_j/dt$) and to classical mechanics (where $J_j = 0$). This opens up the possibility not only of bringing their conceptual system and mathematical apparatus closer together, but of obtaining, on their basis, all the main provisions of these disciplines as consequences of energodynamics.

III. Non-Equilibrium Thermodynamics as a Consequence of Energodynamics

Energodynamics differs from TIP in that it does not exclude from consideration any (reversible or irreversible) component of real processes and finds fluxes J_j and forces X_j not on the basis of the principle of increasing entropy, but on a more general basis of the law of conservation of energy in the form (4). This makes it possible to study on its basis both the processes of energy transfer and the processes of its transformation, i.e., This allows us to consider energodynamics as a theory of the rate of real processes, as a generalization of TIP to processes of useful energy conversion.

The subject of TIP research - relaxation processes - was included in the competence of classical thermodynamics [2]. However, the latter was limited to considering internally equilibrium (homogeneous) systems and quasi-static (infinitely slow) processes, that is, it was actually a thermostat. TIP, however, was considered from the very beginning as a method for describing the kinetics of irreversible processes. To this end, L. Onsager assumed the existence in an adiabatically isolated system of some extensive parameters A_j, characterizing the deviation of its state from equilibrium, and introduced the concept of the generalized rate of the j-th relaxation process $J_j = dA_j/dt$ as a derivative of this parameter with respect to time t, calling it stream. Then he introduced the concept of thermodynamic force $X_j=dS/dJ_j$ as a derivative of the entropy S over these flows. This made it possible to represent the rate of increase in the entropy dS/dt of the system under consideration as the sum of the products of fluxes J_j and forces X_j of different nature:

$$dS/dt=\Sigma_j X_j J_j. \quad (6)$$

Thus, the concept of force and the ability to explain the cause of a particular relaxation process, to indicate its direction and rate of flow, the power of scattering processes TdS/dt and the final result, returned to thermodynamics.

Fundamentally new for thermodynamics and physical kinetics was another postulate, according to which each of these flows J_i arises under the action of all forces X_j present in the system. At the same time, it linearly increases with an increase in any of them [2]:

$$J_i=\Sigma_j L_{ij} X_j. \quad (7)$$

where L_{ij} are constant proportionality coefficients characterizing the conductivity of the system with respect to the j-th applied force X_j and called by him "phenomenological".

Linear Onsager laws (7) had a matrix form with the number of coefficients L_{ij} equal to n^2 (j = 1, 2, ... n), i.e., J_i was considered as a superposition of fluxes $J_{ij}=L_{ij}X_j$, excited by independent thermodynamic forces X_j. This made it possible to explain the well-known at that time thermomechanical, thermochemical thermoelectric and other effects as a result of their "superposition" but required knowledge of a much larger number of empirical coefficients than before. To somewhat compensate for the increase in their number, L. Onsager substantiated the existence of the so-called reciprocity relations:

$$L_{ij}=L_{ji} \quad (8)$$

To substantiate them L. Onsager needed the theory of fluctuations, the principle of microscopic reversibility, the principle of detailed equilibrium and an additional postulate about the linear nature of the laws of decay of fluctuations [2]. All these provisions went beyond thermodynamics, which is why he called his theory "quasithermodynamics". Due to these relations, the number of coefficients L_{ij} decreased from n^2 to $n(n+1)/2$.

However, since the parameters A_j in equilibrium thermodynamics of that time were obviously absent, the practical application of Onsager's theory was difficult. The situation changed when I. Prigogine proposed to find fluxes J_i and forces X_j on the basis of the expression "production" of entropy due to irreversibility $d_iS/dt>0$ and the equations of balance of energy, mass, charge, momentum and its moment, compiled on the basis of other fundamental disciplines, taking into account kinetics of processes [9]. However, since these disciplines lacked the concept of entropy and, moreover, its source d_iS, he had to make a number of additional assumptions. The main one was the hypothesis of local equilibrium, according to which the volume elements of the nonequilibrium continuum dV are in a state of equilibrium (despite the absence of its sign - the termination of macroprocesses), and their state is characterized by the same set of variables as in equilibrium (despite the appearance of potential gradients), so that the equations of equilibrium thermodynamics are valid for them (despite their inevitable transition to inequalities). Nevertheless, this hypothesis made it possible to find the "entropy production" $d_iS/dt>0$ in stationary irreversible processes supported by "external compulsion" (external forces X_j). Such a theory of irreversible processes (TIP) aroused keen interest of researchers in many countries [10-18] and was evaluated by the award of two Nobel Prizes (L. Onsager, 1968, I. Prigogine, 1977).

It would seem that TIP opened the way to accounting for irreversibility in other fundamental disciplines, which until then were limited to the study of reversible processes and the so-called "conservative systems" in which the sum of external kinetic and potential energies was assumed to be constant. However, this did not happen, since TIP was based on the principle of entropy increase $d_iS/dt>0$, thereby deliberately excluding from consideration the reversible part of real processes associated with the performance of useful work. Meanwhile, the processes of performing this work, that is, converting energy from one form to another, are primarily of interest to mechanics and representatives of other engineering disciplines. Therefore, the task of developing a more general theory, which would not exclude from consideration any (reversible or irreversible) component of real processes, remains topical. This is exactly what energy dynamics is, which is based on the law of conservation of energy (6) and takes into account the irreversibility of real processes. Its application to continuous systems with any finite number of degrees of freedom makes it possible to detect the presence of internal sources not only in the entropy S or in the number of moles N_k of any k-th substance arising in the course of chemical reactions, but also in purely mechanical quantities. It is known, for example, that in the processes of cutting metals or crushing materials, the amount of released heat of dissipation Q^d is always less than the expended work W due to the transfer of part of the ordered energy into other forms of their internal energy. At present, this is taken into account in calculations with a "heat output coefficient" less than one. In the general case, internal sources can be found in all energy carriers and in all "emergent" degrees of freedom acquired by the system in the process of evolution and lost in the process of its

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involution (degradation). This reveals the inconsistency of the attempts of R. Clausius and his followers to make the entropy S a "scapegoat" for dissipation and irreversibility. It becomes obvious that the problem of thermodynamic inequalities is solved by passing to scalar J_i and vector J_i energy carrier flows through the system boundaries, as follows from equations (6) and (7) [19]. These equations already include relation (11) and therefore are also valid for non-static (irreversible) processes. It is also important that they already contain the required flows J_i and forces X_i, giving them an unambiguous definition and a very specific meaning. This makes it superfluous to compose cumbersome and complex balance equations for k-th substances, charge, momentum, momentum, energy and entropy. In addition, this approach eliminates the arbitrariness in dividing their product into factors, which distorts the contribution of each process to the overall rate of energy dissipation. However, the main advantage of this approach is that it allows one to obtain the main content of TIP without resorting to any hypotheses, postulates and considerations of a statistical-mechanical nature, which comes to a number of non-trivial consequences [20].

First of all, in this way it can be shown that the Onsager reciprocity relations follow directly from the energy conservation law (4). Based on the independence of the mixed derivative from the order of differentiation with respect to the variables X_i and X_j(i,j= 1, 2, n), we have:

$$\partial^2U/\partial X_i\partial X_j = \partial^2U/\partial X_j\partial X_i \qquad (9)$$

This directly implies the relationship between unlike flows and forces, which we call differential reciprocity relations:

$$(\partial J_i/\partial X_j) = (\partial J_j/\partial X_i). \qquad (10)$$

These relations are applicable to both linear and nonlinear transport laws and admit any dependence of the coefficients L_{ij} on the parameters of the equilibrium state ψ_i and Θ_i. Their application to linear Onsager laws (7) directly leads to the symmetry of the matrix of phenomenological coefficients $L_{ij} = L_{ji}$:

$$(\partial J_i/\partial X_j) = L_{ij} = (\partial J_j/\partial X_i) = L_{ji.} \qquad (11)$$

Their justification shows that these relationships are a consequence of more general reasons than the reversibility of microprocesses. It is equally important that in this way it is possible to simplify Onsager's laws by translating them from matrix form (7) into a diagonal one containing the resulting force X_j[20]:

$$J_i = L_iX_j. \qquad (12)$$

where $L_i = \Sigma_j(\Theta_j/\Theta_i)\, L_j$ are empirical coefficients containing both thermodynamic parameters Θ_i, Θ_j and kinetic coefficients L_j of the type of thermal conductivity, electrical conductivity, diffusion, etc. This explains why the phenomenological Onsager coefficients L_{ij} in consumer goods neither the one nor the other make sense[13].

Further, the diagonal form of the transfer laws (12) allows us to propose a new method for finding the so-called "superposition effects", according to which these effects can be found as a consequence of the onset of incomplete equilibrium (J_i= 0). The specificity of this method is easier to understand by the example of the diffusion of the kth substance in continuous ones that are inhomogeneous in composition (concentration of components c_j, temperature T and pressure p). According to (12), the diffusion law has the form:

$$J_k = -D_k\nabla\mu_k, \qquad (13)$$

where D_k is the diffusion coefficient of the k-th substance; μ_k is its chemical potential.

This expression differs from the diffusion law $J_k = -\Sigma_jD_{kj}\nabla\mu_{kj}$, proposed by Onsager himself, by the absence of the sum of such terms, which makes the problem of finding the diffusion coefficients D_{kj} mathematically incorrect [21]. If we now represent $\nabla\mu_k$ in terms of its derivatives with respect to the concentrations c_j of independent components, their temperature and pressure, then equation (12) can take the form:

$$J_k = -D_k(\Sigma_j\mu_{kj}{}^*\nabla c_j + s_k{}^*\nabla T + \upsilon_k{}^*\nabla p). \qquad (14)$$

where $\mu_{kj}{}^* \equiv (\partial\mu_k/\partial c_j)$, $s_k{}^* \equiv (\partial\mu_k/\partial T)$, $\upsilon_k{}^* \equiv (\partial\mu_k/\partial p)$.

Three components of the resulting force F_k on the right side of this expression are responsible for the usual (concentration) diffusion $F_{kc} = \Sigma_j\mu_{kj}{}^*\nabla c_j$, thermal diffusion $F_{kT} = -s_k{}^*\nabla T$ and barodiffusion $F_{kp} = \upsilon_k{}^*\nabla p$. This allows one to separate the thermodynamic $\mu_{kj}, s_k{}^*$, $\upsilon_k{}^*$ and kinetic D_k factors of multicomponent diffusion and establish a number of relationships between them, which are experimentally confirmed [19]. To obtain such results based on the Onsager diffusion equation $J_k = -\Sigma_jD_{kj}\nabla\mu_{kj}$, with the existing experimental means, turned out to be a mathematically incorrect problem [21].

From expression (14) under conditions of diffusion equilibrium ($J_k = 0$), a number of relationships between these forces follows. In particular, if a temperature difference ($\Delta T \neq 0$), is created in an inhomogeneous system divided into two parts by a porous partition, then a gas or liquid flow through the partition $J_k = D_k(s_k{}^*\nabla T - \upsilon_k{}^*\nabla p)$, arises, leading to the occurrence of a pressure difference on both sides of the partition (Feddersen effect, 1873):

$$(\Delta p/\Delta T)_{st} = -q_k{}^*/T\upsilon_k{}^*, \qquad (15)$$

where $q_k{}^* = Ts_k{}^*$ is the so-called heat of transfer of the k-th substance.

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The opposite phenomenon is also known - the appearance of a temperature difference on both sides of the partition when air or other gas is forced through it. Both of these effects have the same nature with the Knudsen effect (1910) - the appearance of a pressure difference in vessels connected by a capillary or a narrow slit and filled with gas of different temperatures, as well as with the Allen and Jones fountain effect (1938) in liquid helium II, consisting in the outflow of helium from a vessel closed with a porous stopper, at the slightest heating. The opposite phenomenon - the occurrence of a temperature difference when creating a pressure difference on both sides of the partition - is called the mechanocaloric effect (Daunt-Mendelssohn).

If the systems initially had the same pressure on both sides of the porous partition ($\Delta p = 0$) and the same concentration of the kth substance ($\Delta ck = 0$), then when a temperature difference ΔT is created, a concentration difference occurs on both sides of it (Soret effect, 1881):

$$(\Delta c_k/\Delta T)_{st} = -q_k^*/T\mu_{kk}. \tag{16}$$

The opposite phenomenon is also known - the appearance of temperature gradients during diffusion mixing of components, discovered by Dufour in 1872 and bearing his name. In isothermal systems ($\Delta T = 0$), when a pressure difference Δp is created on the membrane, the phenomenon of reverse osmosis occurs - the separation of a binary solution with the release of the k-th component (usually a solvent) from it. This phenomenon is widely used in water treatment plants. The resulting concentration difference of the k-th component is described by the expression:

$$(\Delta c_k/\Delta p)_{st} = -\upsilon_k/\mu_{kk}. \tag{17}$$

These results correspond to those obtained in the framework of TIP [13,15]. However, now they were the result of the imposition of forces, which followed from Newtonian mechanics. At the same time, it was not necessary to admit either the linearity of Onsager's phenomenological laws, or to resort to his reciprocity relations. All this not only simplifies TIP, but also expands the scope of its applicability to nonlinear systems and states that are far from equilibrium.

The advantages of the above method for finding the above effects lie not only in its simplicity, but also in the possibility of its application in nonlinear systems far from equilibrium, where the Onsager reciprocity relations are violated [20]. No less important advantage of the proposed method is a further reduction in the number of L_{ij} coefficients subject to experimental determination from $n(n + 1)/2$ in consumer goods to n. Such a reduction is especially noticeable in the group of so-called "thermos-galvano-magnetic" effects, which are caused by the superposition of temperature, electric and magnetic fields, and especially for anisotropic media. The system of equations, which gives a purely phenomenological description of such processes, contains 36 empirical coefficients. Thanks to the use of reciprocity relations, the number of such coefficients can be reduced to 21. Energy dynamics allows you to go even further and, by establishing additional links, reduce the number of these coefficients to 6 [5]. Thus, serious progress is achieved in the study of nonequilibrium systems.

IV. Mechanics as a Consequence of Energodynamics

The applicability of the mathematical apparatus of energodynamics in the form of its basic equation (5) becomes especially obvious if the average transfer rate $\bar{\boldsymbol{\upsilon}}_j$ of any energy carrier Θ_j is decomposed into a translational $\bar{\mathbf{w}}_j$ and rotational (circumferential) component $\bar{\boldsymbol{\varpi}}_j \times R_o$, expressed as a vector product of the angular velocity $\bar{\boldsymbol{\varpi}}_j$ and the instantaneous radius of rotation of the volume element R_o. In this case, an additional sum appears in equation (5), expressed as the scalar product of the average moment of forces $M_j = \int (H_j \times R_o) dV$ and the average angular velocity:

$$dU/dt = -\Sigma_j \Psi_j J_j + \Sigma_j F_j \cdot \bar{\mathbf{w}}_j + \Sigma_j M_j \cdot \bar{\boldsymbol{\varpi}}_j . \tag{18}$$

This (integral) form of the energy balance makes it possible to operate with the nonequilibrium parameters of the continuum system as a whole, without dividing it into an infinite number of elementary volumes dV. This approach makes it possible to preserve the "system-forming" properties of the object of study, the loss of which during the fragmentation of the system "was the biggest shock for physicists since the time of Newton" [22]. The study of continuum systems as a whole frees from the need to resort to any postulates such as the hypothesis of local equilibrium by I. Prigogine [9], especially since, according to (3), the splitting of the system does not reduce the magnitude of the gradients of the potential $\nabla\psi_i$ in volume elements and does not bring them closer to equilibrium. Therefore, it should be expected that the above approach to continuum mechanics from the standpoint of energy dynamics will lead to non-trivial consequences.

a) Correction and generalization of Newton's laws from the standpoint of energodynamics

It is known that bodies or a system of bodies can move uniformly and rectilinearly or rotate uniformly in the absence of applied forces F_j or moments M_j, that is, "by inertia". This means that in the deductive

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construction of mechanics (from the general to the particular).

The first principle of mechanics (Newton's law of inertia) [23] should be formulated without excluding rotating systems from consideration: "Anybody continues to be held in its state of rest or uniform translational or rotational motion, until and since it is not forced by the applied forces F_j or change this state at moments M_j". Ignoring the prevailing rotational motion in the Universe by the Poincaré - Einstein theory of relativity led to the requirement of invariance of the laws of physics in any inertial reference frames[1](IRF)and ignoring the prevailing frame of reference inherent in rotating systems.

No less serious consequences have a generalization of Newton's 2nd postulate - the law of force, which states that "the change in the momentum is proportional to the applied force" F. This expression defines only the accelerating force, that is, it is too particular. Energodynamics, on the contrary, gives the most general definition of the concept of force $F_j=\int\rho_j\nabla\psi_j dV$ as a measure of the in homogeneity of the system and the cause of a particular process, expressing it through the gradient of the corresponding form of energy ∇U_j. Such a definition of mechanical force emphasizes its vector nature, which could not be taken into account by I. Newton due to the absence of the concept of a vector at that time. This definition is applicable to mechanical and non-mechanical, external and internal, long-range and short-range, useful and dissipative, active (applied) and reactive (opposing) forces. In this case, all forces acquire a single meaning, a single analytical expression and a single dimension. This gives researchers a unified method for finding clearly distinguishable forces of nature and opens up the prospect of creating a theory of a unified field as a region of space in which any forces are found.

From the standpoint of energodynamics, it becomes extremely clear that any force fields are generated not by the presence of any energy carrier, but by its uneven distribution in space. The same is the field of inertial forces $F_j= -M\boldsymbol{a}$, understood as the forces of reaction to the acceleration process. It is also generated by the in homogeneity of the velocity field $\nabla\boldsymbol{v}$. This becomes clearer if we consider that it is impossible to accelerate a body without moving it in space. But along with the displacement, the density of the medium also changes in the place where the body moved, i.e., there is a redistribution of the fields of density and momentum in space. This is reflected in the vector-gradient of velocity $\nabla\boldsymbol{v}$, which is a tensor of the 2nd rank. The presence of this tensor of a symmetric (translational) and antisymmetric (rotational) component of acceleration (similar to the translational and rotational component of velocity) confirms the possibility of rotational acceleration in the field of inertial forces, and thus the possibility of transferring this acceleration from one rotating body to another.

The difference between active forces and forces of inertia is also clearer. Their difference is manifested in the fact that the applied forces and inertial forces have not only opposite signs, but also different values. In energodynamics, the derivative $dP_i/dt = F_i$, which determines the force of inertia F_i, is only one of the flows J_i arising under the action of the applied force F_j, so that $F_i \neq F_j$. This requires the introduction of a phenomenological coefficient L_{ij}:

$$J_i=L_{ij}F_j. \tag{19}$$

This equation is nonlinear, since upon reaching the limiting speed $|v| = c$ no force F_j can cause changes in momentum J_i. From this it follows that with an increase in speed, this coefficient changes, and not the mass M in the expression for the momentum $P = M\boldsymbol{v}$, as postulated by the SRT. This solves the long-standing dispute about the existence of inertial forces and fields of inertia, which are quite real in the presence of the acceleration process but disappear when it stops. The latter is due to the fact that the forces F_j are functions of the state that do not depend on how it is achieved: by performing work against equilibrium in the system or by its relaxation, while the reaction forces of the system are a function of the process $F_i= - dP/dt$ as its consequence (in the spirit of the Le Chatelier - Brown principle). Thus, the fields of inertial forces as functions of state, available at any moment of time, do not exist.

The application of energodynamics to mechanics reveals the need to generalize and Newton's third law, according to which "an equal response always corresponds to an action," and the forces of action and reaction lie on the same straight line. If we denote active forces and reaction forces as F^a and F^r, this position has the form $F^a= -F^r$. However, in polyvariant systems there are many active forces F_i^a and reaction forces F_j^r, and in closed systems their sum always vanishes. This means that each active force F_i is opposed by the resulting F_i^r of reaction forces of various kinds:

$$F_i^a= -\Sigma_j F_j^r, (i, j=1, 2, n). \tag{20}$$

According to this expression, equilibrium takes place only when the forces of action F_i^a and reaction forces F_i^r have the same nature. Otherwise, the process of transformation of energy of the i-th kind into the j-th form of energy occurs, in which their sum remains unchanged:

$$F_i\boldsymbol{v}_i+F_j\boldsymbol{v}_j=0. \tag{21}$$

This expression indicates the possibility of "branching" the trajectory of the process in the space of

[1] The use of IFR excludes the search for a preferential FR. Meanwhile, the very existence of IFR is nothing more than a postulate, since, according to the same A. Poincaré, "we will never have the opportunity to make sure that they all move uniformly and rectilinearly" [20].

the opposing forces F_j, which is the most common reason for the irreversibility of the process in its most general understanding as the impossibility of returning all nature to its original state even in the absence of dissipation. It is characteristic that, in this form, Newton's third law admits the possibility of the action of separate forces F_i and F_j not along one straight line, which is currently considered as a violation of the laws of mechanics.

Thus, a more general approach from the standpoint of energy dynamics allows one to give a generalized formulation of all three Newton's laws [24].

b) Short-range (field) form of the law of gravitation

It is known that Newton's law of gravitation has no theoretical basis and is the result of processing the experimental data of Kepler and his predecessors [23]. For the case of gravitation of two bodies of mass m and *M*, located in a void (ρ = 0) at a distance of their centers of mass from each other *R*, this law of force had the form:

$$F_g = GmM/R^2, \tag{22}$$

where *G* is the constant of gravity.

This law is valid for astronomical scales, when the intrinsic dimensions of gravitating bodies are negligible compared to the distance between celestial bodies, and the interaction between them is of a "paired" nature (without interference from foreign bodies). Moreover, it is not applicable to continuous media in which there are no "field-generating" or "test" bodies. It is quite obvious that in the presence between the masses *M* and *m* of a medium with the same density ρ as theirs, that is, in the absence of a gradient or density difference, the gravitational force would be different. It is all the more interesting to find this force as a consequence of energodynamics for the general case of a continuous medium with an arbitrary density distribution $\rho(r)$ in space.

To do this, we will use the above definition of the local strength of any (including gravitational) field $H_g = \partial F_g/\partial V$as a negative gradient of gravitational energy density $-\nabla\rho_g$. The derivative $\nabla\rho_g \equiv \partial\rho_g/\partial r$can be represented in the form of the product $(\partial\rho_g/\partial\rho)\nabla\rho$, in which $(\partial\rho_g/\partial\rho)$is equal, according to the theory of acoustic vibrations [25], to the square of the propagation velocity of vibrations in any medium c^2(in this case the speed of light c). This immediately implies that

$$H_g = -c^2\nabla\rho\,(\text{Нм}^{-3});\ g = -H_g/\rho = c^2\nabla\rho/\rho,\ \text{мс}^{-2}. \tag{23}$$

This law fundamentally differs from Newton's law in that it reveals the existence of gravitational forces of both attraction ($\nabla\rho > 0$) and repulsion ($\nabla\rho < 0$). Therefore, we called it bipolar [26]. In this respect, it does not differ from Coulomb's law, which indicates the unity of the "mechanism" of all interactions.

The most important prediction of this law of gravity is the discovery that the gravitational interaction is the strongest of all known interactions. This follows from the fact that with equal relative density gradients of the energy carrier $\nabla\rho/\rho$, the magnitude of the gravitational field strength Hg and acceleration g is maximum in the “physical vacuum”, where the speed of light is *c*. For any material medium, it is lower, since the propagation velocity of perturbations in it is equal to the speed of light divided by its refractive index in it. This opens a direct path to the creation of a unified field theory, which A. Einstein dreamed of.

An equally important consequence of the bipolar law of gravity (23) is the prediction of the existence of a gravitational equilibrium corresponding to the condition $\nabla\psi_g$, $\nabla\rho = 0$. This condition is satisfied by the antinodes of waves and any wavelike structures. This explains the stability of various structures, without requiring the balancing of charges of opposite signs or the equality of centrifugal and gravitational forces.

Finally, this law does not require knowledge of parameters that cannot be measured by modern means. This (field) form of the law of gravity is indispensable where it is impossible to single out "field-forming" and "test" bodies with masses M and m. According to him, in the field environment, which is the ether, the "hidden" mass of the Universe, "dark" matter, physical vacuum or "dark energy", the forces of gravity are directed towards increasing the density of the medium, i.e. they are "pushing" in nature with respect to to denser regions of the Universe, including clusters of stars and galaxies. This gives it a meaning far beyond a mere generalization of Newton's law.

c) Proof of the principle of least action

For the first time this principle was formulated by P. Maupertuis in 1744, proceeding from the theological ideas of that time that all processes occurring in nature occur with a specific purpose and proceed in the most rational (economical) way. Only after quite a long time, thanks to L. Euler and J. Lagrange, this principle acquired a concrete mathematical meaning, asserting that for the actual path of a material point in a conservative force field, the integral of the momentum of a particle, taken along a segment of the trajectory between any of its two points, is minimal in comparison with the same integrals taken over the segments of other curves.

The first who gave the principle of least action the status of a general law of mechanics was H. Helmholtz [27]. He took the "Lagrangian" $L(r_i, p_i, t)$as the initial value as the difference between the kinetic Eк and potential Ep energy of the system, expressed in terms of the generalized coordinates $r_i(t)$ and momenta $p_i(t)$of all particles of the system. This made the Lagrangian

$L(r_i, p_i, t)$ a function of the time t and made it possible to write down the mentioned principle in the form of the requirement for the minimality of some functional

$$\Phi(t) = \int L(r_i, p_i, t)dt = min. \qquad (24)$$

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The first who gave the principle of least action the status of a general law of mechanics was H. Helmholtz [27]. He took the "Lagrangian" $L(r_i, p_i, t)$as the initial value as the difference between the kinetic E^k and potential E^p energy of the system, expressed in terms of the generalized coordinates $r_i(t)$ and momenta $p_i(t)$of all particles of the system. This made the Lagrangian a function of the time t and made it possible to write down the mentioned principle in the form of the requirement for the minimality of some functional

$$\Phi(t) = \int L\,(r_i, p_i, t)dt = \min. \qquad (24)$$

From the properties of the extremum of this function, Helmholtz succeeded in deriving the laws of motion for a number of systems. Gradually, this method of finding the laws of motion from a single mathematical function became one of the most widely used and most important physical principles, which, in capable hands, turned out to be applicable to most sections of theoretical physics [28].

Nevertheless, attempts to derive this principle from the general laws of the mechanics of conservative systems have so far been unsuccessful. It is all the more interesting to show that it is a consequence of the non-entropy evolution criteria proposed by energy dynamics [29]. To do this, we express the current nonequilibrium state of an arbitrary system by the integral of the power of the process of moving it away from equilibrium $dU/dt = \Sigma_j X_j \cdot J_j$, caused by external coercion taken from the initial equilibrium state:

$$U = \Sigma_j \int X_j \cdot J_j dt + U_o, \qquad (25)$$

where U_o is the energy of the system in a homogeneous (internally equilibrium) state.

The product $J_j dt = \Theta_j \overline{\boldsymbol{\upsilon}}_j\, dt$ included in this expression is the total differential of the extensive state parameter $Z_j = \Theta_j \Delta R_j$, characterizing the distance of the system from the state of equilibrium of the j-th kind and called in energodynamics "the moment of energy carrier distribution" Θ_j [5]. These are vector analogs of the very parameters that L. Onsager had in mind when he introduced scalar variables A_j, the time derivatives of which give flows $J_j = dZ_j/dt = \Theta_j dR_j/dt = \Theta_j \overline{\boldsymbol{\upsilon}}_j$. The meaning of the parameters Z_j is easy to understand if we pay attention to the change in the position of the center of the quantity Θ_j when its density ρ_j is redistributed over the volume of the system. This position in the current (inhomogeneous) R_j and the initial (equilibrium) state R_{jo} with density ρ_{jo} is determined in a known way:

$$R_j = \Theta_j^{-1} \int \rho_j r dV; \; R_{jo} = \Theta_j^{-1} \int \rho_{jo} r dV, \qquad (26)$$

where $\boldsymbol{r}$ is the running (Euler) coordinate.
This immediately implies that

$$Z_j = \Theta_j\,(R_j - R_{jo}) = \int (\rho_j - \rho_{jo}) r dV, \qquad (27)$$

Thus, the inhomogeneous distribution of any field quantity in the volume occupied by the system is characterized by a displacement $\Delta R_j = R_j - R_{jo}$ of its center from the equilibrium position coinciding with the center of this volume V. It is quite obvious that in a system that tends to establish equilibrium, this is the displacement tends to zero and, in the presence of external compulsion, takes on a minimum value compatible with it. This reflects the expression

$$U = \Sigma_j \int X_j \cdot dZ_j = \min, \qquad (28)$$

which would be more correct to call the principle of least coercion, especially since it has nothing to do with the concept of "action" in mechanics as the product of the force F_j and the time dt of its action.

The meaning of this principle is quite clear: it reflects the fact that the relaxing system "chooses" from all possible trajectories of the system's motion the one at which it remains closer to equilibrium (Z_j, ΔR_j=min). The approach of these parameters to zero ($dZ_j, dR_j < 0$) is a more visual and informative criterion of involution (approach to equilibrium) of the system for each inherent degree of freedom than the maximum of its entropy. This concern, in particular, the hydrodynamic degree of freedom of the system associated with the motion of the fluid, where X_j =- $\nabla\upsilon, dZ_j = Pdt$. Then (34) takes on the meaning of the minimum of the kinetic energy of the flow U^k, which also includes the turbulent component. This removes any veil of "mystery" from the PLA. Moreover, it becomes obvious that this circumstance is universal in nature and is true not only for mechanical motion, but for processes of any other nature. It is also valid for non-conservative systems, since it follows from energodynamics, all equations of which take into account irreversibility [30]. This greatly expands the scope of this principle. In particular, it becomes clear why the laminar flow of a viscous fluid remains stable until the moment of bifurcation associated with the appearance of a new degree of freedom in it - vortex motion, or why, under conditions of invariability of external "compulsion", the flow is steady. It also becomes clear why this principle could not be obtained within the framework of disciplines that are not related to evolution. All this refutes the opinion of I. Prigogine that “dynamics and thermodynamics are two different worlds” [3].

V. Conclusion

1. The appearance in the twentieth century of three new fundamental theories - quantum mechanics (QM), the theory of relativity (RT) and thermodynamics of irreversible processes (TIP), containing poorly consistent and even mutually exclusive provisions, makes it necessary to search for alternative ways of synthesizing new knowledge within the framework of a unified physics.
2. The proposed method for the synthesis of continuum mechanics (MC) and nonequilibrium thermodynamics (TIP) by generalizing the law of conservation of energy to the processes of transfer and transformation of any forms of energy and inhomogeneous systems, with any finite number of degrees of freedom, allows you to do this without additional hypotheses and postulates.
3. A new version of nonequilibrium thermodynamics, called energy dynamics, reveals the inconsistency of the hypothesis of local equilibrium and generalizes the TIP by introducing additional parameters of the heterogeneity of the studied systems (moments of distribution of energy carriers), conjugated with potential gradients, just as these energy carriers themselves-with the generalized potentials of their fields.
4. The proposed approach makes it possible to find the driving forces X_i and generalized velocities of various processes (flows J_i), proceeding not from the principle of increasing entropy, but on a more general basis of the law of conservation of energy, without excluding from consideration any (reversible or irreversible) component real processes.
5. Energodynamics allows to give a strictly thermodynamic substantiation of all the provisions of the TIP, without involving for this statistical-mechanical and molecular-kinetic theories, which extends the scope of its applicability to nonlinear processes and states far from equilibrium.
6. The new method proposed by energy dynamics for finding the effects of "superposition" of dissimilar processes makes it possible to further reduce the number of empirical coefficients from n $(n + 1)/2$ in TIP to n and give a new explanation of these effects.
7. The application of energy dynamics to the mechanics of the continuum reveals the unity of the nature of all force fields as a consequence of the uneven distribution of their energy carriers and offers a unified method for finding clearly distinguishable driving forces and their moments for a number of processes of mechanical and non-mechanical nature.
8. Approach to mechanics from the standpoint of energy dynamics reveals the existence, along with the force fields, of the fields of their torques, which allows generalizing all three Newton's laws to rotational motion and to irreversible processes generated by the counteraction of active forces on the part of "alien" reaction forces. This makes it possible to take into account irreversibility into the equations of mechanics without revising its foundations.
9. From the main equation of energy dynamics follows the existence of the bipolar law of gravity, which differs from the Newtonian law of gravitation by the presence of forces of both attraction and repulsion, the discovery of the phenomenon of gravitational equilibrium and the "super-strong" nature of gravitational interaction, its short-range action and applicability to continuous media, in which it is impossible to distinguish "Field-forming" bodies.
10. The synthesis of nonequilibrium thermodynamics and continuum mechanics reveals the nature of the principle of least action as a consequence of thermodynamic criteria for the evolution of nonequilibrium systems, dictating to the system the choice of a single process path with a minimum distance from equilibrium. This explains why this principle was not substantiated within the framework of mechanics and expands the scope of its applicability to non-conservative systems and dissipative processes.
11. The heuristic value of the synthesis of nonequilibrium thermodynamics and continuum mechanics consists in the mutual complementarity and enrichment of these disciplines, reducing the number of their initial postulates and expanding the scope of their applicability. The results of this synthesis refute the opinion of I. Prigogine that

dynamics and thermodynamics are two different worlds.

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The similarity of the methods of nonequilibrium thermodynamics, operating with the concept of force X_j, with mechanics increases with the transition to the forces F_j in their general physical sense. Indeed, the entire set of interacting (mutually moving) bodies or particles can be considered as an isolated system, for which its total energy E becomes identical to its internal energy U. In this case, the basic law of energodynamics (5) is applicable to it, in which both parts the equalities vanish. All forces F_j in this expression have the meaning of derivatives of the "partial" energy of the j-th form U_j with respect to the radius vector of the field r_j ($F_j=\partial U_j/\partial r_j$), and the velocity $\bar{\boldsymbol{\upsilon}}_j$ includes the translational $\bar{\boldsymbol{w}}_j$ and rotational (circumferential) components $\bar{\boldsymbol{\omega}}_j \times R_o$, expressed by the vector product of the angular velocity $\bar{\boldsymbol{\varpi}}_j$ and the instantaneous radius of rotation of the volume element R_o. Therefore, from equation (3), it follows that (7) contains a term characterizing the power of the rotation processes of the system as a whole, expressed by the scalar product of the averaged moment of forces $M_j = \int(H_j \times R_o)dV$ and the averaged angular velocity:

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Higher Order Conditional Probability and Concentration-Concentration Fluctuation in the Long Wavelength Limit of Molten Binary Alloys

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Abstract- A thermodynamic model based on cluster of four atoms is considered to obtain conditional probability enumerating the higher order atomic correlation in the nearest neighbor shell of liquid binary alloys. This has enlightened the discussion of how the higher order atomic correlation is related to pairwise distribution. The Cd-Ga liquid alloy is a candidate of homo-coordination. Bi-Cd liquid alloy indicates partly homo-coordination. The higher order conditional probability of Bi-Cd binary alloy is uniformly displayed. There is band-like formation of the higher order conditional probability of Cd-Ga liquid alloy. The values of concentration-concentration fluctuation and higher order conditional probabilities computed for Bi-Cd and Cd-Ga, are presented.

Keywords: atomic correlation, ordering energy, higher order conditional probability, concentration-concentration fluctuation.

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Strictly as per the compliance and regulations of:

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I. Introduction

The neutron diffraction experiment is always carried outto determine some structural details and information pertaining to some easily detectable thermodynamic properties of binary liquid alloys [1]. The exceptional cases might occur if the experimental data for some alloys is not available due to cumbersome tasks involved and experimental difficulties. For instance, the Short Range Order (SRO) [1] which has a connection with Concentration-Concentration Fluctuation in the long wavelength limit Scc(0) can be experimentally determined from the knowledge of concentration-concentration partial structural factor, $S_{cc}(q)$, and the number-number partial structural factor S_{NN} (q) [2]. However, these structures are not easily measurable in most diffraction experiments. Hence SRO is usually computed without necessarily making reference to its experimental values. Additionally, a direct experimental determination of Scc (0) is often avoided due to the complexities involved. For this reason, the option of a thermodynamic model, which is readily used, was employed.

The thermodynamic model is commonly used to extract the macroscopic chemical structure of some thermodynamic systems. By considering a Quasi-chemical Model of the Four Atoms Cluster (say FACM), with the view to obtain Higher Order Conditional Probabilities (HOCP) enumerating the atomic distribution in the nearest neighbor shell. (For example, i/iji, is the probability of finding i atoms in the given lattice site. While other three neighboring sites in the cluster are occupied by atoms i, j, and I atoms. This should give a more realistic of ordering energy (w) and the concentration-concentration fluctuation [Scc(0)] and thus a qualitative discussion is attempted for either hetero-coordination (i.e. preference for unlike atoms as to pair as nearest neighbors) or self-coordination (preference for like atoms as the nearest neighbors) in molten alloys [3].

In this study, ordering energy values were determined from Scc (0) [3] of which two alloys were considered. In the application of the thermodynamic model, the determined values of ordering energy, the Scc(0), and HOCP were recorded at different temperatures.

The calculations of the thermodynamic quantities at different temperatures involve getting the available experimental data and employing a suitable theoretical model. The alloys were preferred because the two alloys represent the classes of metal and semiconductor.

Investigations of liquid metallic alloys on the basis of the Quasi Chemical Model (QCM) and its usage for extracting values is also found in [3, 4] where this model was used for the calculations of some thermodynamic properties of the compound forming binary molten alloys at their melting temperatures[4].

In this observation, the QCM is applied to Bi-Cd and Cd-Ga liquid alloys for the qualitative investigation of their thermodynamic properties. Ordering energy values determined from Scc (0) are recorded in Table 1.The C^{++} Computer programs were inscribed to generate data for thermodynamic expressions as functions of concentration, c, using ordering energy values, w, coordination number, Z, Boltzmann constant, K and temperature, T presented in Table 1.

Therefore, in the observation write up the attention is geared towards determining the ordering energy values of two binary alloys from values of deviations in Scc(0) [4] and calculating of some thermodynamic properties.

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The determined values of ordering energy are displayed in Table 1.

Table 1: Ordering energy (w) in eV of Binary Liquid Alloys

Alloy	Temperature (°K)	Z	w (eV)
Bi-Cd	773	10.0	-0.0147
Cd-Ga	700	10.0	+0.1133

II. Expression for Concentration-Concentration Fluctuation in the Long Wave Length Limit (SCC (0))

$$S_{cc}(0) = \frac{S_{cc}^{id}(0)}{1+\frac{Z}{2\beta}(1-\beta)} \tag{1}$$

Where $S_{cc}^{id}(0)$ is the ideal concentration-concentration Fluctuation in the long wavelength unit

Z is the coordination number, and β has an interwoven parameters such as w, η, k_B, T and c.

c is the concentration of atom i and 1-c is the concentration of atom j, w is ordering energy, K_B is Boltzmann's constant, T is the melting temperature.

$$S_{cc}^{id}(0) = c(1-c) \tag{2}$$

$$\eta = e^{\frac{w}{zk_T T}} \tag{3}$$

$$\beta^2 = 1-4c(1-c)(\eta^2-1) \tag{4}$$

Expression for Higher Order Conditional Probability (HOCP)

$$\frac{B/AAA}{A/AAA} = a\sigma^{z-3}\eta^{-3} \tag{5}$$

$$\frac{B/AAB}{A/AAB} = a\sigma^{z-3}\eta^{-1} \tag{6}$$

$$\frac{B/ABB}{A/ABB} = a\sigma^{z-3}\eta \tag{7}$$

$$\frac{B/BBB}{A/BBB} = a\sigma^{z-3}\eta^{3} \tag{8}$$

Where

$$a = (\frac{1-c}{c})\sigma^{-z} \tag{9}$$

$$\sigma = \frac{\beta-1+2c}{2\eta c} \tag{10}$$

$$\eta = e^{\frac{w}{zk_T T}} \tag{11}$$

$$(A/AAA) + (B/AAA) = 1 \tag{12}$$

$$(A/AAB) + (B/AAB) = 1 \tag{13}$$

$$(A/ABB) + (B/ABB) = 1 \tag{14}$$

$$(A/BBB) + (B/BBB) = 1 \tag{15}$$

$$(A/AAA) = \frac{1}{1+a\sigma^{(z-3)}e^{-3\beta w/z}} \tag{16}$$

$$(A/AAA) = \frac{1}{1+a\sigma^{(z-3)}e^{-\beta w/z}} \tag{17}$$

$$(A/AAA) = \frac{1}{1+a\sigma^{(z-3)}e^{\beta w/z}} \tag{18}$$

$$(A/AAA) = \frac{1}{1+a\sigma^{(z-3)}e^{3\beta w/z}} \tag{19}$$

III. Results and Discussion

Table 1: Calculated concentration-concentration fluctuation of Bi-Cd alloy using Four Atoms Cluster Model (FACM). C_{Bi} is the concentration of Bismuth in the alloy.

C_{Bi}	Scc(0)	Scc(0)id
0.1	0.089	0.09
0.2	0.166	0.16
0.3	0.250	0.21
0.4	0.296	0.24
0.5	0.296	0.25
0.6	0.256	0.24
0.7	0.284	0.21
0.8	0.156	0.16
0.9	0.065	0.09

Table 2: Calculated concentration-concentration fluctuation of Cd-Ga alloy using Four Atoms Cluster Model (FACM). C_{cd} is the concentration of Cadmiun in the alloy.

C_{cd}	Scc(0)	Scc(0)id
0.1	0.371	0.09
0.2	0.437	0.16
0.3	0.776	0.21
0.4	0.718	0.24
0.5	0.745	0.25
0.6	0.143	0.24
0.7	0.038	0.21
0.8	0.347	0.16
0.9	0.212	0.09

Table 3: Calculated Higher Order Conditional Probability of Bi-Cd alloy using Four Atoms Cluster Model (FACM). C_{Bi} is the concentration of Bismuth in the alloy

C_{Bi}	A/AAA	A/AAB	A/ABB	A/BBB
0.1	0.0879	0.0922	0.0967	0.1014
0.2	0.1805	0.1884	0.1965	0.2050
0.3	0.2772	0.2879	0.2968	0.3099
0.4	0.3774	0.3899	0.4024	0.4151
0.5	0.4302	0.4934	0.5065	0.5197
0.6	0.5848	0.5975	0.6100	0.6225
0.7	0.6900	0.7011	0.7120	0.7227
0.8	0.7549	0.8034	0.8115	0.8194
0.9	0.8965	0.9032	0.9077	0.9121

Table 4: Calculated Higher Order Conditional Probability of Cd-Ga alloy using Four Atoms Cluster Model (FACM). C_{cd} is the concentration of Cadmiun in the alloy

C_{cd}	A/AAAA	A/AAB	A/ABB	A/BBB
0.1	0.2403	0.1757	0.1256	0.0882
0.2	0.3838	0.2974	0.2219	0.1612
0.3	0.4898	0.3928	0.3036	0.2271
0.4	0.5726	0.4744	0.3782	0.2907
0.5	0.6438	0.5491	0.4508	0.3561
0.6	0.7092	0.6217	0.5255	0.4273
0.7	0.7728	0.6963	0.6071	0.5101
0.8	0.8387	0.7790	0.7025	0.6141
0.9	0.9117	0.8943	0.8242	0.7537

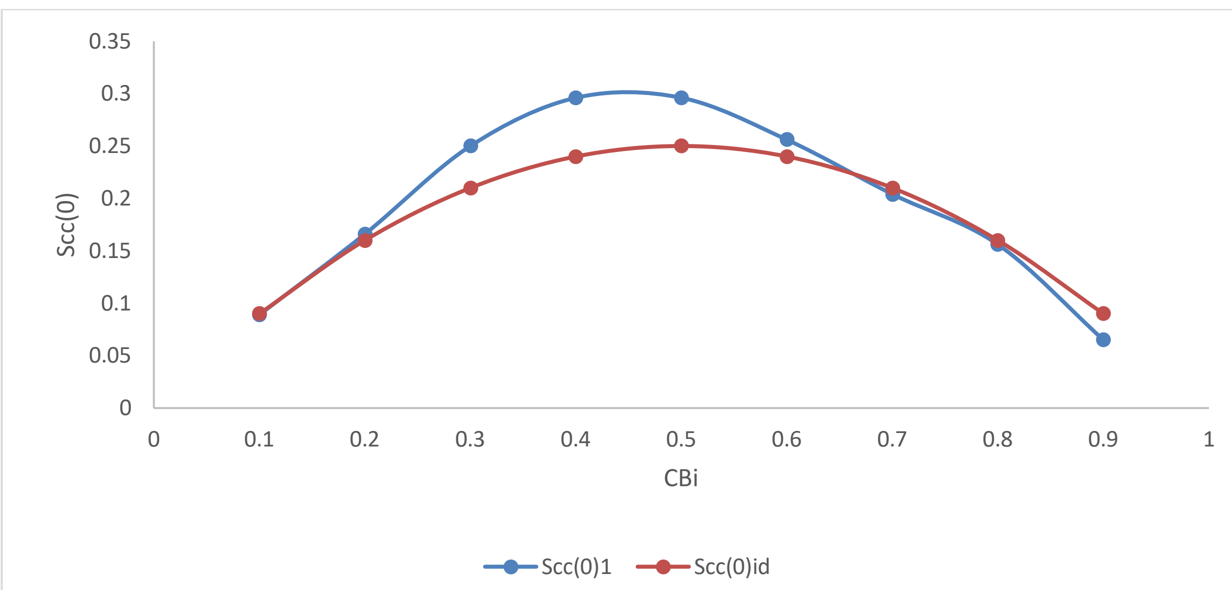

Fig. 1: Concentration-concentration fluctuation Scc(0) versus concentration C_{Bi}

In Figure 1, the values of Scc(0) for Bi-Cd liquid alloy portray homocoordination at some concentrations C_{Bi} =0.3, 0.4, 0.5 and 0.6. At the remaining concentrations, their exits perfect agreement between the ideal solution and the Scc(0) of Bi-Cd liquid binary alloy. In the alloy at elevated temperature same atom are bound to pair-up with each other in the nearest neighbourhood at some specific composition of bismuth. The Scc(0) of these alloy increases initially to a maximum (owing to the charge transfer between neighboring atoms) within the entire concentration range [5, 6]. This is due to chemical alternation of positive and negative charges with length scale approximately twice the nearest neighbor distance.

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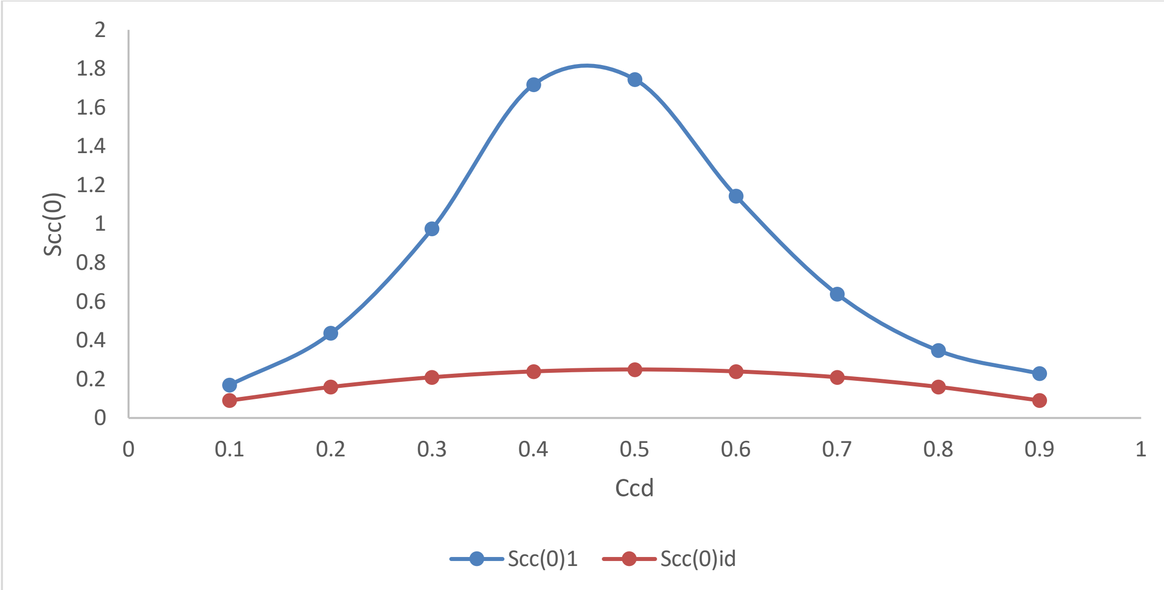

Fig. 2: Concentration-concentration fluctuation Scc(0) versus concentration C_{cd}

In Figure 2, the values of Scc(0) for Cd-Ga liquid alloy signifies homocoordination throughout the entire composition of Cadmium. The values of Scc(0) of Cd-Ga liquid binary alloy are higher than the ideal case representing the complete homocoordination in the nearest neigbour shell. In the alloy at elevated temperatures, the same atoms are bound to pair up with each other in the nearest neighborhood at the entire concentration of cadmium. This is possibly due to the disordered potential which too large [7].

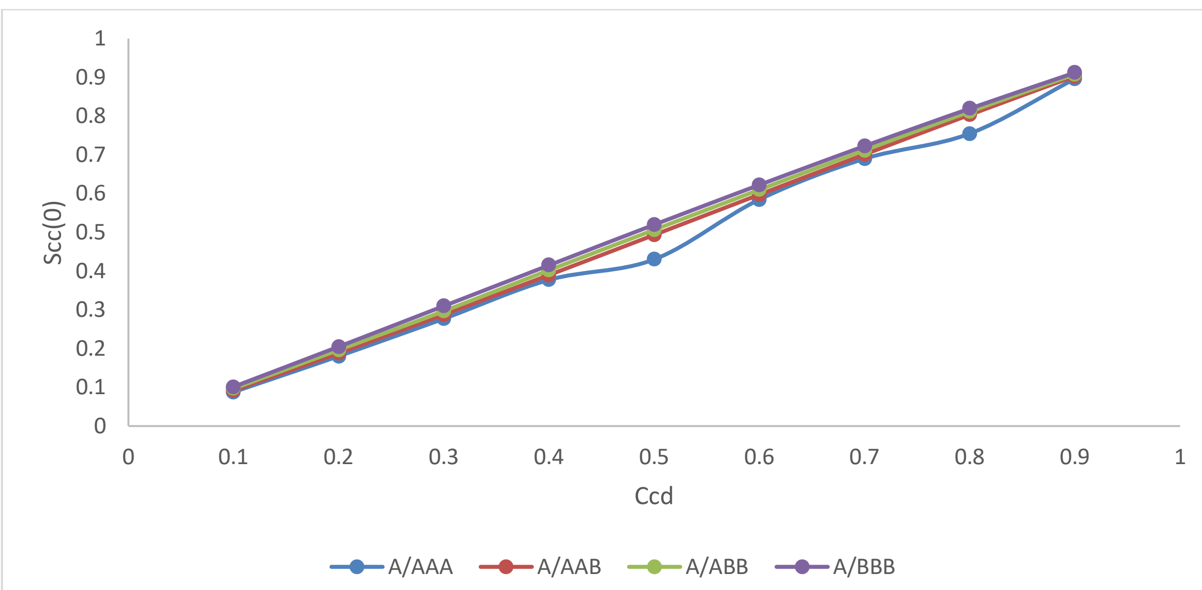

Fig. 3: Higher Order Conditional Probability (HOCP) versus concentration C_{Bi}

The three probabilities (A/AAB, A/ABB and A/BBB) have formed unified paths undeviated at higher order cluster of four atoms irrespective of the possibilities. Only one of the possibilities has slight deviations at concentrations C_{Bi} = 0.5 and 0.8. The three possibilities agree with the one another on the distributions of a particular atom as reference atom having either the same or and different atom as the nearest neigbour shell in the cluster. Because of the topological short range order at Ccd= 0.5 and 0.8. i.e. geometrical arrangements of atoms) it indicates and supports homocoordination (Preference of like atoms as the nearest neighbor) [8].

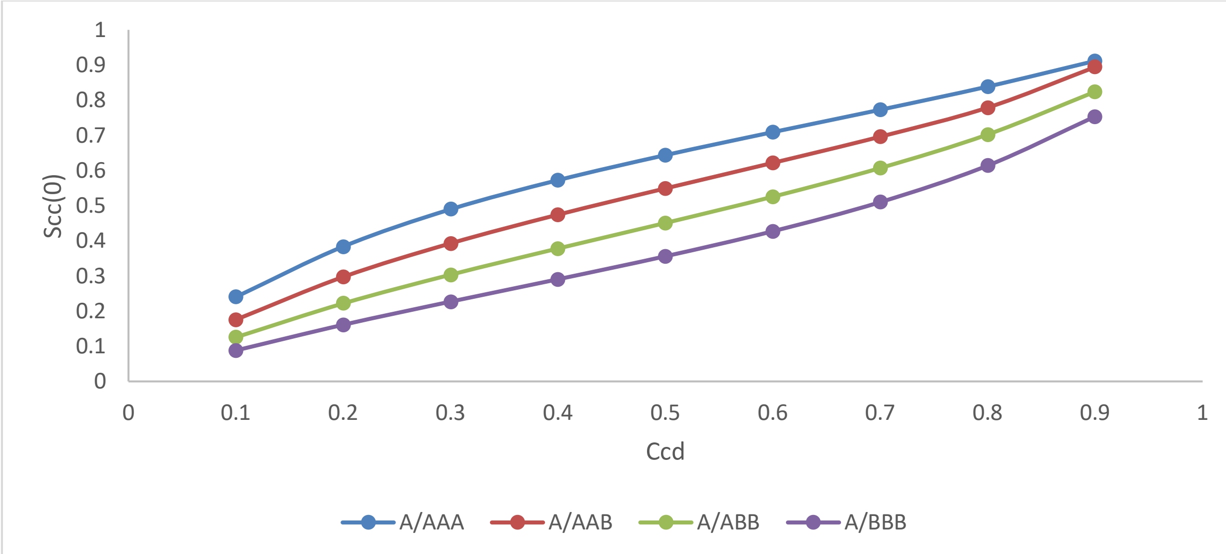

Fig. 4: Higher Order Conditional Probability (HOCP) versus concentration C_{cd}

The four possibilities of higher order conditional probability (i.e A/AAA, A/AAB, A/ABB and A/BBB) are not uniform because there is a near cancellation of the ionic potentials while at large distances ionic potentials was screened in Figure 4. In addition, in this perspective it has calculated values for HOCP of Cd-Ga been spaced for the four possibilities which are also in support of homocoordination or self-coordination. There are other reasons of directional bonding, which are also responsible for slight curve of the plot of HOCP of Cd-Ga binary liquid alloy [9, 10].

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The Universal Gravitational Constant(G) in an Expanding Universe

By John A. T. Bye

The University of Melbourne

Abstract- This paper indicates how the inclusion of dark matter, which is shown in Bye (2021) to have a constant density (ρ_D) throughout the Universe, together with the velocity of light (c), which is also a constant, leads to the expression, $G=[3c^2/4\pi\rho_D]/R^2$, for the universal gravitational constant in which R is the radius of the Universe. As the Universe ages G decreases.

Keywords: dark matter, universal gravitational constant (G).

GJSFR-A Classification: DDC Code: 530.1 LCC Code: QC6

THEUNIVERSALGRAVITATIONALCONSTANTGINANEXPANDINGUNIVERSE

Strictly as per the compliance and regulations of:

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Keywords: dark matter, universal gravitational constant (G).

I. Introduction

Theoretical cosmology has been traditionally underpinned by two universal constants, the speed of light (c) and the universal gravitational constant (G). A recent investigation of dark matter (Bye 2021) has found that there is a third universal constant, which is the density of dark matter (ρ_D). This note assumes that c and ρ_D are absolute constants, i.e. they are independent of the evolutionary state of the Universe, from which an expression for the universal gravitational constant (G) is derived.

II. The Key Relations

(i) The azimuthal velocity at the edge of the Universe is,

$$c = (G\,M/R)^{1/2} \qquad (1)$$

where c is the velocity of light, and M and R are respectively the mass and the radius of the Universe. From (1),

$$2\,\pi\,R\,/\,T = c \qquad (2)$$

where T is the orbital period of the dark matter. On substituting (2) in (1) we obtain
Newton's Law for the mass (M),

$$GM=4\pi^2R^3/T^2 \qquad (3)$$

in which
(ii) The mass of the universe (M) is,

$$M= 4/3\,\pi\,\rho_D\,R^3 \qquad (4)$$

where ρ_D is the density of the dark matter, which the planetary data indicate is a universal quantity [1].

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III. The Universal Gravitational Constant

On eliminating M between (3) and (4), we find that the universal gravitational constant (G) is,

$$G = 3\,\pi\,/(\rho_D\,T^2) \qquad (5)$$

Eq. (5) is a general expression for G, which, on using (2) yields,

$$G = [3c^2/4\pi\rho_D]/R^2 \qquad (6)$$

Hence the universal gravitational constant (G)is inversely proportional to the square of R. At the birth of the Universe ($R \to 0$), $M \to 0$ and $T \to 0$, and $G \to \infty$, whereas at the death of the Universe ($R \to \infty$), $M \to \infty$ and $T \to \infty$ and $G \to 0$. The intermediate phase between these two limits may be regarded as the mature Universe, of which we are a part.

Planetary data indicate that $\rho_D = 2.1\ 10^{-6}$ kg m^{-3} and also that $R = R_o$ where $R_o = 1.25\ 10^{16}$ m (Bye 2021). On substituting in (6) we obtain $G = 6.54\ 10^{-11}$ kg^{-1} m^3 s^{-2}, which is very similar to the observed value of $6.674\ 10^{-11}$ kg^{-1} m^3 s^{-2}(Wikipedia 2022)and well within the likely error bounds for ρ_D and R_o. On evaluating (6) for an arbitrary R, we obtain,

$$G = A\,R^{-2} \qquad (7)$$

in which for $\rho_D = 2.1\ 10^{-6}$ kg m^{-3}, $A=1.02\ 10^{22}$ kg^{-1} m^5 s^{-2}. We suggest that (6) should be used for G in cosmic models in which R is evolving, rather than the traditional relation in which $G = 6.674\ 10^{-11}$ kg^{-1} m^3 s^{-2}.

IV. The Expanding Universe

Eq.(6) shows that the universal gravitational constant is a function of the size of the Universe (R) as might have been expected a priori, and the properties of the present Universe predict a value for G($6.54\ 10^{-11}$ kg^{-1} m^3 s^{-2}), which is similar to the observed experimental value of $G = 6.674\ 10^{-11}$ kg^{-1} m^3 s^{-2}. This gives confidence in the use of (6). Eq. (6) has already been incorporated implicitly in the universal energy balance expressions due to dark matter in Bye (2021) through Eq. (15).Here it is shown to be a seminal expression for the evolving Universe, which in particular, relates the time variability of G to that of R.

V. Conclusion

The most important conclusion is that as the Universe ages, the universal gravitational constant reduces according to (6). We propose that this reduction of G must be fully included in cosmological modelling.

In broad brush terms the decrease of the universal gravitational constant (G) with time is 'a secular relativity' in which, (1) shows that as the Universe ages, in order to maintain an azimuthal velocity which is equal to the velocity of light (c), the reduction in the universal gravitational constant (G) is compensated by an increase in mass density (M/R). Within the Universe, however, as the universal gravitational constant (G) decreases, the orbital velocity about a principal mass (M_o = M) at a radius (R) slows, arguably promoting planetary formation.

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Competition and Cooperation in the Dynamics of Imperial Invasion: A Strategic Model

By Kishore Dutta
Handique Girls' College

Abstract- In the evolution of every great empire of antiquity, the process of invasion was so inextricably interwoven that even the most powerful empire was incapable of escaping its barbarizing effect. A sudden invasion imposed major perturbation to a massive, centrally-organised system within a relatively shorter period and became a long-lasting destabilizing factor that brought drastic changes in the productivity, economy, man-power, and social order of the system. In order to understand such a vibrant dynamics as an interplay between competition and cooperation, here we show how a simple prototype can be constructed by taking into account some of the essential sociophysical processes in their simplest settings. The simulation of the model visualizes how the outcomes depend on factors such as the strength of the invaders, defensive manoeuvre of the empire and its internal configuration.

Keywords: *competition and cooperation; centrally-organized system; historical processes; imperial invasion; computational model.*

GJSFR-A Classification: DDC Code: 332.041 LCC Code: HB501

COMPETITIONANDCOOPERATIONINTHEDYNAMICSOFIMPERIALINVASIONASTRATEGICMODEL

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Keywords: competition and cooperation; centrally-organized system; historical processes; imperial invasion; computational model.

I. Introduction

As chronicled in a great many episodes of human history [1{7], almost every empire of antiquity, irrespective of their sizes and strengths, endured a number of vital sociophysical processes that include the growth, assimilation, aggression, and annihilation and each of them took place at different stages of their lifespans over historical time scales [1, 8{13]. Associated with every such historical process, the activity of invasion was so inextricably related that it played a key role in determining the evolutionary track of an empire. The huge Achaemenid Persian empire (550 - 330 B.C.) that was built largely through military conquest, took nearly 65 years to grow and survived for more than a century after saturation. Being aided by political instability in Persia, Alexander the Great with his exceptional military leadership abilities, embarked on the great campaign in 336 B.C. to conquest the mighty Persian Empire and by 327 B.C., the entire Persian Empire was brought under his control [1]. The Egyptian empire that ourished in the Nile Valley civilization (5500□300 B.C.), was invaded by a number of foreign powers including the Hyksos, the Libyans, the Nubians, the Assyrians, the Achaemenid Persians, and the Macedonians under the command of Alexander the Great [9,14]. The Greek Ptolemaic Kingdom, formed in the aftermath of Alexander's death, ruled Egypt until it fell to the Roman Empire in 30 B.C. and became a Roman province. The Roman empire (27 B.C.- 476 A.D.) that belonged to the Roman civilization (753 B.C.- 476 A.D.), was one of the largest empires in the ancient world. Through conquest, cultural and linguistic assimilation, at its height it controlled the North African coast, Egypt, southern and most of western Europe, much of the Middle East, and parts of Mesopotamia and Arabia [2, 3]. The Harappa empire that was culminated in the Indus Valley (3500 □ 1500 B.C.), was destroyed by the Indo-European (Aryan) invaders sometime between 1800 and 1700 B.C. Repeated cycles of rising and collapse occurred in ancient India, most notably with the Mauryan and the Gupta Empires [4{7]. The Mogul Empire that was established early in the sixteenth century, was destroyed by European invaders in the centuries following 1700 A.D.

All such historical episodes indicate that the processes of growth, expansion, and assimilation in an empire took place at different historical time scales while, an invasion was a comparatively short-time process and it happened at any evolutionary stage of the empire. Within a relatively shorter period, a sudden invasion imposed a quantifiable perturbation to a centrally-organized system and became a long-lasting destabilizing factor that brought drastic changes in the productivity, economy, manpower, and social order of the system [9]. By creating major upheavals in the economy, manpower and politics, it made a complete mess of many empire's lives and, most often, put an end to the richness and diversity of their entire evolutionary process. Being an unexpected event, it made impossible to foresee how the lifespan of such a huge centrally-organized system suddenly started shrinking and how a small empire rose all of a sudden to a powerful empire [5, 15]. The greatness of an emperor, therefore, lies in how the emperor can devise an optimal solution to resist the invaders at minimal defence costs instead of declaring a full-scale war. A great and far-ung empire thus requires to accumulate and distribute its total military strength among its powerful provinces in an optimal way so that they can resist the invaders at minimal defence costs.

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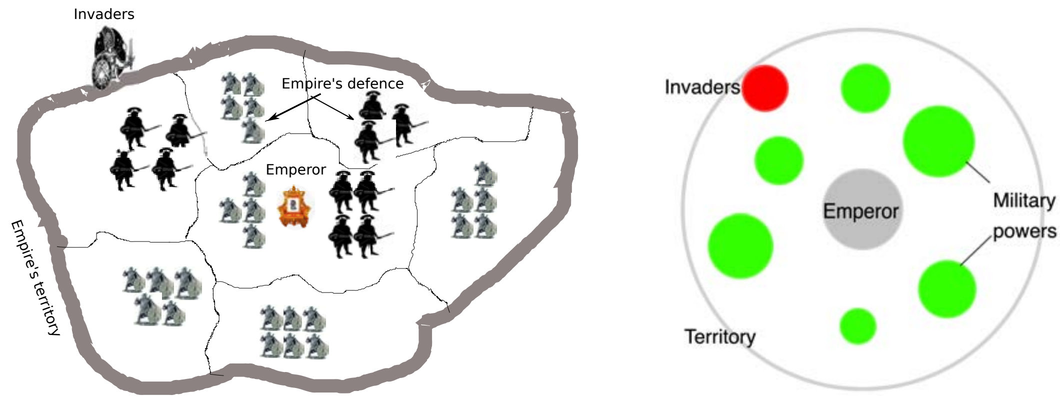


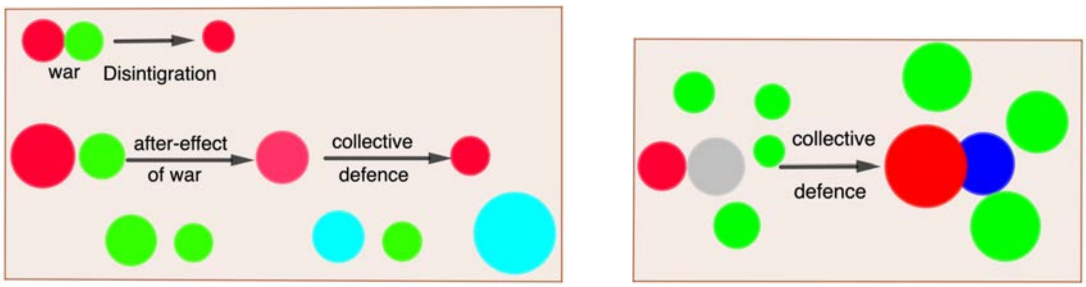
(a) (b)

Figure 1: (Color online) A replica of an empire. (a) A schematic view of an empire comprising the emperor, a territory, the internal defensive structure and the outside invaders (b) the prototype of the empire comprising a circular territory, an emperor (grey circular domain), a number of powerful provinces (PPs) or the centres of military powers of different sizes (green circular domains), and the outside invaders (red circular domain).

In order to quantify how such a strategy of defence as well as the strength of invaders impact the outcomes, we construct a simple dynamic model based on some essential sociophysical rules. We visualize the entire picture by constructing an artificial empire as a replica of a centrally-organised system, as schematically displayed in Fig. 1. As soon as the invaders pierce the territory of the empire, they proceed towards the emperor with an aim to seize the core of the empire. This engenders major perturbations that causes expansion, coalescence, and disintegration of military powers within the empire. The competition and cooperation are taken into account through the warfare strategies as well as the defensive manoeuvre of the empire. Since the invaders can pierce the territory at any arbitrary point and since the empire can distribute its military powers across the kingdom in a widely different ways, the outcomes (the victory of either the empire or the invaders) in every single invasion remains highly indeterministic. Thus, a physically meaningful quantity would be the invaders' capture probability which can only be determined by repeating the same processes for a considerably large number of random invasions on empires with random distribution of their powerful provinces (PPs) or the centres of the military powers. Such a computation would allow us to quantify the outcomes in terms of both the strength of the invaders and the defensive manoeuvre of the empire. It would also provide a way to visualize how a far-ung empire withstood the invaders of any strength, how a small empire remained irresistible over a long historical period, and how an empire could resist the invaders at minimal defence cost.

II. The Prototype

As schematically shown in Fig. 1, we construct a prototype of an empire with a circular territory and a number of powerful provinces (PPs) or the centres of military powers of different sizes that are evenly distributed across the kingdom. The core or the central state of the empire is occupied by the emperor (or the empress) who politically controls over its inhabitants, military, economy, and culture. The emperor is heavily fortified either by the strong military forces or by the seemingly impenetrable provinces so that the attacks of any strategic invasion can be evaded. It is the size of the evenly distributed PP's that determine the military strength of the empire. The invaders are also represented by a circular domain (the red circle in Fig. 1). As soon as the dynamics begins, the invaders pierce the territory at any arbitrary point. They start expanding and proceeding towards the emperor with an aim to capture the emperor by defeating the PPs through warfare. The expansion and advancement of the invaders are assumed to take place at a constant rate, which in turn determines their strength. During this process, the invading domain encounters the nearby PPs and each such interaction is considered to be a vicious war. The outcome of the war is simply assumed to depend on the sizes of the domains at the point of their interaction. If the size of the invading domain (r_i) is smaller than that of the PP (r_p) at the point of interaction, the invaders will be destroyed and the process stops. If $r_i > r_p$, the PP will be annihilated and the invading domain would suffer the casualty [Fig. 2(a)]. Due to the after-effect of war, the invading domain would start shrinking in size at a constant rate to an extent $r_i - \varepsilon r_p$, where the fairness parameter of warfare, ε, usually lies in the range $0 \leqslant \varepsilon \leqslant 1$ [16, 17]. We simply assume here each and every single war as a vicious one and, accordingly, we set $\varepsilon = 1$ throughout our simulation. The after-war effect prevails until the size of the invading domain reduces to $r_i - \varepsilon r_p$ in discrete time steps. Once the shrinking is over, the domain would again start expanding and proceeding towards the emperor at the same rate as before. The defensive strategy of the empire is such that, as soon as one of the PPs falls victim to invasion, it sends a message to its nearest PPs that lie within a certain minimum radial distance. The PPs that receive the message (represented by the color cyan in our simulation), would start expanding and coalescing among themselves for collective defence [Fig. 2(a)]. The expansion and coalescence of the PPs take place at a predefined constant rate. Relative to the expansion rate of PPs, the expansion rate of the invaders determine whether the invaders are faster or slower. If invaders approach at a faster rate, then there is a high chance to destroy the nearby PPs before the PPs start coalescing. On the move, if the invaders are able to attack the emperor, the emperor would immediately declare a high alert in the kingdom for collective defence [Fig. 2(b)]. To enhance their military power, the remaining PPs at once will start expanding and coalescing among each other. As the expansion persists, a PP would either coalesce with other nearby PPs or engage himself in a vicious war with the invaders. The process would continue until the invaders get destroyed or all the PPs are invaded. The dynamical evolution of the empire in a single invasion following the above-mentioned rules can be visualised from the supplementary video that is generated from our simulation run.



(a) (b)

Figure 2: (Color online) Sociophysical rules during the process of invasion. (a) The moment the invaders (red in color) interact with a PP (green in color), the smaller domain disintegrates and the surviving domain suffers after-effect of war. During such an interaction, the PP that falls victim to invasion, sends an alert message to its nearest PP (cyan in color) for collective defence (b) The moment the invaders attack the emperor, the emperor changes its color from grey to blue and initiates the expansion and coalescence among the remaining PPs.

III. Results and Discussions

For the simulation of the entire dynamics, we construct a circular territory of the empire with radius $R = 50$ units. The emperor is represented by a grey circular domain of radius $r_c = 10$ units and it lies at the centre of the empire. The PPs are assigned random sizes with their radii lying in the range $3 \leqslant r_p \leqslant 5$. They are distributed in such a way that their centres lie in the belt $20 \leqslant r_b \leqslant 40$ that surround the emperor. At the onset of the dynamics, the invaders of size $r_i = 1$ unit appears at any arbitrary point on the empire's territory; it then pierces the territory and starts expanding (the radius increases linearly with time). At the same time, the centre of the invading domain also starts advancing towards the emperor at the same rate. To quantify the probabilistic outcomes in terms of invaders' strength, we perform the simulation with different relative strengths of the invaders. Since we assume for simplicity that the military strength is proportional to the domain size, the relative strength of the invaders is determined by their expansion and advancing rates in comparison to that of PPs. Accordingly, we choose different expansion rates of the invaders' and assume their advancing rate same as the expansion rate. By assigning the expansion rate of PPs as $f_{gp} = 0.5$ units, the relative strength of the invader's are considered as slower and higher based on whether their rate of expansion $f_{gi} \leqslant 0.5$ and $f_{gi} \geqslant 0.5$.

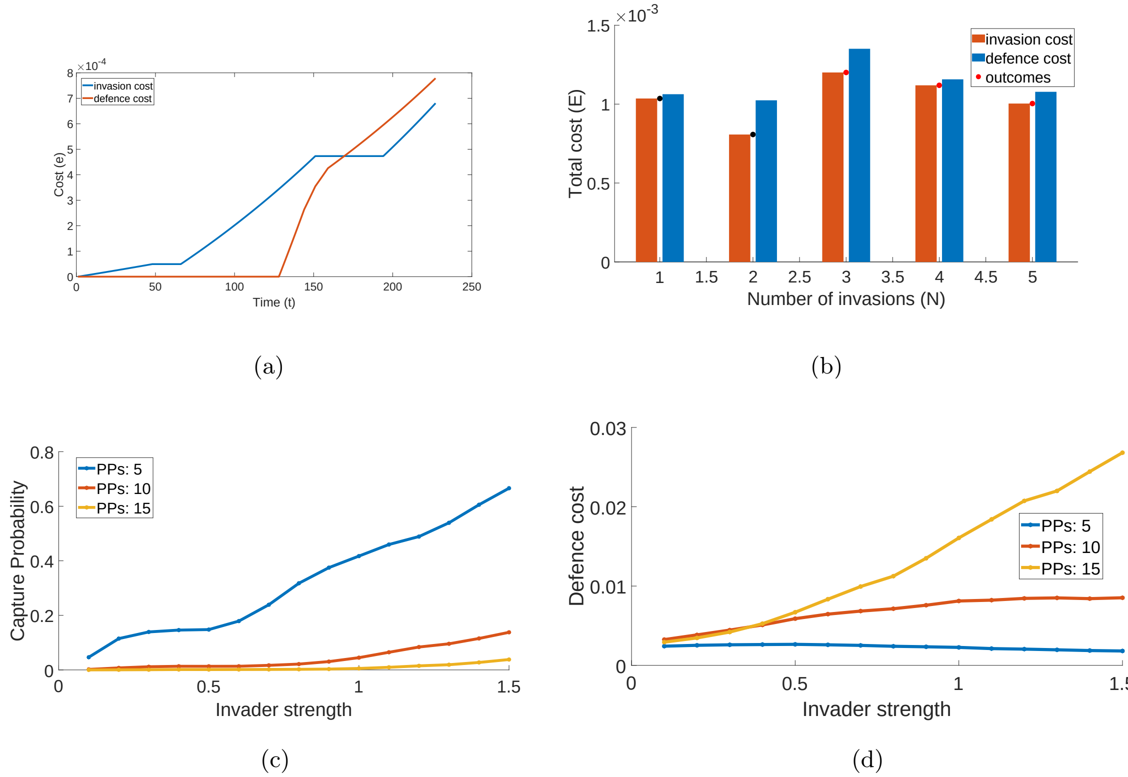


Figure 3: (Color online) Simulation results for varying strength of invaders and varying configuration of the empires. (a) a typical cost profile both for the invaders and for the empire in a single invasion (b) a typical variation of total costs in five consecutive invasions. The outcomes of each invasion are shown as the victory of either the empire (indicated by the small red circles on the top right corners of the orange bars) or the invaders (small black circles) (c) the variation of capture probability with invader's strength in the empires comprising $n =$ 5, 10, 15 PPs as indicated in the legend (d) the corresponding variation of the average defence costs

As we are interested in the outcomes in terms of the invader's capture probability, *Pc*, we run our simulation for an exceptionally large number of invasions, namely, for N = 50; 000 to obtain a stable value for *Pc*. Since we assume the military strength is proportional to the domain size, the expansion of any PP incurs a defence cost while the expansion of the invaders incurs an invasion cost. Thus, we assign a cost proportional to the area covered by a domain during its expansion and, accordingly, for each run, we compute the outcome as well as the defence and invasion costs. Fig. 3(a) displays the cost profiles that are obtained in a typical event. From the defence cost incurred by the empire in a single event, we estimate the total defence cost and, similarly the total invasion cost for the invaders. Figs. 3(b) display the results for five random invasions over the empire comprising n = 5 PPs. The outcomes of each event are indicated by small circles at the top right corner of the orange bars; a red circle represent the victory of the empire while a black circle represents the victory of the invaders. Out of N = 50, 000 such simulation runs for each strength of the invaders, we compute the number of events n_c in which invaders capture the empire. This allows us to calculate the capture probability $P_c = n_c/N$. The profiles of P_c that are obtained for the empires with different number of PPs, namely $n =$ 5, 10, 15, are displayed in Fig. 3(c). The corresponding average defence costs incurred by the empire for invaders of different strength are also shown in Fig. 3(d).

From the graphical plots of Fig. 3(c), one can see that the capture probability increases with increasing strength (f_{gi}) of the invaders. However, an empire with increasing number density of PPs remains impregnable for slow (weak) invaders ($f_{\mathrm{gi}} < 0.5$). Even if the invaders are moderately strong ($0.5 \leqslant f_{\mathrm{gi}} < 1.0$), such an empire remains nearly invincible because the capture probability is negligibly small. However, if the invaders are intensely strong ($f_{\mathrm{gi}} > 1.0$), the capture probability increases. On the other hand, an empire with a small number of PPs remains vulnerable even for weak invaders. At the small time, if we look at the economy in terms of the defence costs, we see from Fig. 3(d) that the empire with a small number of PPs always incurs a very less amount of defence cost and it remain nearly constant irrespective of the strength of the invaders. In the empire with *n* = 15PPs, the defence costs increases with increasing strength of the invaders. All these results visualise us a rough picture as to how the increasing density of PPs affect the outcomes. It suggests that while an empire with increasing number density of PPs remains nearly invulnerable for invaders of any strength, it is difficult to withstand the extremely strong invaders with such a simple defence strategy.

To see how the invader's strength as well as the internal distribution of PPs affect the outcome, we run the simulation over a set of fixed empire whose internal maps remain constant for a fixed number of PPs. Unlike the previous case, here we do not consider a random distribution of PPs for each run; instead we construct a constant map with a particular n number of PPs (say, for n = 5) and we distribute them within a circular belt of radii $20 \leqslant r_b \leqslant 40$ around the emperor in such a way that each PP lies within the angle $\theta = 360°/n$. For a particular n, we construct five different maps and then perform $N = 50,000$ number of runs on each empire and for each particular strength of the invaders. This way, we perform the simulations on different empires with different strength of invaders and compute the corresponding capture probability. The results are graphically displayed in Fig. 4.

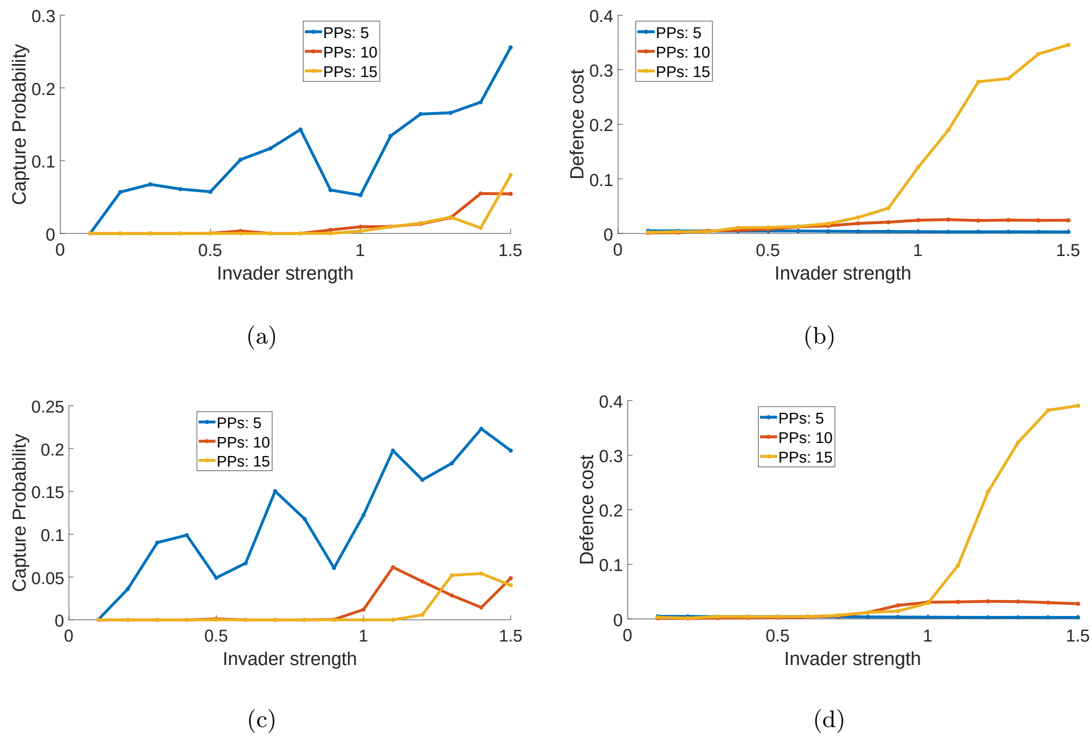
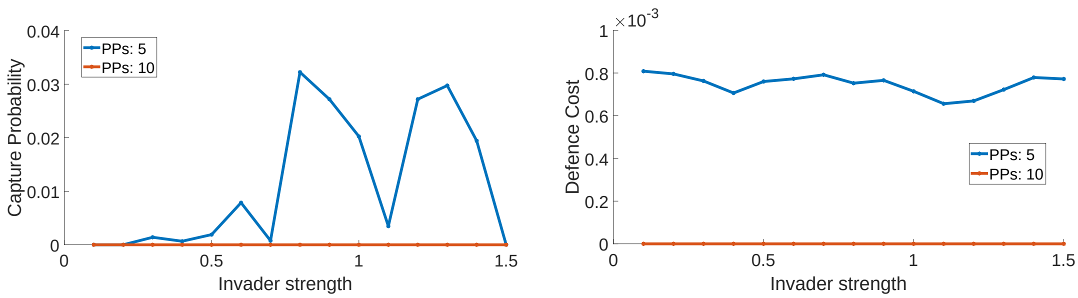


Figure 4: Simulation results for the empires with constant maps. The variation of invader's capture probability and average defence costs are displayed for two different configurations: (a), (b) correspond to the empires where PPs are distributed in a narrow belt $20 \leqslant r_b \leqslant 40$ while (c), (d) correspond to a relatively wider distribution of PPs in the belt $15 \leqslant r_b \leqslant 45$.

As one can see from the plots of Fig. 4(a), for the empire with $n = 5$ PPs, the variation of Pc with the strength of the invaders significantly differs from that of the previous one. How the distribution of PPs affects the outcome can also be seen from a comparison of the plots given in Figs. 4(a) and (c). It indicates that a small empire with a wider distribution of its PPs remains more irresistible than that of a narrow distribution. Empires with such a configuration cannot be easily captured just by enhancing the invader's strength.

This type of anomalous behavior, in fact, signifies how the competition and cooperation conspire together in more realistic problems of similar kind and germinate indeterminism as one of the inherent characteristics of such systems. This is, however, not a surprise because, as far as war is concerned, nonlinearity and unpredictability are fundamental, enduring elements [18] and it seems that, the sociophysical rules that are embedded in our model, engender the nonlinearity and unpredictability through the distribution of PPs. Apparently, the degree of complexity lies on how enormously one can arrange the PPs within the kingdom, simply because the consequences of wars in our model depend on both the sizes and positions of PPs on the empire.

From the plots of the defence costs [Figs. 4(b) and (d)], one can visualize that the empire with $n = 15$ PPs incurs a relatively higher defence costs against stronger invaders than that of $n = 10$, but still both of the empires have nearly the same probability of winning victory against moderately strong invaders. It is true that the defence costs together with the maintenance costs in a real empire will increase with increasing number of PPs. Thus, to sustain a balance between the economy and the survivability, the empire needs to design an optimal defensive structure so that the empire can withstand the invaders at minimal defence costs. To visualize a way as to how the layout of such an optimal defensive structure can be designed, we construct two empires comprising $n = 5$ and $n = 10$ PPs having their sizes $3 \leqslant r_p \leqslant 8$ and distribute them over constant maps. Performing simulations on these two maps, we find that the empire with $n = 5$ remains more irresistible as indicated by it's very low values of invader's capture probability [Fig. 5(a)] than that of the previous one [Fig. 4(a)]. Further, the variation of Pc with the invader's strength exhibits an anomalous behavior and indicates that the empire remains impregnable even for the intensely strong invaders (fgi = 1:5). The empire with $n = 10$ PPs, on the other hand, remains always impregnable irrespective of the strength of the invaders. One can also see from Fig. 5(b) that the empire with $n = 10$ incurs no defence cost for resisting the invaders. This is simply because the PPs lies more or less in the vicinity of the territory and, as they are comparatively bigger in size, they almost occupy the entire territorial region, thereby quickly destroy the invaders in a single war. In contrast to this, the empire with $n = 5$ PPs incurs a finite but nearly constant amount of defence costs. All these realise us a scenario as to how the great empires of antiquity withstood the foreign invaders of any strength. What is more is the impregnability of the small empires who, with a limited amount of military powers and with a limited amount of defence costs, could resist the invaders of any strength (the very low value of capture probability) if each PP have a considerable amount of military power (determined by their size) and if they lie close to the territory.



(a) (b)

Figure 5: The results on optimal con_gurations comprising $n = 5$ and $n = 10$ PPs. The variation of invader's capture probability and average defence costs are displayed for two different configurations: (a) and (b) correspond to the empires where PPs are distributed in a narrow belt $20 \leqslant r_b \leqslant 40$ while (c) and (d) correspond to a relatively wider distribution of PPs in the belt $15 \leqslant r_b \leqslant 45$.

IV. Concluding Remarks

We have shown here how the dynamics of sudden invasion on empires can be understood by constructing a simple model that considers the centrally organised system as a playground of a handful of sociophysical processes being triggered by foreign invasion. Under the action of invasion of varying strength, we have visualized how the tangled web of all processes leads to a vibrant dynamics and gives rise to nonlinearity and unpredictability. Although we have shown through our model how the rise and fall of ancient empires could be quantified as the probabilistic outcomes of short-time invasion process, similar model practices and in-silico experiments would equally be applicable for other similar systems of our biosphere where competing interaction among different species leads to diversity and where construction of a simple theory by taking into account the relevant sociophysical processes is cumbersome. Strictly speaking, we have simply shown here how, instead of constructing a concrete theory, one could proceed and design in-silico experiments to visualize the probabilistic outcomes as an emergent of interaction and competition governed by sociophysical rules. There are, indeed, many subtleties in the construction of both the defence and the invasion strategies. The coordination among the military powers, tactics of warfare, invasion through deception, maintenance of hidden military powers are some of the important factors that needs to be considered seriously in more realistic strategies. We hope our work would inspire researchers from diverse background to apply a similar approach in exploring processes and consequences of social phenomena that are inherently unpredictable by analytical means.

Declaration of interests

The authors declare that there is no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Measurement and Evaluation of Radio Signal Attenuation by Tree Foliage: A Case Study of Federal College of Forestry Jos, Nigeria

By Shaka O. S, J. T. Zhimwang, E. P. Ogherohwo & Frank, Lagbegha-Ebi Mercy

Federal University Lokoja

Abstract- This paper presents the measurement and evaluation of radio signal attenuation by tree foliage. Attenuation measurements were conducted using two disjoint antennas, one operating as a transmitter and the other operating as a receiver. The system was setup such that the two antennas are operated in a line-of-sight mode with random medium (in this case the foliage) positioned between the two antennas. At the transmitting section, the network interface was used to enable data to be forwarded from one network transmission out at the path to the receive antenna. The attenuation obtained was found to be dependent on many factors and parameters of the trees like geometry of measurement, (either trunk or canopy path), state of trees foliation, frequency, canopy thickness among others. The results revealed that attenuation under free space condition is insignificant at 20m and 40m either at 20m the maximum attenuation is 25dB and 28dB at 40m. The attenuation under free space increases as the distance is increase. The result also revealed that under the effect of single tree and vegetation, part of the transmitted signals are being absorbed and scattered by the tree elements such as the leaves, branches, twigs and trunks though signals are more absorbed and scattered under vegetation condition than single tree.

Keywords: *radio signal, attenuation, tree foliage, propagation and vegetation.*

GJSFR-A Classification: *DDC Code: 621.3845 LCC Code: TK6570.M6*

MEASUREMENTANDEVALUATIONOFRADIOSIGNALATTENUATIONBYTREEFOLIAGEACASESTUDYOFFEDERALCOLLEGEOFFORESTRYJOSNIGERIA

Strictly as per the compliance and regulations of:

Measurement and Evaluation of Radio Signal Attenuation by Tree Foliage: A Case Study of Federal College of Forestry Jos, Nigeria

Shaka O. S [α], J. T. Zhimwang [σ], E. P. Ogherohwo [ρ] & Frank, Lagbegha-Ebi Mercy [Ѡ]

Abstract- This paper presents the measurement and evaluation of radio signal attenuation by tree foliage. Attenuation measurements were conducted using two disjoint antennas, one operating as a transmitter and the other operating as a receiver. The system was setup such that the two antennas are operated in a line-of-sight mode with random medium (in this case the foliage) positioned between the two antennas. At the transmitting section, the network interface was used to enable data to be forwarded from one network transmission out at the path to the receive antenna. The attenuation obtained was found to be dependent on many factors and parameters of the trees like geometry of measurement, (either trunk or canopy path), state of trees foliation, frequency, canopy thickness among others. The results revealed that attenuation under free space condition is insignificant at 20m and 40m either at 20m the maximum attenuation is 25dB and 28dB at 40m. The attenuation under free space increases as the distance is increase. The result also revealed that under the effect of single tree and vegetation, part of the transmitted signals are being absorbed and scattered by the tree elements such as the leaves, branches, twigs and trunks though signals are more absorbed and scattered under vegetation condition than single tree.

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I. Introduction

The study of Signal propagation through vegetation is challenging due to nature of the vegetation either the vegetation density, measurement geometry or vegetation composition. In addition, vegetation is prone to environmental effects, such as wind, that often introduced dynamic variations in the channel (ITU-R, 2007). Trees attenuate the line-of-sight (Los) path or scatter the radiated wave, compelling it to follow different paths (multipath) to the receiver. Basically, waves may be diffracted, reflected and scatter along the propagation path, a situation that may degrade signal quality and reduce link distance. Also due to absorption of power, the radiated wave may be attenuated as it propagates through foliage to the receive antenna (Herben et al 2014). The level of attenuation is determined by the density of the tree elements (e.g. leave, twigs, and branches). Also, the attenuation is dependent on the frequency, depth of penetration into the tree, path geometry and leave state (either wet, dry, full-leaf or no-leaf) (Hashim et al, 2013).

In communication system, antennas are used to transmit information through the atmosphere from one point to another and radio wave propagation is very sensitive to the properties and effect of the medium located between the transmitting and the receiving antennas (Collin, 2013). There are often significant reductions in the level of the received signal if there are obstacles in the signal path (Pon et al, 2010). The interaction of radio wave with the obstruction reduces its received signal strength. For the fact that radio waves are very sensitive to obstacles, the existence of vegetation elements such as trees along the path of communication link have been found to play a great influence on the quality of service (Qos) in outdoor propagation is inevitable especially in suburban and rural areas, beside other factors from terrestrial objects that are diversified by buildings and mountains.

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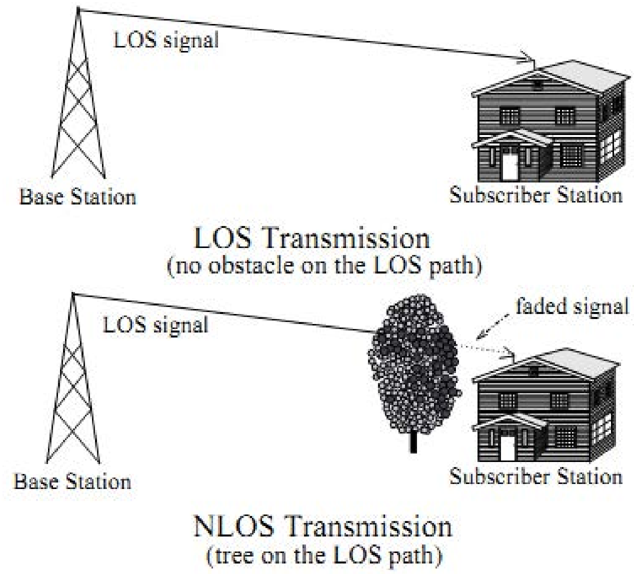

Figure 1: LOS versus NLOS Transmissions

Signal distortion and fading caused by the motion of tree foliage obstructing the line-of-sight path as shown in figure 1 translates into variations in the amplitude and phase response of the channel. Knowledge of the variations in the amplitude and phase response of the channel is critical in order to efficiently design a system that can compensate for these variations (ITU-R, 2012). Elements such as hills, buildings, or trees located on the path of the RF signal affect the way the signal propagates. Most of the changes occurring on the signal propagation paths can be explained in terms of reflection, diffraction, and scattering. Reflection occurs when the electromagnetic wave impinges the smooth surface of an object having a size much larger than the wavelength of the RF signal. Diffraction takes place when a very dense object with a sharp edge is located very near the LOS path. Waves bend over the sharp edge of the structure and reach the receiver (Michael, 2013). If the object is opaque and is in the line-of-sight path, then the only signal reaching the subscriber's antenna is the diffracted signal. This phenomenon is called shadowing since the signal reaches the receiver despite the total obstruction of the LOS signal. Scattering occurs when the electromagnetic wave impinges upon objects of size comparable to or shorter than the wavelength (Meng et al 2009; Meng et al 2010).

The aim of this study is to investigate the influence of trees (foliage) on radio signal at transmission frequency of 2,450MHz and to determine the dependence of propagation loss due to tree foliage. Most of the available researches in this subject area within the study location have been limited to few parameters of trees like depth (df) and operating frequency (f). The effects of other parameter of trees like leaves, twig and Branches on signal attenuation have been investigated with inadequate results. This has left a research gap which must be filled in order to get a more comprehensive technique. One of the ways to achieve this is to consider the effects of individual elements of trees.

The antenna (both transmitter and receiver) used in this study are horizontally polarized. The polarization state of the transmitted electromagnetic wave was affected by the vegetation that acts as a scatter (Perras and Bouchard, 2010). Some of the energy from the transmitted horizontal polarization state is transferred to the vertical polarization state by scattering or reflection of the transmitted electromagnetic wave. As shown in figure 2, the middle graph shows a horizontally polarized wave that could be generated by scattering or reflection of the vertically.

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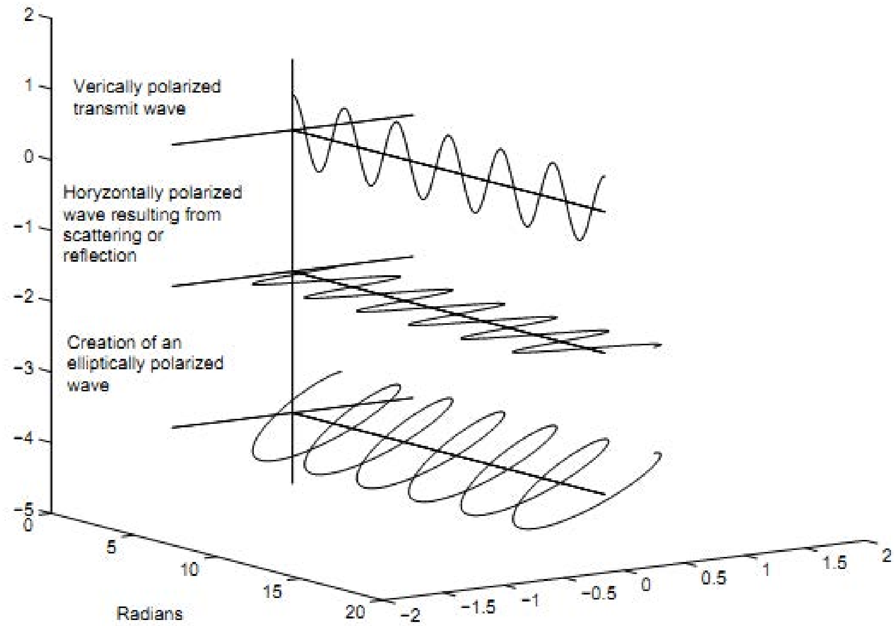

Figure 2: Creation of an Elliptically Polarized Wave (Δθ = π/5)

If the phase difference, Δθ, between the vertically polarized and horizontally polarized waves differs from $\frac{\pi}{2}$, k =0,1,2, ..., then these waves combine into an elliptically polarized wave, as shown by the bottom graph of Figure 2, when Δθ = $\frac{\pi}{5}$.

The polarization state of the RF signal resulting from the combination of the vertically polarized and horizontally polarized waves is function of the difference of phase, Δθ, but also of the amplitudes, E_{0x} and E_{0y}, of these two waves. The polarization state of the receive signal, based on these parameters, is given by

$$(\frac{E_y}{E_{0y}})^2 + (\frac{E_x}{E_{0x}})^2 - 2(\frac{E_x}{E_{0x}})(\frac{E_y}{E_{0y}})\cos(\Delta\theta) = sin^2(\Delta\theta) \quad (1)$$

Where E_x is the horizontally polarized component of the receive signal, E_y is the vertically polarized component of the receive signal. When Δθ = $\frac{\pi}{2} + 2k\pi, k = 0,1,2, \ldots.$, and $E_{0x} = E_{0y} = E_0$ then equation 1 become

$$(E_y)^2 + (E_x)^2 = (E_0)^2 \quad (2)$$

Each branch and each leaf on the RF signal propagation paths will affect E_{0x}, E_{0y}, and Δθ differently. This will result in a receive signal that can be modeled as the sum of an elliptically polarized signal and an unpolarized signal corresponding to noise. Both of these signals vary with time, especially when the wind blows through the trees and changes the structure of the foliage. The system devised in this research measures the temporal variation in the vertically polarized component of the receive signal. The effect of the leaves may change when the leaves are wet since the RF signal is in the 2450 MHz frequency range and water is known to absorb radio waves in that frequency range.

II. Methodology

The experiment was carried out at Federal College of Forestry Jos. Attenuation measurements are conducted using two disjoint antennas, one operating as a transmitter and the other operating as a receiver. The system was setup such that the two antennas are operated in a line-of-sight mode with random medium (in this case the foliage) positioned between the two antennas. At the transmitting section, the network interface was used to enable data to be forwarded from one network transmission out at the path to the receive antenna. Along the transmission path lays either a tree or group of trees, which obstructs the radio signal. The receiving section consisted of a Router networking device that was connected to a computer for data logging, a stabilizer for power regulation and an uninterruptible Power Supply (UPS) to provide emergency power whenever there was power disruption, which might eventually result in data loss. The Router was adjusted to a transmission frequency of 2450 MHz at sampling rate of 500ms. The receiver antenna was directional while the transmitting mast had no restriction. Investigation site captures ranges from 20m to 80m at intervals of 20 meters with a constant power of $\pm 19\ dB$ from the transmitters.

a) Free Space Path Loss Method

Free space path loss occurs as the signal travels from transmitter to receiver through space without any other effects attenuating the signal (Sharma and Singh, 2010). Free space path loss is dependent

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only on the distance from the transmitting antenna. In free space, the path loss increases by 20dB per decade. The equation used to determine free space follows (Idah, 2004)

$$PL_{FS}\ (dB) = 32.4 = 20\log(r)\ 20\log(f) \quad (3)$$

Equation (3) can be simplifies as

$$PL_{FS}\ (dB) = 32.4 = 20\log(r*f) \quad (4)$$

Where

PLFS = free space path loss

r = the distance from the transmitter (KM)

f = the frequency

b) Single Trees Path loss Method

Presented in this section are analysis of measured data and results for isolated trees which culminated into prediction of propagation loss parametric equation more suitable for isolated trees. The parametric equation incorporated both the free space loss and tree loss factors. The tree loss factor is incorporated in the technique to calculate for the increase in attenuation of the receive signal when radio waves propagates through a tree. The tree loss factor is incorporated in the method to calculate for the increase in attenuation of the received signal power when the receiver is placed behind a tree. The expression for the path loss from the transmitting antenna to a receiving antenna in the presence of a tree is written as (perras and Bouchard, 2010);

$$PL_{tree} = L_{FS} + L_t \quad (4)$$

Where;

PL_{tree} = Path loss in the presence of a tree.

L_{FS} = Free space loss.

L^t = Tree loss factor.

c) Method used for Simulating Group of Trees (Vegetation) Path Loss

An analysis was conducted over group of trees in the path of the transmitted radio signal based on the following steps.

Step 1: Evaluation of the Equivalent value of the total cross section of leaves and Branches of the vegetation canopy tree.

The equivalent value of the total cross section of leaves and branches of the vegetation canopy tree is given as

$$\sigma^{eq} = n_i(\sigma^{tl}) + \sum_{b=b1}^{n} n_b(\sigma^{tb}) \quad (5)$$

Where σ^{tl} equals the cross section of a single leaf, σ^{tb} is the cross section of a single branch, n_i is the number of leaves of a tree canopy, n_b is the number of branches of a vegetation canopy tree, and b = b1, b2, bn is the number of branches of different size categories. We first evaluated the mean value of cross section of a single leaf from

$$\langle \sigma^{tb} \rangle = \int_0^{2\pi} \int_{-\frac{\pi}{2}}^{\frac{\pi}{2}} \sigma^{tb}(\theta,\phi)\, f\theta^1(\theta)\, f\phi^1(\phi) \cos\theta\, d\theta\, d\phi \quad (6)$$

The leaf cross section is averaged over angles ϕ and θ with $0 \le \theta < 2\pi$, $f\phi^1(\phi) = 1$, $-\frac{\pi}{2} \le 0 < \frac{\pi}{2}$, and $f\theta^1(\theta) = 1$. Therefore equation 6 becomes:

$$\langle \sigma^{tl} \rangle = \int_0^{2\pi} \int_{-\frac{\pi}{2}}^{\frac{\pi}{2}} \sigma^{tl}(\theta,\phi) \cos\theta\, d\theta\, d\phi \quad (7)$$

Step 2: evaluation of the Free Space loss.
The free space loss is given as;

$$L_{fs} = \frac{(4\pi f r)^2}{C^2 D_t D_r} \quad (8)$$

Where r is the distance from the transmitting antenna to the receiving antenna (in meters), f is the frequency of transmission (in MHz), C is the velocity of light in air, D_t is the directivity gain of the transmitting antenna, and D_r is the directivity gain of the receiving antenna. Multiply the result gotten from the free space loss and result from attenuation of the mean values of the total cross section per unit volume of the vegetation canopy tree, either

$$L_{fs} = \frac{(4\pi f r)^2}{C^2 D_t D_r} \times 4[n_i(\sigma^{tl}) + \sum_{b=b1}^{n} n_b(\sigma^{tb})] \quad (9)$$

Therefore, the vegetation canopy tree path loss converted to decibel (dB) is given as;

$$PL_{veg} = 10\log\left\{\frac{(4\pi f r)^2}{C^2 D_t D_r} \times 4[n_i(\sigma^{tl}) + \sum_{b=b1}^{n} n_b(\sigma^{tb})]\right\} \quad (10)$$

III. Results

In this section, results from field measurement under free space condition and that where the Radio wave is obstructed by a single tree and group of trees (vegetation) are presented.

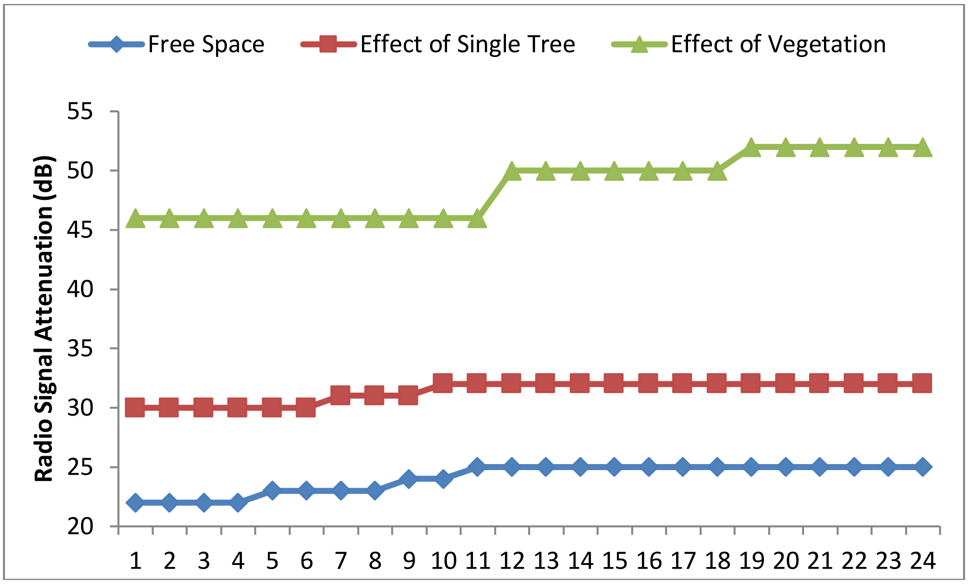

Figure 3: Radio signal attenuation under Free Space Condition, behind a Tree, and inside vegetation at a distance of 20m

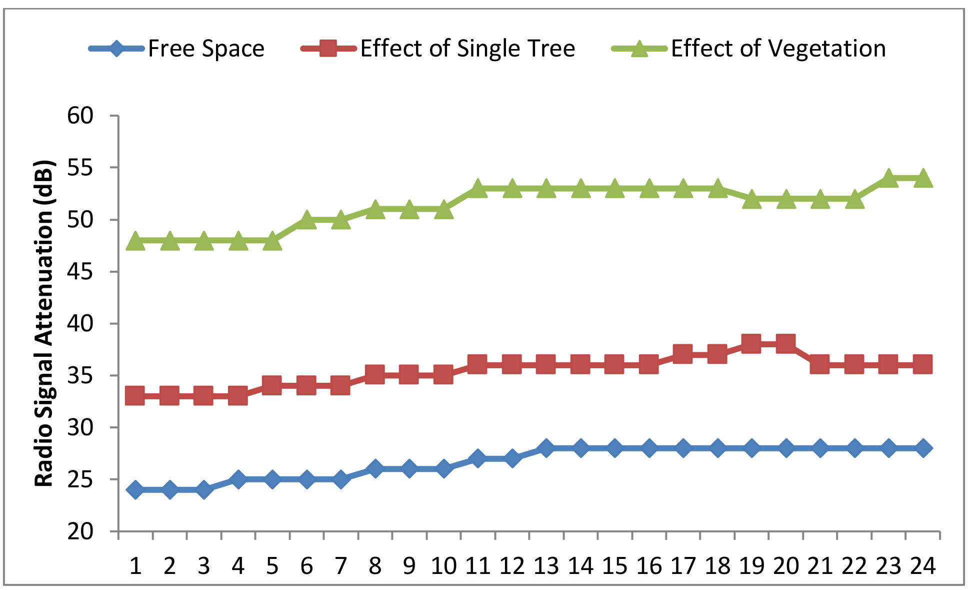

Figure 4: Radio signal attenuation under Free Space Condition, behind a Tree, and inside vegetation at a distance of 40m

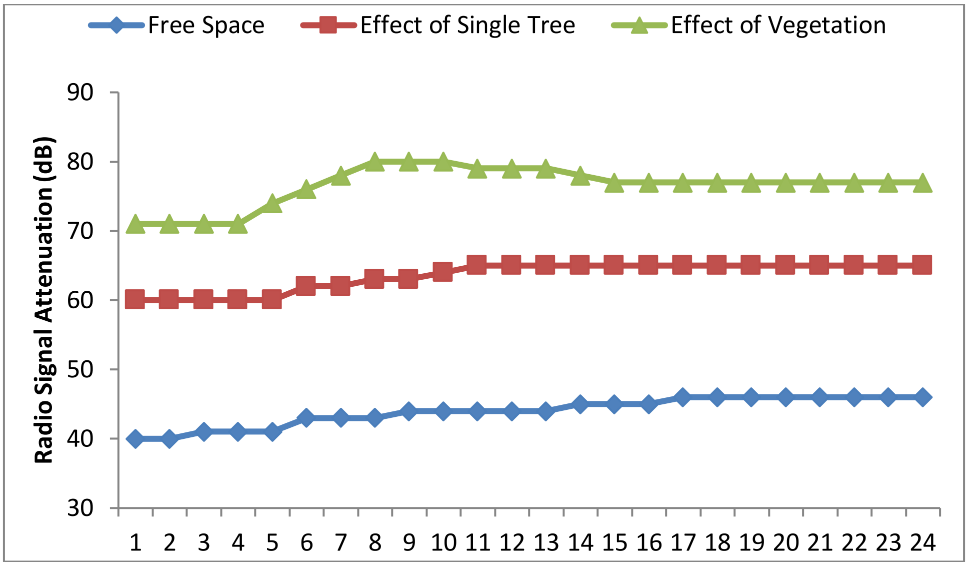

Figure 5: Radio signal attenuation under Free Space Condition, behind a Tree, and inside vegetation at a distance of 60m

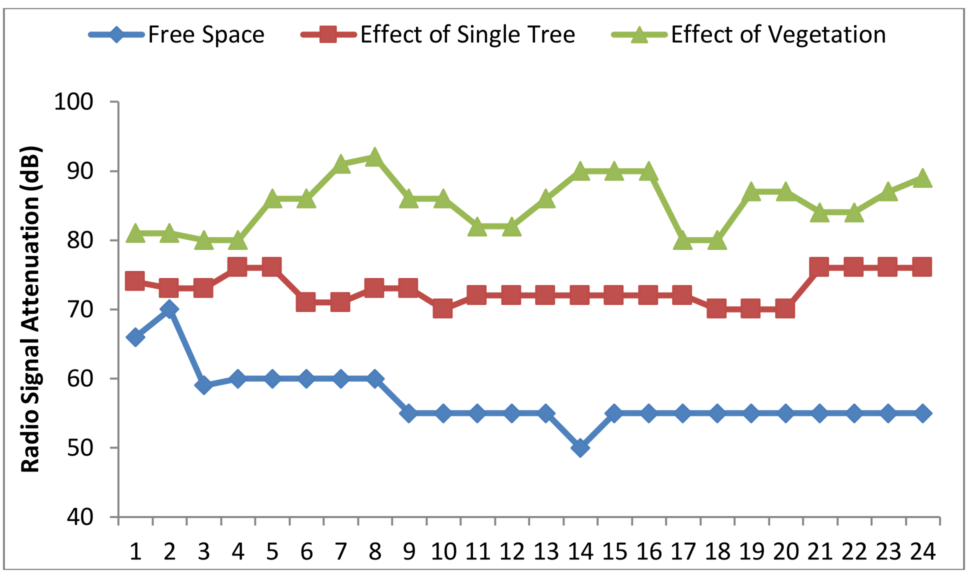

Figure 6: Radio signal attenuation under Free Space Condition, behind a Tree, and inside vegetation at a distance of 80m

VI. Discussions

Figure 3, figure 4, figure 5 and figure 6 presents the radio signal attenuation under Free Space Condition, behind a Tree, and vegetation at a distance of 20m, 40m, 60m and 80m respectively. Figure 3 and figure 4 shows that attenuation under free space condition is insignificant at 20m and 40m either at 20m, the maximum attenuation is 25dB and 28dB at 40m. The attenuation under free space increases as the distance is increase as shown in figure 5 and figure 6. The result further shows that under the effect of single tree and vegetation, part of the transmitted signals are being absorbed and scattered by the tree elements such as the leaves, branches, twigs and trunks. As it can be seen from the results, the signals are more absorbed under vegetation condition than single tree. This is in agreement with the reports by Zhimwang et al (2021) and Ndzi et al (2012) which stated that attenuation under vegetation is more pronounce than that of the single tree.

V. Conclusion

The measurement and evaluation of radio signal attenuation by tree foliage was conducted in the federal college of forestry Jos. The attenuation was found to be dependent on many factors and parameters of the trees e.g. Geometry of measurement, (either trunk or canopy path), state of trees foliation, frequency, canopy

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thickness among others. The results revealed that attenuation under free space condition is insignificant at 20m and 40m either at 20m the maximum attenuation is 25dB and 28dB at 40m. The attenuation under free space increases as the distance is increase. The result also revealed that under the effect of single tree and vegetation, part of the transmitted signals are being absorbed and scattered by the tree elements such as the leaves, branches, twigs and trunks though signals are more absorbed and scattered under vegetation condition than single tree.

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Optimization and Matching of Electric Vehicle Wireless Charging based on Two-Port Network

By Fei Shao

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Keywords: wireless charging; electromagnetic coupling resonance; two-port network; neumann formula; simulated annealing algorithm.

I. Restatement of the Problem

a) Background

Electric vehicles are favored by consumers because of their advantages over traditional fuel cars. However, the existing wired charging method of ELECTRIC vehicles is complicated in operation and has safety risks. Therefore, the adoption of wireless charging method to charge electric vehicles quickly, safely and conveniently has become the goal pursued by the electric vehicle industry.

Currently, many manufacturers are developing wireless charging technology for electric cars. When the electric car parked in a specific location, power grid through underground launch mechanism of high frequency alternating magnetic field to wireless charging of electric cars, has the advantages of convenient operation, small space occupied, but there are many electric car manufacturers at present, proprietary models must use the special-purpose wireless charging equipment, this causes the waste of electricity. Therefore, it is of great significance to optimize the non-on-board part of wireless charging to make the connectivity between wireless charging equipment and electric vehicles of different manufacturers.

b) Restatement of the Problem

Wireless charging system is composed of vehicle-mounted part and non-vehicle-mounted part. The on-board part consists of an RLC circuit and a load, and the non-on-board part consists of a power supply and another RLC circuit. Two inductance elements, L_1 (transmitting coil inductance, also known as matching impedance) and L_2 (receiving coil inductance), transmit electrical energy by coupling to produce a magnetic field. It can be assumed that the mutual inductance between the two coils depends only on distance.

A lab conducted 10 experiments to study the transmission efficiency of wireless charging. Known wireless charging vehicle part and ground part at different distances of 10 experimental data. (The experiment was carried out under the condition that the vertical projection of the transmitting and receiving coils overlapped perfectly.) The parameters of the wireless charging ground launcher used in the experiment and the electromagnetic-mechanical adjustable range of the experimental equipment launcher are known.

Problem 1: Under the condition of complete resonance of transmitting and receiving coils, mathematical models of transmitting frequency, matching impedance and radio energy transmission efficiency were established to calculate the power transmission efficiency of 10 experiments of wireless charging.

Problem 2: Due to the design of the electric vehicle itself, the distance between the on-board part of its wireless charging and the ground may be any value within the regulation. The mathematical models of transmitting frequency, matching impedance, distance between two coils and radio energy transmission efficiency are established by modifying the mathematical model of question 1. When the distance between the two coils in the first experiment was changed from 100mm to 150mm, 200mm and 250mm, the power transmission efficiency of wireless charging was recalculated and compared.

Problem 3: Previous studies have shown that transmission efficiency can be improved by changing transmission frequency and matching impedance. In the first experiment (the distance between the two coils is 100mm), can transmission efficiency be maximized by adjusting transmission frequency and matching impedance value? What's the maximum?

Problem 4: When the electric vehicle stops for wireless charging, it is difficult to ensure the complete vertical projective overlap between the transmitting coil and the receiving coil, and there will always be more or less deviation. The radius of the coil is R, and the center of

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the receiving coil (h away from the transmitting coil) deviates a (mm) from the positive direction of the X axis. Continuing the research in question 3, please calculate the maximum value of A under the premise that the maximum transmission efficiency is greater than 80% when h is 100mm from the ground vertically.

II. Problem Analysis

In order to establish the energy transmission model between the transmitting coil and the receiving coil in wireless charging, calculate the power transmission efficiency and optimize the coil design, the four questions given by the topic are analyzed.

a) *Analysis of Problem 1*

It is clear that the circuit is in full resonance, that is, the transmitting frequency is the resonant frequency of the RLC oscillation circuit. In order to calculate the power transmission efficiency of several experiments, a linear equation containing coupling coefficient and circuit quality factor should be established based on kirchhoff equation and grid analysis theory. After solving the linear equation, the power transmission efficiency can be obtained by substituting the experimental parameters.

b) *Analysis of Problem 2*

Question 2 On the basis of question 1, it is necessary to further explore the influence of distance between two coils on power transmission efficiency. In view of the distance only affects the mutual inductance between the two coils, but does not affect the circuit quality factor, capacitance and inductance value. Therefore, this question only explores the relationship between mutual inductance and distance. In order to get the relationship between the two, it is necessary to derive the relationship between mutual inductance and distance based on electromagnetic theory, then determine the parameters by fitting, and substitute the obtained relationship into the model obtained in question 1 to calculate the electric energy transmission efficiency.

c) *Analysis of Problem 3*

In the third problem, it is necessary to adjust the transmission frequency and matching impedance on the basis of the fixed distance between the two coils to maximize the transmission efficiency. Using the model of problem 1, it can be seen that the matching impedance affects the resonant frequency of the circuit, thus affecting the quality factor of the circuit, and the transmission frequency affects the calculation of parameter A, both of which will affect the power transmission efficiency. Considering that the range of transmission frequency and matching impedance given by the problem is not large, the ergodic method can be adopted to find the optimal solution.

d) *Analysis of Problem 4*

The fourth problem needs to find the maximum value of horizontal offset under the condition that the maximum transmission efficiency is greater than 80% on the basis of the fixed vertical distance between the two coils. Considering that distance will affect mutual inductance between two coils, horizontal offset will cause mutual inductance change. Referring to the models in question 1 and 3, it can be seen that the transmission frequency, matching impedance and horizontal offset distance need to be adjusted to find the maximum power transmission efficiency. Due to the large number of optimization variables and large search space, simulated annealing algorithm can be used for global optimization to find the maximum horizontal offset distance that meets the requirements.

III. Problem Analysis

Due to the complexity of the energy coupling transfer process of the actual electromagnetic system and the limited data provided by the topic, the following hypotheses are proposed in order to better understand the physical nature of the problem and simplify the model:

1. The circuit is a lumped parameter circuit, that is, the voltage between any two endpoints of the circuit and the current flowing into any device terminal knob are completely determined, independent of the geometric size and spatial position of the device.
2. Electromagnetic coupling in a circuit occurs only between the transmitting coil and the receiving coil.The energy transfer losses between the power supply and the transmitting coil, the receiving coil and the load, and the two RLC circuits are negligible, and their coupling coefficient is considered to be 1.For mutual inductance between two coils, mutual inductance is only related to the distance between them.
3. For coils, it is considered that the inductance does not change significantly at the frequency set in the topic. The coil is regarded as an ideal hollow solenoid structure without considering the shape and edge effect of the coil. The influence of the distributed capacitance of the coil on the model is not considered.
4. For the receiving coil, the resistance is considered to be 0.2.Ω Generally speaking, the resistance of the solenoid wound by copper wire is less than 1. The solenoid turns of the general wireless charging device is 10 turns, and the calculated resistance is about 0.1~0.2.$\Omega\Omega$ This paper discusses this problem at the end.

IV. SIGN EXPLANATION AND NOUN EXPLANATION

Table 1: Symbol description

Symbol	Instructions	Unit
L_1	Transmitting inductance	H
L_2	Inductance of receiving coil	H
Q_1	Transmitting loop RLC circuit quality factor	1
M	Mutual inductance	H
j	Imaginary unit	There is no
k_{12}	The coupling coefficient	1
η	Power transmission efficiency	1
t_0	Initial temperature in simulated annealing algorithm	1
k_t	Probability coefficient of temperature	1

(Note: Unlisted symbols and duplicate symbols are subject to their occurrence.)

V. THE ESTABLISHMENT AND SOLUTION IF THE MODEL

a) *Problem 1: two-port network model of wireless charging*

i. *Model preparation*

In order to study the electromagnetic energy transmission process between transmitting loop and receiving loop, this paper needs to model the electromagnetic energy distribution of transmitting loop, receiving loop and intermediate transmission process. Before modeling, some basic laws of circuit theory and basic conclusions of common circuits are introduced.

1. *Lumped hypothesis:* the circuit can be divided into lumped parameter circuit and distributed parameter circuit according to the relationship between the geometrical dimension of the actual circuit and the working signal wavelength. $\mathrm{d}\lambda$ The lumped parameter circuit corresponds to the circuit satisfied, that is, the size of the device is far less than the wavelength corresponding to the normal operating frequency of the circuit. $\mathrm{d} \ll \lambda$In lumped parameter circuits, the concepts of voltage and current can be used to describe the circuit without the distribution of electric and magnetic fields along the circuit.Generally speaking, the circuit whose operating frequency is less than 20MHz can be called the low-frequency circuit, and the low-frequency circuit applies to lumped hypothesis.
2. *Kirchhoff's current law:* At any moment in a lumped parameter circuit, assuming that the current entering a node is positive and the current leaving the node is negative, the algebraic sum of all currents involved in the node is equal to zero. That is, the current flowing into the node must equal the current flowing out of the node. Kirchhoff's current law reflects the conservation of current.
3. *Kirchhoff's voltage law:* in lumped circuit, the algebraic sum of the voltages of each branch is equal to zero at any time, along any closed path. Kirchhoff's voltage law reflects the conservation of energy.
4. Sinusoidal and phasor method: in actual AC, voltage and current often change in sinusoidal way, called as the amount of sinusoidal, which is called the effective value of the sinusoidal, is the circular frequency of the sinusoidal, is the initial phase. $\mathrm{i(t)} = \sqrt{2}\mathrm{I}\cos(\omega \mathrm{t} + \varphi)\,\mathrm{I}\omega\varphi$ For circuit contains only the linear element of linear circuit (i.e., passive component contains only resistor, inductor and capacitor circuit), the circuit equations can be expressed as the linear ordinary differential equation, the solution for convenient, often think of sine using euler's formula is expressed as the plural, namely the definition, which for the plural unit (avoid confused with current without using), called the phasor. $\dot{\mathrm{I}} = \mathrm{I}\angle\varphi = \mathrm{I}e^{j\varphi}\mathrm{j}\mathrm{i}\mathrm{i}\dot{\mathrm{I}}$ Using the concept of phasor, differential equation can be transformed into algebraic equation, which is easy to solve.
5. *Capacitive reactance and inductive reactance:* when applying the phasor method to solve the circuit, the inductance and capacitance can be defined as impedance, following the definition of resistance, to facilitate the solution.$\dot{\mathrm{U}}/\dot{\mathrm{I}}$ For the inductance, by definition, it is called the inductive reactance of the inductance, whose dimension is (ohm); $\dot{\mathrm{U}} = \mathrm{j}\omega\mathrm{L}\dot{\mathrm{I}}\mathrm{X_L} = \omega\mathrm{L}\Omega$ For capacitance, by definition, it is called the capacitance reactance, which has dimension (ohm). $\dot{\mathrm{U}} = \frac{1}{\mathrm{j}\omega\mathrm{C}}\dot{\mathrm{I}}\mathrm{X_C} = -1\,/\,(\omega\mathrm{C})\Omega$
6. *Two-port network:* the actual circuit is generally complicated. In order to understand the input and output functions of the circuit system more clearly, Brisig, 1921[3]It is pointed out that a two-port

network composed of linear elements can always be described by a set of equations regardless of its internal structure and parameters. The internal structure of the circuit is regarded as a black box, and the function of the system is studied through the relationship between different inputs and outputs.

ii. *Model establishment*

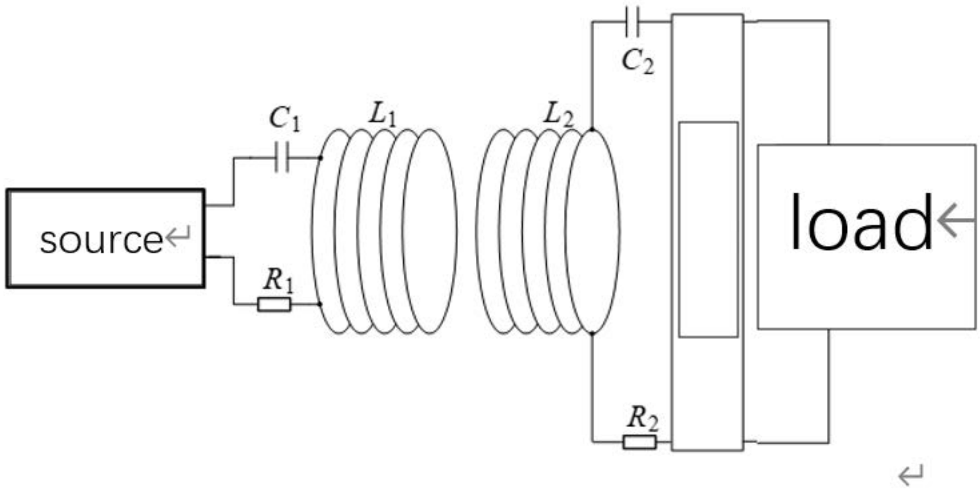

Fig. 1: Structural equivalent diagram of wireless charging system

As shown in Figure 1, the wireless charging process of ev is simplified into vehicle-mounted part and non-vehicle-mounted part, wherein the vehicle-mounted part is composed of an RLC circuit and load, and the non-vehicle-mounted part is composed of power supply and an RLC circuit.

First, the interaction between two inductors is dealt with. Consider the simplified circuit as shown

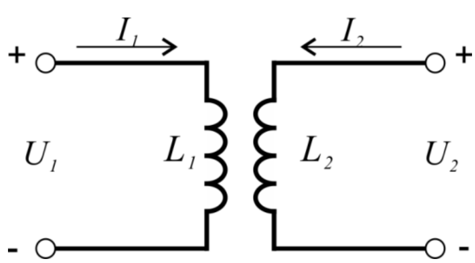

Fig. 2: Interaction circuit between inductors

Using Kirchhoff's voltage law, we know that

$$U_1 = L_1 \frac{di_1}{dt} + M \frac{di_2}{dt}, U_2 = L_2 \frac{di_2}{dt} + M \frac{di_1}{dt}$$

Perform the identity transformation, then

$$U_1 = (L_1 - M)\frac{di_1}{dt} + M\frac{d(i_1 + i_2)}{dt}$$

$$U_2 = (L_2 - M)\frac{di_2}{dt} + M\frac{d(i_1 + i_2)}{dt}$$

Thus, the circuit shown in Figure 2 can be transformed into a T-shaped equivalent circuit, as shown in Figure 3[4].

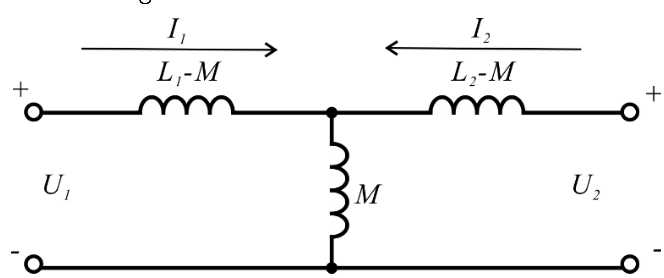

Fig. 3: T-shaped equivalent circuit

In this case, it is necessary to add elements such as resistors and capacitors on the basis of the t-shaped equivalent circuit. For wireless charging of electric vehicles, there are four common capacitive connection modes, namely SS (primary series-secondary series), SP (primary series-secondary parallel connection), PS (primary series-secondary series connection), and PP (primary series-secondary parallel connection).[1].In this case, the load resistance is large, and only THE SP connection mode has a strong load capacity. Therefore, the SP connection mode is selected, and the equivalent circuit obtained is shown in Figure 4. Where are resistors in RLC circuit respectively, and are circuit load. $R_1, R_2 R_L$

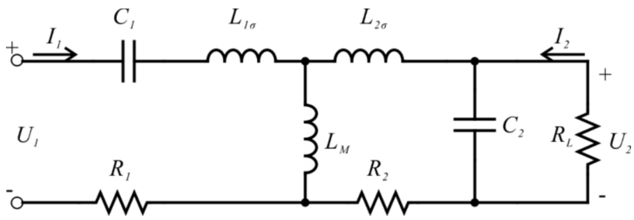

Fig. 4: Two-port network model of wireless charging system

Based on the foregoing results, it can be known that. Define the coupling coefficient, the ratio of turns, the ratio of effective turns. Specify the inflow direction as the current reference direction.$L_{1\sigma} = L_1 - M, L_{2\sigma} = L_2 - M,\ L_M = Mk_{12} = \frac{M_{12}}{\sqrt{L_1L_2}}n = N_2/N_1\, n_e = L_2/L_1$ Using Kirchhoff's law, it can be deduced that (equality in a matrix is phasor, the same as below)V_1, I_1

$$\begin{cases} V_1 = a_{11}V_2 + a_{12}(-I_2) \\ I_1 = a_{21}V_2 + a_{22}(-I_2) \end{cases}$$

Written in matrix form, then

$$\begin{bmatrix} V_1 \\ I_1 \end{bmatrix} = \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix} \begin{bmatrix} V_2 \\ -I_2 \end{bmatrix}$$

Call the coefficient matrix the A-parameter matrix. For the circuit shown in Figure 4, the calculation can be obtained

$$\begin{cases} a_{11} = \omega^2 MC_2 + \frac{1}{M}\left(\frac{C_2}{C_1} - \omega^2 L_1C_2 + j\omega R_1C_2\right)\left(\frac{R_2}{j\omega} + L_2 - \frac{1}{\omega^2 C_2}\right) \\ a_{12} = -j\omega M + \frac{1}{M}\left(L_1 + \frac{R_1}{j\omega} - \frac{1}{\omega^2 C_1}\right)(j\omega L_2 + R_2) \\ a_{21} = \frac{j\omega}{M}\left(L_2C_2 + \frac{R_2C_2}{j\omega} - \frac{1}{\omega^2}\right) \\ a_{22} = \frac{1}{M}\left(L_2 + \frac{R_2}{j\omega}\right) \end{cases}$$

The following is the calculation of power transmission efficiency, which is defined as

$$\eta = \left|\frac{V_2I_2}{V_1I_1}\right| = \left|\frac{V_2}{V_1}\right|\left|\frac{I_2}{I_1}\right|$$

Define voltage transfer coefficient, current transfer coefficient, then. By using the definition of parameter A, it can be known that$K_V = |V_2/V_1| K_I = |I_2/I_1| \eta = K_V K_I$

$$K_V = \left|\frac{V_2}{a_{11}V_2 + a_{12}(-I_2)}\right| = \left|\frac{1}{a_{11} + a_{12}/R_2}\right|$$

$$K_I = \left|\frac{I_2}{a_{21}V_2 + a_{22}(-I_2)}\right| = \left|\frac{-1}{a_{22} + a_{21}R_2}\right|$$

The power transmission efficiency can be obtained by substituting the calculation result of parameter A before.

iii. *Model solution and results*

According to problem 1, the circuit is in complete resonance state during the experiment, that is, the transmitting loop and receiving loop are in resonance state at this time, then the capacitance can be calculated. Based on the above discussion, the solution process can be defined as follows: $2\pi f_0 = \frac{1}{\sqrt{LC}}$

1. *Step 1:* calculate the coupling coefficient and quality factor according to the experimental data. $k_{12}Q$
2. *Step 2:* solve A parameter matrix.
3. *Step 3:* calculate the voltage transmission coefficient and current transmission coefficient, and then calculate the power transmission efficiency. η

To calculate efficiency, you also need to determine the receiving loop coil resistance. In general,. Refs $R_2 R_2 \ll R_L$[1] In this paper, the sensitivity analysis is carried out.$R_2 = 0.2\Omega$ Matlab is used for programming calculation, and the calculation results are shown in Table 2.

Table 2: Calculation results of Problem 1

The serial number	Two coil distance h(mm)	Transmitting inductance L1 (mu H)	Inductance of receiving coil L2 (mu H)	Mutual inductance coil M12 mu (H)	Transmission efficiency %
1	100	162.21	163.6	63.83	87.90
2	125	161.46	163.04	51.49	86.47
3	150	161.36	163.15	40.17	84.17
4	175	161.75	162.87	33.24	82.73
5	200	161.79	162.96	28.24	80.06
6	225	161.59	163.15	26.17	78.17
7	250	161.53	163.25	24.78	76.82
8	275	161.35	162.72	22.12	74.52
9	300	162.61	163.74	21.25	73.61
10	325	161.39	163.26	20.53	71.93

b) Problem two: model of mutual inductance varying with distance

i. *Model establishment*

The change of the distance between the two coils will directly affect the mutual inductance, and then affect the power transmission efficiency through the coupling coefficient. As shown in FIG. 5, the axis is taken as the vertical axis, and the two coils are apart and there is no deviation in the plane.$zhx-y$The radius of each coil is P and Q are points on each coil. $r=35mm$Let the turns of the two coils be respectively and.$N_1 N_2$

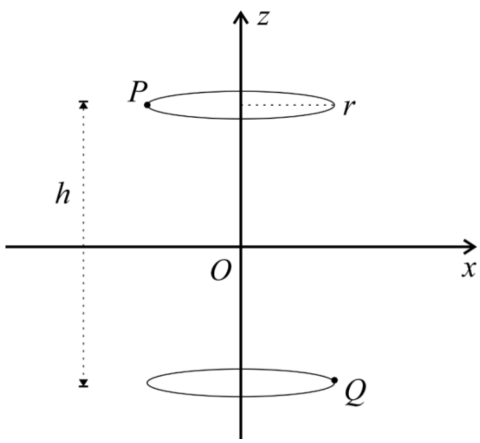

Fig. 5: Geometric diagram of the vertical distance of two coilsh

The cylindrical coordinate system is adopted, the coordinate of point P is, the coordinate of point Q is, then the distance between two points satisfies$(r_1,\theta_1,z_1)(r_2,\theta_2,z_2)\mathcal{D}$

$$\mathcal{D}=[2r^2-2r^2\cos(\theta_2-\theta_1)+h^2]^{\frac{1}{2}}$$

Use the Neumann formula[5], mutual inductance between coaxial circular coils can be expressed as

$$M=\frac{\mu_0 N_1 N_2}{4\pi}\oint_{l_1}\oint_{l_2}\frac{d\vec{l_1}\cdot d\vec{l_2}}{\mathcal{D}}$$

Where respectively represent the circumference of the two coils, respectively are the elements on the coils. $l_1, l_2 d\vec{l_1}, d\vec{l_2}$ Using Figure 5, can be obtained

$$M=\frac{\mu_0 N_1 N_2}{4\pi}\int_0^{2\pi}d\theta_2\int_0^{2\pi}\frac{r^2\cos(\theta_2-\theta_1)d\theta_1}{\sqrt{2r^2-2r^2\cos(\theta_2-\theta_1)+h^2}}$$

Plug in the parameters and use the computer to solve the integral. From the integral form, should be inversely proportional to, this conclusion conforms to physical intuition. Mh The resulting curve after plugging in the parameters is shown in the figure. $h-M$

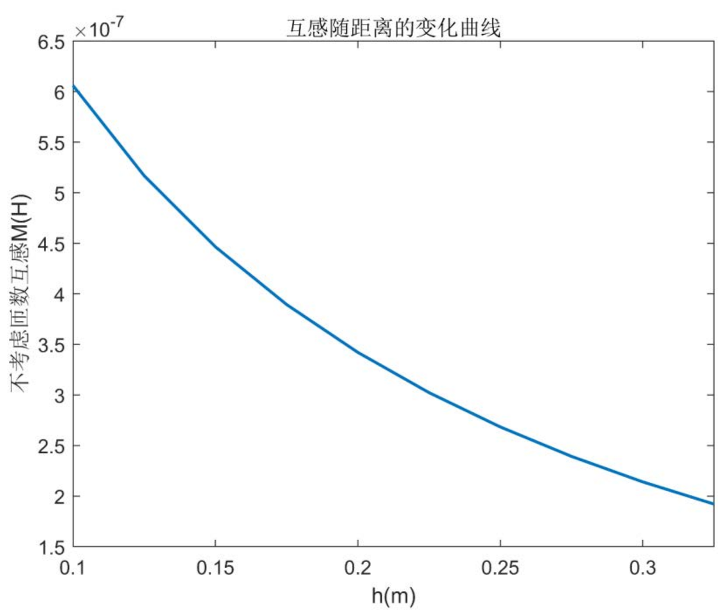

Fig. 6

ii. *Model calculation*

The model obtained based on Question 1 and the mutual-inductance model established above varies with distance. In order to calculate the power transmission efficiency when different distances are changed under the first experimental condition, the solving process is formulated as follows:

1. *Step1:* use integral formula, substitute in known experimental parameters, calculate. M_{calc}
2. *Step2:* Fit and calculate. $M_{calc}M_{Question}N_1 N_2$

3. *Step3:* use the obtained model and substitute it into the model in the first question to set parameters and calculate the electric energy transmission efficiency. $N_1N_2M_{calc}$

iii. *The model results*

In this paper, the distance provided by the experiment is firstly used to calculate the theoretical mutual inductance value without considering the number of turns. The results are shown in Table 3. M_{calc}

Table 3: Theoretical mutual inductance values calculated without considering the number of turns

H/mm distance	100	125	150	175	200	225	250	275	300
Theoretical mutual inductance without considering the number of turns $M_{calc}/10^{-7}H$	6.060	5.168	4.465	3.894	3.421	3.023	2.684	2.393	2.140

In order to determine the number of turns, this paper makes a linear fitting between the above obtained values and the measured values. $N_1N_2M_{calc}$ The result is shown in Figure 6.

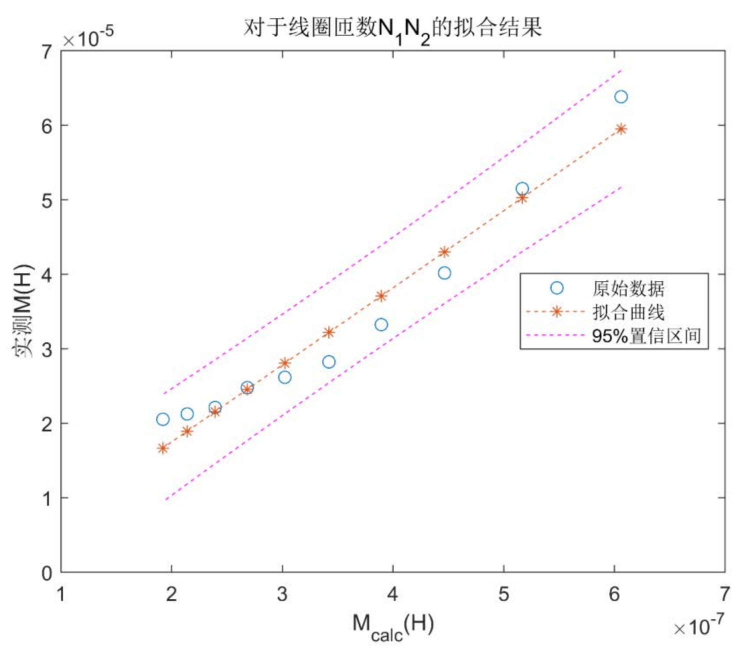

Fig. 6: Fitting results for the number of turns of the coil N_1N_2

The results show that the expression obtained by fitting is, i.e., given that integer should be taken and 103 is prime, this paper selects the following formula in the subsequent calculation. $y = 103.5x - 3.223 \times 10^{-6} N_1N_2 = 103.5 N_1N_2 N_1N_2 = 104$

The relevant information of the fitting is shown in Table 4. It can be seen from the table that the fitting effect is very good. Therefore, the model in this section can be used to describe the relationship between mutual inductance and distance.

Table 4: Fitting evaluation

And variance (SSE)	R^2	Adjusted R^2	Root mean square (RMSE)
8.283×10^{-11}	0.9562	0.9508	3.218×10^{-6}

Finally, according to the requirements of the question, we calculated the results of the distance of 100mm, 150mm, 200mm and 250mm in the first experiment. See Table 5.

Table 5: Calculation results of question 2

H/mm distance	100	150	200	250
Transmission efficiency (%)	87.90	86.02	83.35	79.61

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c) *Problem three: emission frequency and matching impedance optimization model*

i. *Model establishment*

Under the condition of constant distance, mutual inductance remains constant. According to the theoretical analysis of problem 1, the change of can directly affect the parameter matrix A, and then affect the power transmission efficiency. L_1, f Therefore, it is possible to improve transmission efficiency by adjusting transmission frequency and matching impedance.

In view of the complex form of parameter matrix A, it is very tedious and unnecessary to work out the relationship between energy transmission efficiency, transmission frequency and matching impedance analytically. Considering that the range of change is not large, we can take the way of traversal and use the computer to search for the most efficient point. f, L_1

ii. *Model calculation*

Based on the mathematical model obtained in question 1 and combined with the experimental data of the first experiment, the solving process is formulated as follows.

1. *Step 1:* use the A parameter matrix obtained in question 1 to define relevant variables and substitute in parameters.
2. *Step 2:* Set the search step length and traverse all possible combinations to obtain the energy transmission efficiency matrix. $(f, L_1)\eta_{all}$
3. *Step 3:* find the maximum value and find the maximum point accordingly. η_{all}

iii. *The model results*

Matlab was used to search for the maximum efficiency, and the search step of transmitting frequency was set to 10Hz, and the search step of matching impedance was set to 0.1μF. The traversal results are shown in Figure 7. As can be seen from the figure, the maximum power transmission efficiency does exist. Detailed calculation results show that the maximum point corresponds to F =29.73kHz,L_1=147.3μF, the maximum transmission efficiency is 89.32%.

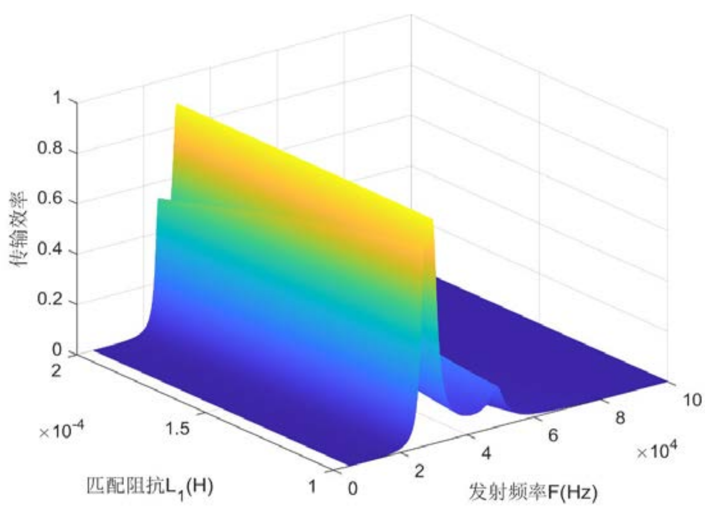

Fig. 7: Results of traversing search for maximum transmission efficiency

Considering that step size setting may affect the traversal search results, this paper sets different search step sizes for emission frequency and matching impedance respectively, and observes the corresponding output results. The calculation results are shown in Table 6.It can be seen from the table that the results obtained under the search step set above are stable, and the search step set above is reasonable.

Table 6: Maximum transmission efficiency obtained at different search steps

Transmitting frequency search step (Hz)	5000	1000	100	50	10	1
Emission frequency search step (μF)	50	10	1	5	0.1	0.01
Maximum power transmission efficiency (%)	89.07	89.07	89.32	89.32	89.32	89.32

d) *Problem four: maximum horizontal migration model*

i. *Model establishment*

Consider the dislocated coil model shown in Figure 8.The centers of the coils are at (0,0,0) and (0,a,h) respectively. By taking any point P and Q on the two coils and using the rectangular coordinate system, the coordinates of the two points can be expressed as P and Q respectively. .$(r\cos\theta_1, r\sin\theta_1, 0)(r\cos\theta_2 + a, r\sin\theta_2, h)$

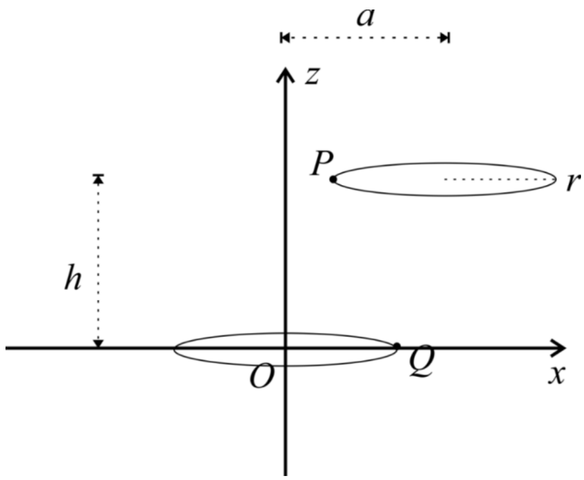

Fig. 8: Misaligned coil model

The distance between two points can be expressed as

$$\mathcal{D} = [(r\cos\theta_2 + a - r\cos\theta_1)^2 + (r\sin\theta_1 - r\sin\theta_2)^2 + h^2]^{\frac{1}{2}}$$

By using Neumann formula, mutual inductance between the two coils can be expressed as

$$M = \frac{\mu_0 N_1 N_2}{4\pi}\int_0^{2\pi} d\theta_1 \int_0^{2\pi} \frac{r^2\cos(\theta_2 - \theta_1)d\theta_2}{\mathcal{D}}$$

In terms of integral form, it is inversely proportional to the horizontal offset distance. ML After substituting parameters, the relationship curve between M and horizontal offset obtained is shown in FIG. 9.It can also be seen from the figure that mutual inductance is even function of horizontal offset distance, which is consistent with physical intuition.

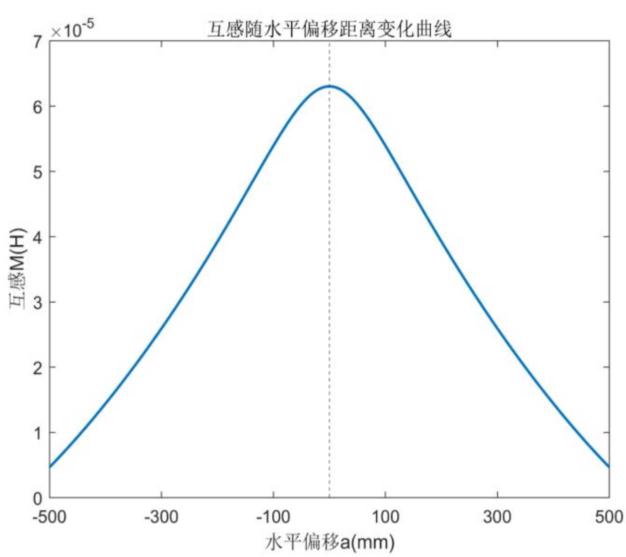

Fig. 9: Variation curve of mutual inductance with horizontal deviation

ii. *Model calculation*

Based on the variation of mutual inductance with horizontal migration, a computer can be used to search various combinations of emission frequency, matching impedance and horizontal distance. Considering the large search space, this paper uses simulated annealing algorithm to find the optimal solution.

The idea of the simulated annealing algorithm is derived from the solid annealing process: the solid is heated to a high enough temperature, and then it is cooled slowly. During heating, the particles inside the solid become disordered as the temperature rises, and the internal energy increases. Then, when the particles are cooled slowly, the arrangement gradually tends to be orderly, and finally reaches the ground state at room temperature, and the internal energy decreases to the minimum. Solid annealing process was used to simulate combinatorial optimization problem, the internal energy E simulation as the objective function, the corresponding metal objects combinatorial optimization problem, the corresponding state, optimal solutions corresponding to the lowest energy state, the temperature evolution T T for control parameters, according to the boltzmann distribution, the temperature reached its lowest point, obtain the optimal solution of probability is the largest. In simulated annealing algorithm, the introduction of Metropolis acceptance criterion makes the algorithm appear to jump, thus reducing the dependence on the initial solution. The traditional simulated annealing algorithm is:

1. Initial cooling schedule [(initial temperature), (Markov chain length), (temperature attenuation factor), S (stop criterion)], initial solution =; $t = t_0 L_k \alpha x_i x_0$
2. If the number of internal cycles reaches at this temperature, then turn to 3;L_k Otherwise, determine the chosen neighborhood structure (2_opt or 3_opt), generate a new solution randomly from the neighborhood, calculate δ f()-f(), if δ, then; $x_j f_{ij} = x_j x_i f_{ij} \leq 0 x_j = x_i$ Otherwise, at that time, make; $\exp(-\Delta f_{ij}/t) > \mathrm{random}(0,1) x_j = x_i$ Repeat 2;
3. If the stop criterion S is met, the calculation is terminated; Otherwise =α-1, go to 2;$t_k t_k$
4. Output the optimal solution. Intuitively, for each value of the control parameter T, the algorithm continues the process of generating new solution-judge-accept/reject.

Based on the traditional simulated annealing algorithm and combined with the actual situation, the solution process is formulated as follows:

1. *Step1:* Determine the solution space. According to FIG. 9 and the requirements of the problem, considering symmetry, the solution space is defined

as, and the initial solution is set as. $S = \{a|0 \leq a \leq 10000\} x_i = 0$

1. *Step 2:* set the objective function. We know that the objective function is $f(x) = x$
2. *Step 3:* generate a new solution. First, a quantity subject to a normal distribution centered on the average distance is generated to generate a random number of 0-1.dxIf the random number is greater than 0.5, dx is negative; otherwise, dx is positive. Finally, the new solution is.$x_j = x_i + dx$
3. *Step 4:* define constraints. Different from the general simulated annealing case, the new solution needs to be satisfied

$$\begin{cases} 0 \leq x_j \leq 10000 \\ \max \eta \geq 80\% \end{cases}$$

If the constraint conditions are met, the new solution is accepted, otherwise a new solution is generated until the condition is met. x_j

5. *Step 5:* define acceptance criteria. Is defined as the initial temperature and is the probability coefficient of temperature.$t_0 k_t$ Calculate, if, then; $\Delta f_{ij} = f(x_j) - f(x_i) \Delta f_{ij} \geq 0 x_j = x_i$If, at that time, make, otherwise repeat Step3-Step5.$\Delta f_{ij} < 0 \exp(-\Delta f_{ij}/(t_0 * k_t)) > \text{random}(0,1)\ x_j = x_i$Here to pick up.$t_0 = 50, k_t = 0.05$
6. *Step 6:* solve iteratively until finding the optimal solution that meets the conditions.

iii. *The model results*

Using Matlab programming, the maximum value satisfying the problem conditions is 286.0349mm. At this time, mutual inductance is obtained. When the maximum power transmission efficiency is achieved, the transmission frequency is 29.85kHz, the matching impedance is 166.6μH, and the maximum power transmission efficiency is 80.55%, which meets the requirements of the problem.$aM = 27.67\mu H$

VI. Sensitivity Analysis

In the above paper, two parameters and are estimated. $N_1 N_2 R_2$ This section will discuss parameter Settings and conduct sensitivity analysis.

a) *Analysis of parameters* $N_1 N_2$

N_1, N_2Is the number of turns of transmitting coil and receiving coil respectively. In question 2, in order to obtain the model of mutual inductance changing with distance, this paper adopts the fitting method to estimate. $N_1 N_2 \approx 103.5$ Considering that they are all integers and 103 is a prime number, the integer is 104. From the fitting effect, it is relatively consistent with the experimental data. $N_1, N_2 N_1 N_2 = 104$

In order to quantitatively measure the impact of calculation errors on the results, the power transmission efficiency under the first experimental condition was calculated, assuming a fluctuation of 5%, as shown in FIG. 10. $N_1 N_2 N_1 N_2 N_1 N_2 \in [98,110]$

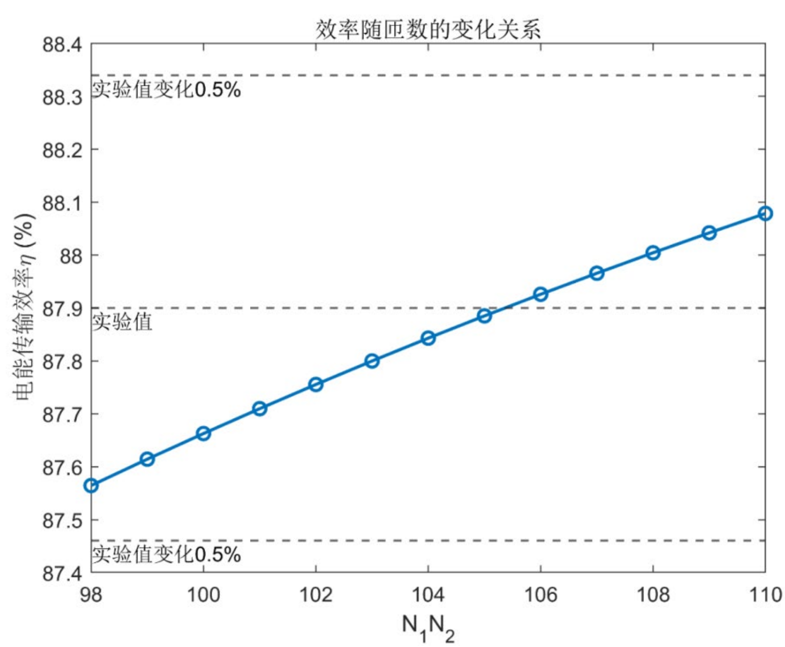

Fig. 10: Sensitivity analysis of the number of turns

As can be seen from the figure, when the number of turns changes by 5%, relative to problem 1, the efficiency obtained through measured mutual inductance only changes by less than 0.5%. Therefore, the power transmission efficiency is not sensitive to the change of the number of turns, and the model has good stability.

b) Analysis of parameters R_2

R_2 Is the resistance of the coil in the receiving loop. In general, the resistance is less than. Make an estimate. Assume that the coil material is made of copper wire, the cross-sectional area of the wire is, and as discussed above, let the number of turns be 10, then the coil resistance is 110-6m2

$$R = \frac{2\pi r \rho N}{S}$$

Access to information[6]After that, the resistivity of copper is. Therefore, the model is more reasonable. $16.8\ \mathrm{n}\Omega \cdot \mathrm{m} R \approx 0.13\Omega R_2 = 0.2\Omega$

In order to measure the influence of changes on the model results, a fluctuation of 5% is assumed, i.e., to calculate the electric energy transmission efficiency under the first experiment. The results are shown in FIG. 11. $R_2 R_2 R_2 \in [0.19, 0.21]$

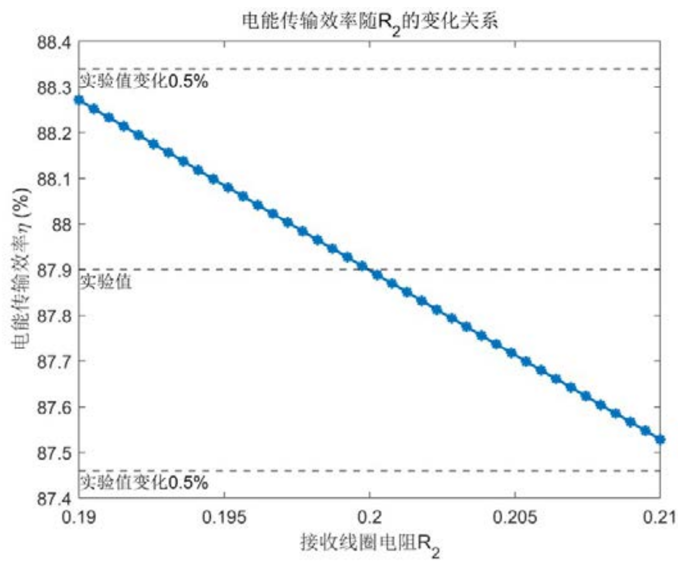

Fig. 11: Sensitivity analysis of pairs R_2

Therefore, when the change is 5%, the power transmission efficiency changes only 0.5%, the power transmission efficiency is not sensitive to the change, and the model has good stability. $R_2 R_2$

VII. Evaluation and Extension of the Model

a) Model advantage

In problem 1, this paper constructs a two-port network model of wireless charging. Based on the basic knowledge of circuit theory, the model regarded the complex power transmission system as A black box, constructed parameter A, and then solved according to the specific circuit structure. The modeling idea changed from general to specific, and the obtained solution met the expectation, and the model had good expansibility.

In the second problem, the model of mutual inductance changing with distance is built, the Neumann formula is used to deduce the relationship between mutual inductance and distance, the unknown parameters are determined by fitting, and the computer numerical solution is used, the results are relatively accurate. The accuracy of the fitting process is analyzed, and the sensitivity of the fitting results is analyzed. The model has good stability.

In the third problem, the optimization model of transmission frequency and matching impedance is constructed. The ergodic method is used to search for the optimal combination of transmission frequency and matching impedance under the premise of constant coil distance, and the highest power transmission efficiency is obtained. The modeling method is simple, the calculation speed is fast, and it can be conveniently applied to practical projects.

In problem 4, the maximum horizontal migration model is constructed. The simulated annealing algorithm is used to find the optimal solution for the problem that there are many optimization variables and large search space. The simulated annealing algorithm can jump out of the local optimal solution and obtain the global optimal solution. Moreover, the algorithm has strong robustness and can resist the influence of external unstable factors on the results. The final solution conforms to the physical intuition and meets the requirements of the problem.

b) Lack of model

In question 2, Neumann formula was used to calculate the multi-turn solenoid and simplify it into a single coil. The size and shape of the multi-turn coil were not considered, and the edge effect was not taken into account. Therefore, the results obtained had certain deviation from the reality.

In question 4, when the simulated annealing algorithm is used for calculation, because the simulated annealing algorithm is affected by the temperature cooling rate, the cooling rate is slow, the search time is long, and the better solution can be obtained, but the solution time is also long. If the cooling rate is increased, the optimal solution may be skipped. Therefore, in practice, in order to obtain the optimal solution, it often takes a long time to calculate.

c) Model to improve

In view of the shortcomings of the model, this paper puts forward the following improvement directions:

1. In view of the assumption that the coil in the model is an ideal hollow solenoid and the coil shape is not considered and the edge effect is ignored, the mutual inductance between the two actual coils can be calculated using the finite element method subsequently. The finite element calculation results are compared with the results in this paper to explore the reasons for the difference and the impact of the edge effect on power transmission.
2. In view of the assumption that the coupling coefficient between each circuit link in the model is 1, if the coupling coefficient does not meet the requirement of 1, the actual coupling coefficient can be obtained by searching the parameter manual for simple circuit equivalence. For example, the transmitting circuit and the power supply can be treated as series or parallel, and the same is true for the receiving coil and the load. In this way, the efficiency calculation results are more accurate.
3. In view of the problem that the mutual inductance in the model is only related to distance and may fail in the presence of magnetic media (such as iron core), when the relative position of the coil is fixed, the corresponding mutual inductance value can be measured by sensor, and the transmission efficiency can be calculated by using the calculation formula in this paper. If there is relative movement between coils, the relationship between mutual inductance and distance and Angle can be measured by numerical simulation or sensor measurement, and then the transmission efficiency can be calculated by using the formula in this paper.

d) Model to promote

The mathematical model based on electric vehicle wireless charging two-port network presented in this paper can be applied to other electromagnetic coupling or electromagnetic induction wireless power transmission technologies, and can also be modified to deal with microwave radiation power transmission at high frequencies.

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- Main text: font size 10 with two justified columns.
- Two columns with equal column width of 3.38 and spacing of 0.2.
- First character must be three lines drop-capped.
- The paragraph before spacing of 1 pt and after of 0 pt.
- Line spacing of 1 pt.
- Large images must be in one column.
- The names of first main headings (Heading 1) must be in Roman font, capital letters, and font size of 10.
- The names of second main headings (Heading 2) must not include numbers and must be in italics with a font size of 10.

Structure and Format of Manuscript

The recommended size of an original research paper is under 15,000 words and review papers under 7,000 words. Research articles should be less than 10,000 words. Research papers are usually longer than review papers. Review papers are reports of significant research (typically less than 7,000 words, including tables, figures, and references)

A research paper must include:

a) A title which should be relevant to the theme of the paper.
b) A summary, known as an abstract (less than 150 words), containing the major results and conclusions.
c) Up to 10 keywords that precisely identify the paper's subject, purpose, and focus.
d) An introduction, giving fundamental background objectives.
e) Resources and techniques with sufficient complete experimental details (wherever possible by reference) to permit repetition, sources of information must be given, and numerical methods must be specified by reference.
f) Results which should be presented concisely by well-designed tables and figures.
g) Suitable statistical data should also be given.
h) All data must have been gathered with attention to numerical detail in the planning stage.

Design has been recognized to be essential to experiments for a considerable time, and the editor has decided that any paper that appears not to have adequate numerical treatments of the data will be returned unrefereed.

i) Discussion should cover implications and consequences and not just recapitulate the results; conclusions should also be summarized.
j) There should be brief acknowledgments.
k) There ought to be references in the conventional format. Global Journals recommends APA format.

Authors should carefully consider the preparation of papers to ensure that they communicate effectively. Papers are much more likely to be accepted if they are carefully designed and laid out, contain few or no errors, are summarizing, and follow instructions. They will also be published with much fewer delays than those that require much technical and editorial correction.

The Editorial Board reserves the right to make literary corrections and suggestions to improve brevity.

Format Structure

It is necessary that authors take care in submitting a manuscript that is written in simple language and adheres to published guidelines.

All manuscripts submitted to Global Journals should include:

Title

The title page must carry an informative title that reflects the content, a running title (less than 45 characters together with spaces), names of the authors and co-authors, and the place(s) where the work was carried out.

Author details

The full postal address of any related author(s) must be specified.

Abstract

The abstract is the foundation of the research paper. It should be clear and concise and must contain the objective of the paper and inferences drawn. It is advised to not include big mathematical equations or complicated jargon.

Many researchers searching for information online will use search engines such as Google, Yahoo or others. By optimizing your paper for search engines, you will amplify the chance of someone finding it. In turn, this will make it more likely to be viewed and cited in further works. Global Journals has compiled these guidelines to facilitate you to maximize the web-friendliness of the most public part of your paper.

Keywords

A major lynchpin of research work for the writing of research papers is the keyword search, which one will employ to find both library and internet resources. Up to eleven keywords or very brief phrases have to be given to help data retrieval, mining, and indexing.

One must be persistent and creative in using keywords. An effective keyword search requires a strategy: planning of a list of possible keywords and phrases to try.

Choice of the main keywords is the first tool of writing a research paper. Research paper writing is an art. Keyword search should be as strategic as possible.

One should start brainstorming lists of potential keywords before even beginning searching. Think about the most important concepts related to research work. Ask, "What words would a source have to include to be truly valuable in a research paper?" Then consider synonyms for the important words.

It may take the discovery of only one important paper to steer in the right keyword direction because, in most databases, the keywords under which a research paper is abstracted are listed with the paper.

Numerical Methods

Numerical methods used should be transparent and, where appropriate, supported by references.

Abbreviations

Authors must list all the abbreviations used in the paper at the end of the paper or in a separate table before using them.

Formulas and equations

Authors are advised to submit any mathematical equation using either MathJax, KaTeX, or LaTeX, or in a very high-quality image.

Tables, Figures, and Figure Legends

Tables: Tables should be cautiously designed, uncrowned, and include only essential data. Each must have an Arabic number, e.g., Table 4, a self-explanatory caption, and be on a separate sheet. Authors must submit tables in an editable format and not as images. References to these tables (if any) must be mentioned accurately.

Figures

Figures are supposed to be submitted as separate files. Always include a citation in the text for each figure using Arabic numbers, e.g., Fig. 4. Artwork must be submitted online in vector electronic form or by emailing it.

Preparation of Eletronic Figures for Publication

Although low-quality images are sufficient for review purposes, print publication requires high-quality images to prevent the final product being blurred or fuzzy. Submit (possibly by e-mail) EPS (line art) or TIFF (halftone/ photographs) files only. MS PowerPoint and Word Graphics are unsuitable for printed pictures. Avoid using pixel-oriented software. Scans (TIFF only) should have a resolution of at least 350 dpi (halftone) or 700 to 1100 dpi (line drawings). Please give the data for figures in black and white or submit a Color Work Agreement form. EPS files must be saved with fonts embedded (and with a TIFF preview, if possible).

For scanned images, the scanning resolution at final image size ought to be as follows to ensure good reproduction: line art: >650 dpi; halftones (including gel photographs): >350 dpi; figures containing both halftone and line images: >650 dpi.

Color charges: Authors are advised to pay the full cost for the reproduction of their color artwork. Hence, please note that if there is color artwork in your manuscript when it is accepted for publication, we would require you to complete and return a Color Work Agreement form before your paper can be published. Also, you can email your editor to remove the color fee after acceptance of the paper.

Tips for Writing a Good Quality Science Frontier Research Paper

Techniques for writing a good quality Science Frontier Research paper:

1. Choosing the topic: In most cases, the topic is selected by the interests of the author, but it can also be suggested by the guides. You can have several topics, and then judge which you are most comfortable with. This may be done by asking several questions of yourself, like "Will I be able to carry out a search in this area? Will I find all necessary resources to accomplish the search? Will I be able to find all information in this field area?" If the answer to this type of question is "yes," then you ought to choose that topic. In most cases, you may have to conduct surveys and visit several places. Also, you might have to do a lot of work to find all the rises and falls of the various data on that subject. Sometimes, detailed information plays a vital role, instead of short information. Evaluators are human: The first thing to remember is that evaluators are also human beings. They are not only meant for rejecting a paper. They are here to evaluate your paper. So present your best aspect.

2. Think like evaluators: If you are in confusion or getting demotivated because your paper may not be accepted by the evaluators, then think, and try to evaluate your paper like an evaluator. Try to understand what an evaluator wants in your research paper, and you will automatically have your answer. Make blueprints of paper: The outline is the plan or framework that will help you to arrange your thoughts. It will make your paper logical. But remember that all points of your outline must be related to the topic you have chosen.

3. Ask your guides: If you are having any difficulty with your research, then do not hesitate to share your difficulty with your guide (if you have one). They will surely help you out and resolve your doubts. If you can't clarify what exactly you require for your work, then ask your supervisor to help you with an alternative. He or she might also provide you with a list of essential readings.

4. Use of computer is recommended: As you are doing research in the field of science frontier then this point is quite obvious. Use right software: Always use good quality software packages. If you are not capable of judging good software, then you can lose the quality of your paper unknowingly. There are various programs available to help you which you can get through the internet.

5. Use the internet for help: An excellent start for your paper is using Google. It is a wondrous search engine, where you can have your doubts resolved. You may also read some answers for the frequent question of how to write your research paper or find a model research paper. You can download books from the internet. If you have all the required books, place importance on reading, selecting, and analyzing the specified information. Then sketch out your research paper. Use big pictures: You may use encyclopedias like Wikipedia to get pictures with the best resolution. At Global Journals, you should strictly follow here.

6. Bookmarks are useful: When you read any book or magazine, you generally use bookmarks, right? It is a good habit which helps to not lose your continuity. You should always use bookmarks while searching on the internet also, which will make your search easier.

7. Revise what you wrote: When you write anything, always read it, summarize it, and then finalize it.

8. Make every effort: Make every effort to mention what you are going to write in your paper. That means always have a good start. Try to mention everything in the introduction—what is the need for a particular research paper. Polish your work with good writing skills and always give an evaluator what he wants. Make backups: When you are going to do any important thing like making a research paper, you should always have backup copies of it either on your computer or on paper. This protects you from losing any portion of your important data.

9. Produce good diagrams of your own: Always try to include good charts or diagrams in your paper to improve quality. Using several unnecessary diagrams will degrade the quality of your paper by creating a hodgepodge. So always try to include diagrams which were made by you to improve the readability of your paper. Use of direct quotes: When you do research relevant to literature, history, or current affairs, then use of quotes becomes essential, but if the study is relevant to science, use of quotes is not preferable.

10. Use proper verb tense: Use proper verb tenses in your paper. Use past tense to present those events that have happened. Use present tense to indicate events that are going on. Use future tense to indicate events that will happen in the future. Use of wrong tenses will confuse the evaluator. Avoid sentences that are incomplete.

11. Pick a good study spot: Always try to pick a spot for your research which is quiet. Not every spot is good for studying.

12. Know what you know: Always try to know what you know by making objectives, otherwise you will be confused and unable to achieve your target.

13. Use good grammar: Always use good grammar and words that will have a positive impact on the evaluator; use of good vocabulary does not mean using tough words which the evaluator has to find in a dictionary. Do not fragment sentences. Eliminate one-word sentences. Do not ever use a big word when a smaller one would suffice.

Verbs have to be in agreement with their subjects. In a research paper, do not start sentences with conjunctions or finish them with prepositions. When writing formally, it is advisable to never split an infinitive because someone will (wrongly) complain. Avoid clichés like a disease. Always shun irritating alliteration. Use language which is simple and straightforward. Put together a neat summary.

14. Arrangement of information: Each section of the main body should start with an opening sentence, and there should be a changeover at the end of the section. Give only valid and powerful arguments for your topic. You may also maintain your arguments with records.

15. Never start at the last minute: Always allow enough time for research work. Leaving everything to the last minute will degrade your paper and spoil your work.

16. Multitasking in research is not good: Doing several things at the same time is a bad habit in the case of research activity. Research is an area where everything has a particular time slot. Divide your research work into parts, and do a particular part in a particular time slot.

17. Never copy others' work: Never copy others' work and give it your name because if the evaluator has seen it anywhere, you will be in trouble. Take proper rest and food: No matter how many hours you spend on your research activity, if you are not taking care of your health, then all your efforts will have been in vain. For quality research, take proper rest and food.

18. Go to seminars: Attend seminars if the topic is relevant to your research area. Utilize all your resources.

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:

- o Single section and succinct.
- o An outline of the job done is always written in past tense.
- o Concentrate on shortening results—limit background information to a verdict or two.
- o 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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