Unified Electromagnetic Theory of Matter and Light

Section A — **Structure of Matter**

Part A1 - **Toroidal Electromagnetic Structure**

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Abstract

This paper introduces a model of a toroidal electromagnetic structure in which electric, magnetic, and displacement-related fields form a dynamically organized and spatially confined system. The proposed structure consists of a closed electromagnetic tube characterized by a major radius R and a minor radius a. The electric field is predominantly concentrated toward the inner region of the tube, while the magnetic field occupies a broader region and contributes to the binding organization of the structure.

A central feature of the model is the distinction between electromagnetic energy magnitude and its structural sign. Maxwell's expressions are retained for determining the magnitudes of electric and magnetic field energies, while the proposed interpretation assigns positive energy to the electric field and negative binding energy to the magnetic field.

The model introduces a preferred electric energy density determined by the spatial organization of the fields and the direction of the Poynting vector. Changes in field geometry are proposed to redirect electromagnetic energy flow, providing a mechanism for regulating energy concentration and maintaining the characteristic toroidal organization.

A displacement field is introduced as a third dynamic component, associated with inertia and periodic energy exchange. Its proposed role is to maintain continuity of internal motion during the alternating electric and magnetic extrema. The signed contributions of electric, magnetic, and displacement-field energy are combined into a constant negative internal energy balance.

Part A1 establishes the geometrical and physical framework of the proposed electromagnetic torus, supported by diagrams and energy-cycle illustrations. Subsequent parts address quantitative stability conditions, electromagnetic stresses, perturbations, and interactions between toroidal structures.

1. Introduction

Electromagnetic fields are commonly described through their electric and magnetic components, governed by Maxwell's equations. These equations determine how the fields evolve, interact, and propagate through space. They also provide expressions for electric and magnetic energy densities and describe the transport of electromagnetic energy through the Poynting vector.

This paper introduces a complementary structural interpretation of electromagnetic fields. Its central proposition is that electric and magnetic fields may form a spatially confined, dynamically organized toroidal structure. Such a structure is not regarded as a static arrangement of fields, but as an electromagnetic system in which electric, magnetic, and displacement-related processes interact continuously.

The proposed torus consists of a closed electromagnetic tube characterized by a major radius R and a minor radius a. Within this geometry, the electric and magnetic fields occupy different but interconnected spatial regions. The electric field is concentrated predominantly toward the inner region of the tube, where its energy density may be relatively high. The magnetic field extends over a broader region and provides the principal binding tendency of the structure.

A fundamental feature of the proposed model is the distinction between the magnitude of electromagnetic energy and its structural orientation. The conventional Maxwell expressions are retained as measures of electric and magnetic field-energy magnitudes. The model assigns a positive contribution to electric energy and a negative binding contribution to magnetic energy. Their opposite signs represent the competing expansive and binding tendencies within the toroidal structure.

The resulting energy organization is supplemented by a proposed displacement field. Unlike a purely static interpretation of electromagnetic confinement, the model attributes an inertial role to the displacement-related dynamics. During electromagnetic oscillation, energy is transferred among the electric, magnetic, and displacement contributions. The displacement field is proposed to maintain the continuity of the structure during the alternating maxima and minima of the electric and magnetic fields.

The Poynting vector plays a central role in this description. Its direction is determined by the local orientations of the electric and magnetic fields. The proposed model associates changes in the spatial organization of these fields with changes in the direction of electromagnetic energy flow. At a preferred electric energy density, the flow is expected to follow the equilibrium path of the toroidal structure. Departures from this density may introduce inward or outward components, providing a possible mechanism for self-regulation.

The torus is therefore characterized not only by its geometry and field amplitudes, but also by a preferred energy density and a periodic internal energy exchange. In the proposed description, the signed electric, magnetic, and displacement-energy contributions combine to form a constant internal energy balance. The electromagnetic fields continue to oscillate, while the overall toroidal organization is maintained.

The purpose of Part 1A is to present this physical model as a coherent and visually understandable structure. Particular attention is given to the toroidal geometry, spatial distributions of the fields, signed energy contributions, the preferred electric energy density, and the role of the displacement field. Figures, diagrams, and tables are used to illustrate the model and the relationships between its components.

The mathematical conditions for stability, detailed electromagnetic stresses, responses to perturbations, and interactions or merging between toroidal structures are reserved for

subsequent parts of this study. The present paper establishes the conceptual and geometrical framework on which those investigations are based.

The proposed electromagnetic torus is considered a potential fundamental building block of matter. Its closed geometry, internal electromagnetic oscillation, magnetic binding, and displacement-related inertia provide a possible physical basis for the formation of stable material particles. In this interpretation, matter is not introduced as a fundamentally separate entity from electromagnetic fields, but as a more complex and stable organization of electromagnetic structures. The torus may therefore represent an elementary structural unit from which increasingly complex particles and material systems are formed. [1,5,7]

2. Toroidal Geometry

2.1. The Electromagnetic Torus

The proposed electromagnetic structure has the geometry of a torus: a closed tube extending around a circular path in three-dimensional space. Its geometry is characterized by two principal dimensions, the major radius R and the minor radius a.

The major radius R defines the distance from the center of the torus to the centerline of its tube. The minor radius a determines the characteristic transverse extent of the tube.

The toroidal geometry provides two distinct spatial directions. The first follows the large circumference of the torus, while the second extends around the cross-section of the tube. These directions provide the geometrical basis for the organization of the electric and magnetic fields and their associated electromagnetic dynamics.

Unlike an electromagnetic wave propagating along an open path, the proposed toroidal structure forms a closed spatial configuration. Its geometry allows the internal electromagnetic processes to repeat periodically without requiring a beginning or an end of the structure.

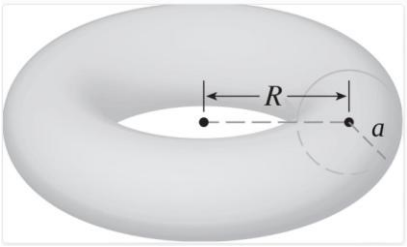


Figure 1. Geometry of the electromagnetic torus. *The major radius R defines the distance from the center of the torus to the centerline of its tube, while the minor radius a determines the transverse radius of the tube.*

The geometrical volume of an ideal torus is

$$V = 2\pi^2 R a^2$$

This expression defines the available geometrical volume, not necessarily the effective volume occupied by each electromagnetic field. The electric and magnetic fields may have different spatial distributions and therefore different effective energy volumes.

2.2. Spatial Organization of the Fields

The electric and magnetic fields are not assumed to have identical spatial distributions.

In the proposed model, the electric field is predominantly concentrated toward the inner region of the toroidal tube. Its local energy density may be relatively high, while the volume in which it is concentrated is comparatively small.

The magnetic field occupies a broader region, extending toward the outer part of the tube. Its geometry is associated with the binding organization of the electromagnetic structure.

Consequently, the total magnitudes of electric and magnetic energy cannot be determined from their local maximum densities alone. They depend on the spatial distribution of each field throughout the toroidal volume.

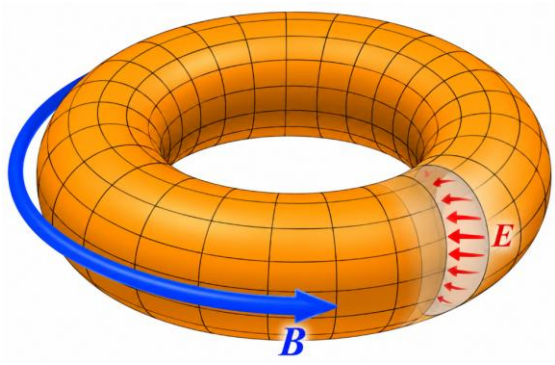


Figure 2. Schematic spatial organization of the electric and magnetic fields in the electromagnetic torus. *The magnetic field B follows a closed path around the torus and represents the binding component of the structure. The electric field E is shown in the cross-section of the toroidal tube, where it is concentrated predominantly toward the inner region. The figure illustrates that the electric and magnetic fields have different spatial distributions and therefore different structural roles within the toroidal organization.*

A region with a higher electric energy density can therefore contain less total electric energy than a broader region containing a lower magnetic energy density.

This distinction between local energy density and integrated field energy is essential to the model's geometrical interpretation.

The electric and magnetic regions should not be understood as sharply separated compartments. Their fields overlap, and their relative intensities vary continuously across the toroidal structure.

2.3. The Displacement Field

In addition to the electric and magnetic fields, the proposed model introduces a displacement-related dynamical field.

The displacement field is associated with the internal electromagnetic energy exchange and the continuity of motion during the alternating phases of electric and magnetic oscillation.

Its geometrical role is distinct from that of the electric and magnetic fields. Whereas the electric field provides an expansive tendency and the magnetic field a binding tendency, the displacement field is proposed to provide an inertial contribution that helps preserve the spatial organization of the torus throughout the oscillation cycle.

The displacement field need not reverse its motion immediately when the direction of electromagnetic energy transfer changes. Its proposed inertia allows continued motion while the electromagnetic interaction alternately accelerates and decelerates it.

In this interpretation, the torus is not simply a superposition of two oscillating fields. It is a spatially organized system involving electric, magnetic, and displacement-related dynamics.

2.4. Closed Geometry and Internal Electromagnetic Motion

The closed toroidal geometry establishes a spatial framework within which the electromagnetic fields can form periodic patterns.

The electric and magnetic fields vary both in space and in time. Their local maxima need not occur at the same positions, and their temporal oscillations may be phase-shifted.

The Poynting vector describes the local direction and magnitude of electromagnetic energy flow:

$$S = \frac{1}{\mu_0} E \times B$$

In the proposed model, the spatial organization of the fields may direct this flow along preferred paths inside the toroidal structure.

The model further proposes that the orientation of the energy flow is linked to the regulation of the toroidal geometry. A radial component directed toward the interior or exterior can indicate a tendency toward redistribution of the electromagnetic structure, whereas a flow following the preferred path corresponds to its geometrical equilibrium.

The geometry therefore provides more than spatial confinement. It establishes the framework for the interaction between field distributions, electromagnetic energy flow, and the proposed displacement dynamics.

The detailed mechanism governing the direction of the Poynting vector and the preferred electric energy density is developed in subsequent sections.

2.5. Geometrical Parameters and Structural Interpretation

The major and minor radii play different roles in the proposed structure.

The major radius R determines the characteristic size of the closed toroidal arrangement and influences the available paths for electromagnetic organization.

The minor radius a determines the transverse dimension of the tube and influences the spatial concentration and overlap of the electric and magnetic fields.

The ratio

$$\beta = \frac{a}{R}$$

characterizes the relative thickness of the torus.

For $\beta \ll 1$, the torus consists of a relatively thin tube around a large circular path. As β increases, the transverse structure becomes more significant and the geometrical distinction between its inner and outer regions becomes more pronounced.

The radii R and a are treated as characteristic dimensions of an organized electromagnetic structure, rather than externally imposed dimensions of a material container.

The mechanisms that select preferred dimensions and preserve them against disturbances are addressed separately. Part 1A establishes the geometrical framework, while subsequent parts investigate detailed stability conditions and structural interactions.

2.6. Geometrical Foundation of the Model

The proposed electromagnetic torus is thus characterized by three fundamental geometrical features: a closed spatial path, a finite transverse extent, and different but overlapping spatial distributions of its electromagnetic components.

These features provide the basis for the model's interpretation of electric expansion, magnetic binding, and displacement-related inertia.

The toroidal geometry also establishes the distinction between local energy density and integrated field energy. This distinction becomes particularly important when the electric and magnetic contributions are assigned opposite structural energy signs.

The following section introduces this signed energy interpretation and its relationship to the conventional Maxwell expressions for electromagnetic energy density. [5,6,7]

3. Signed Electromagnetic Energy

3.1. Energy Magnitude and Structural Orientation

Maxwell's electrodynamics provides expressions for the energy densities associated with electric and magnetic fields. Both expressions are nonnegative and describe the amount of electromagnetic energy stored in a given volume.

The present model retains these expressions for calculating the magnitudes of the electric and magnetic energy contributions. It introduces an additional distinction between energy magnitude and structural orientation.

The electric field is assigned a positive energy contribution associated with an expansive tendency. The magnetic field is assigned a negative energy contribution associated with a binding tendency.

This distinction represents a central postulate of the proposed toroidal model.



Figure 3. Positive Electric Energy and Negative Magnetic Binding Energy. *The diagram illustrates the proposed signed energy contributions of the electromagnetic torus. Positive electric energy (W_E) represents the expansive tendency, while negative magnetic energy (W_B) represents the binding tendency. Their magnitudes follow Maxwell's energy-density expressions, whereas the negative magnetic sign is introduced by the proposed model.*

In conventional electrodynamics, the electric and magnetic field-energy densities are both positive, while the directional properties of their mechanical effects are described through the Maxwell stress tensor and the electromagnetic momentum flux. The present model introduces a different energy interpretation: the structural roles of the fields are represented directly by opposite algebraic signs.

The resulting signed energy quantities are therefore model-specific and must be distinguished from conventional electromagnetic field energy.

3.2. Positive Electric Energy

The electric energy density is defined by the conventional Maxwell expression:

$$u_E = \frac{\varepsilon_0 E^2}{2}$$

The corresponding electric energy contained in the toroidal structure is:

$$W_E = \frac{\varepsilon_0}{2}\int_V E^2 \, dV$$

Since the square of the electric field is nonnegative, the electric energy contribution is positive or zero.

$$W_E \geq 0$$

In the proposed toroidal model, this positive contribution is associated with the tendency of the electric field to expand the electromagnetic structure.

The spatial concentration of the electric field plays an important role. A relatively high electric energy density may be confined to a comparatively small region of the toroidal tube.

Consequently, the maximum local electric energy density does not by itself determine the total electric energy. The latter depends on the complete spatial distribution of the field.

3.3. Negative Magnetic Binding Energy

The conventional Maxwell expression for the magnitude of magnetic energy density is:

$$|u_B| = \frac{B^2}{2\mu_0}$$

The proposed model assigns a negative sign to the magnetic contribution:

$$u_B = -\frac{B^2}{2\mu_0}$$

Its integrated contribution is:

$$W_B = -\frac{1}{2\mu_0}\int_V B^2 \, dV$$

Therefore:

$$W_B \leq 0$$

The absolute magnitude of this energy is:

$$|W_B| = \frac{1}{2\mu_0}\int_V B^2 \, dV$$

The negative sign represents the binding role attributed to the magnetic field within the

proposed structure. It does not imply that a conventional Maxwell magnetic field possesses negative energy density.

This distinction is fundamental. The model uses the Maxwell expression to calculate the magnitude of magnetic energy, while its negative sign expresses the proposed structural relationship between electric expansion and magnetic binding.

Accordingly, the electric and magnetic contributions are treated as physically different tendencies within a common electromagnetic structure.

3.4. Energy Density and Effective Field Volume

The electric and magnetic fields generally occupy different spatial distributions within the torus.

The electric field is concentrated predominantly toward the inner region of the toroidal tube. Its energy density may be high, but its effective volume may be relatively small.

The magnetic field extends across a broader region and may therefore contain a greater total energy magnitude despite having a lower local maximum energy density.

The total field-energy magnitudes are determined by spatial integration:

$$W_E = \int_V u_E \, dV$$

$$|W_B| = \int_V |u_B| \, dV$$

For a simplified geometrical representation, introduce effective volumes for the electric and magnetic fields:

$$W_E = u_s V_E^{\text{eff}}$$

$$|W_B| = u_s V_B^{\text{eff}}$$

Here, u_s is a chosen reference energy density, for example the common magnitude of electric and magnetic energy density at an interface between their characteristic regions.

If the magnetic field occupies a greater effective energy volume,

$$V_B^{\text{eff}} > V_E^{\text{eff}}$$

then:

$$|W_B| > W_E$$

Thus, equal energy-density magnitudes at a selected interface do not imply equal total field energies.

The integrated magnetic contribution may exceed the electric contribution because of its broader spatial distribution.

This provides a possible geometrical basis for a binding-dominated toroidal configuration. Whether the required field distributions also satisfy the complete electromagnetic equations and boundary conditions must be established by a detailed field model.

3.5. Signed Energy Balance

With positive electric energy and negative magnetic binding energy, the signed balance of the two contributions is:

$$W_{EB} = W_E + W_B$$

Equivalently:

$$W_{EB} = W_E - |W_B|$$

Three cases can be distinguished.

$W_E > W_B$	$W_{EB} > 0$	Electric expansion dominates
$W_E = W_B$	$W_{EB} = 0$	Equal signed contributions
$W_E < W_B$	$W_{EB} < 0$	Magnetic binding dominates

For the proposed toroidal structure, a negative signed balance is associated with a binding-dominated configuration.

However, the electric and magnetic contributions vary during electromagnetic oscillation. Their instantaneous signed sum

need not remain negative throughout the cycle.

This leads to the proposed role of a third dynamical contribution: the displacement field.

3.6. Inclusion of Displacement-Field Energy

The model introduces a signed displacement-energy contribution W_p, associated with the proposed inertia and energy exchange of the displacement field.

The resulting internal energy balance is expressed as:

$$W_j = W_E + W_B + W_p$$

The model proposes that the combined internal energy remains constant during periodic electromagnetic oscillation:

$$W_j = -W_v = \text{const.}$$

where $W_v > 0$ denotes the magnitude of the residual negative binding balance.

From this requirement, the displacement-energy contribution must satisfy:

$$W_p = -W_v - W_E - W_B$$

In this interpretation, W_p changes as the electric and magnetic contributions change, allowing their signed sum to remain constant.

The displacement field is further proposed to possess inertia and to participate in maintaining the toroidal organization during the alternating electric and magnetic extrema.

At this stage, the energy-balance equation defines the required contribution of the displacement field. Its independent dynamics and physical energy-transfer mechanism are introduced in subsequent sections.

The negative signed balance should not be confused with the conventional conserved Maxwell energy, which is calculated from the sum of the nonnegative electric and magnetic field-energy densities.

3.7. Structural Significance of Signed Energy

The introduction of signed electromagnetic energy is intended to express a structural property that is not represented by the magnitudes of the two energy densities alone.

In the proposed interpretation, electric energy favors expansion, magnetic energy favors binding, and displacement-related energy participates in the periodic transfer between these contributions.

The signs therefore describe the model's proposed structural roles rather than different mathematical conventions for the same Maxwell energy density.

The spatial distributions of the fields determine their integrated energy magnitudes, while their interaction and temporal evolution determine the changing internal balance.

This interpretation provides the energy framework for the subsequent description of preferred electric energy density, electromagnetic energy flow, and the displacement-field dynamics.

The following sections examine how the geometry of the fields may regulate the direction of the Poynting vector and how the resulting organization may establish a preferred electromagnetic state within the torus. [3,4]

4. Electric and Magnetic Field Structure

4.1. Spatial Organization of the Electromagnetic Fields

The electromagnetic torus is characterized by two interconnected but geometrically different field structures. The electric field is concentrated predominantly toward the inner region of the toroidal tube, whereas the magnetic field extends over a broader region toward its outer boundary.

These distributions are not regarded as two separate systems. They represent interacting components of a single electromagnetic structure, continuously connected through Maxwell's equations.

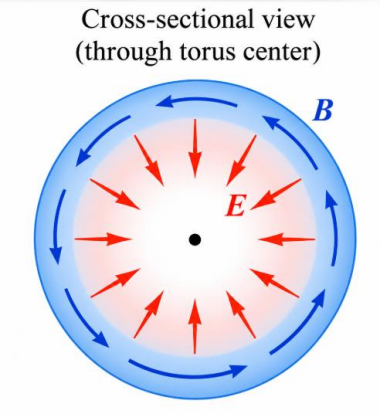


Figure 4. Cross-sectional view of the electromagnetic torus. *The electric field E is concentrated predominantly in the inner region of the toroidal tube and is shown directed toward the center of the cross-section. The magnetic field B occupies the surrounding outer region and follows a closed circular path, indicating its binding and closed-field character. The figure illustrates the different spatial organization and structural roles of the electric and magnetic fields within the proposed toroidal structure.*

The proposed model assigns different structural roles to the two fields. The electric field contributes to the expansive tendency of the torus, while the magnetic field provides a binding tendency associated with its spatial closure.

The distinction is both geometrical and energetic. Electric and magnetic fields can have different maximum energy densities, different effective volumes, and consequently different integrated energy magnitudes.

The structural arrangement is illustrated schematically in Figure 4.

4.2. Electric Field Concentration

The electric field is predominantly concentrated in the central region of the toroidal tube. Its intensity decreases toward the outer region, where the magnetic field becomes increasingly significant.

The electric energy density is:

$$u_E(r,t) = \frac{\varepsilon_0}{2}|E(r,t)|^2$$

The total electric energy is obtained by integration over the toroidal volume:

$$W_E(t) = \frac{\varepsilon_0}{2}\int_V |E(r,t)|^2 \, dV$$

A high local energy density does not necessarily imply a high total energy. The integrated energy depends on both field intensity and the volume over which that intensity is distributed.

In the proposed structure, a relatively narrow electric region may contain a high energy density while contributing less total energy than the more spatially extended magnetic region.

The electric field is associated with an expansive structural tendency. Its spatial concentration produces electromagnetic stresses that depend on the field orientation and the geometry of the surrounding electromagnetic structure.

The detailed calculation of these stresses is reserved for subsequent studies.

4.3. Magnetic Field Distribution and Closure

The magnetic field occupies a broader region of the toroidal tube. In the proposed model, its spatial organization is associated with the closure and binding of the electromagnetic structure.

The magnitude of magnetic energy density is determined by:

$$|u_B(r,t)| = \frac{|B(r,t)|^2}{2\mu_0}$$

Its total magnitude is:

$$|W_B(t)| = \frac{1}{2\mu_0}\int_V |B(r,t)|^2 \, dV$$

The model assigns a negative structural energy contribution to the magnetic field:

$$W_B(t) = -|W_B(t)|$$

This negative sign represents the proposed binding role of the magnetic field, rather than a negative value of conventional Maxwell field energy.

Magnetic field lines are divergence-free and form continuous configurations. The toroidal geometry provides a natural setting for closed magnetic patterns, although their exact spatial arrangement depends on the field solution.

In the proposed structure, magnetic closure is expected to contribute to confinement by opposing the tendency of the electric field to expand the toroidal tube.

The direction and magnitude of the resulting electromagnetic stresses depend on the complete spatial configuration of both fields.

4.4. Overlap Between Electric and Magnetic Fields

The electric and magnetic fields are not separated by a rigid physical boundary. Their regions overlap continuously.

Within the inner region, electric energy density may dominate. Moving toward the outer region, the relative importance of magnetic energy density increases.

A characteristic interface may be identified where the magnitudes of the two energy densities become equal:

$$u_E(r_s) = |u_B(r_s)|$$

Equivalently:

$$\varepsilon_0 |E(r_s)|^2 = \frac{|B(r_s)|^2}{\mu_0}$$

The equality can also be written as:

$$|E(r_s)| = c|B(r_s)|$$

This interface is not necessarily fixed throughout the oscillation cycle. It identifies a location where the two field-energy densities have equal magnitudes at the selected time or within the selected reference distributions.

Equal local densities do not imply equal total electric and magnetic energies, because the fields extend over different effective volumes.

The continuous overlap of the fields is an essential aspect of the electromagnetic organization of the torus.

4.5. Effective Energy Volumes

The spatial distinction between electric and magnetic fields can be expressed through effective energy volumes.

Let u_s represent a reference energy density. Define:

$$V_E^{\text{eff}} = \frac{W_E}{u_s}$$

$$V_B^{\text{eff}} = \frac{|W_B|}{u_s}$$

These quantities characterize the spatial extent of the corresponding energy distributions relative to the common reference density.

The ratio of integrated energy magnitudes is then:

$$\frac{|W_B|}{W_E} = \frac{V_B^{\text{eff}}}{V_E^{\text{eff}}}$$

If the magnetic field occupies a greater effective volume, its integrated energy magnitude can exceed that of the electric field even when the maximum electric energy density is higher.

Thus, a binding-dominated configuration can be represented by:

$$V_B^{\text{eff}} > V_E^{\text{eff}}$$

and consequently:

$$|W_B| > W_E$$

This relation provides a geometrical interpretation of the proposed negative internal energy balance.

The effective volumes are descriptive quantities derived from the field distributions. Their values must ultimately follow from the electromagnetic geometry rather than being independently prescribed.

4.6. Field Geometry and the Poynting Vector

The orientation of the electric and magnetic fields determines the local electromagnetic energy flux through the Poynting vector:

$$S = \frac{1}{\mu_0} E \times B$$

Both the magnitude and direction of this vector depend on the local fields.

In the proposed toroidal structure, the orientation of the Poynting vector is particularly important because it describes the direction of electromagnetic energy transfer within the confined geometry.

The model proposes that changes in the spatial organization of the electric and magnetic fields can alter the direction of the energy flux.

A flux directed toward the inner region may favor inward redistribution, whereas an outward-directed component may favor expansion or outward redistribution. A preferred field configuration is associated with an energy-flow pattern that does not produce a net departure from the characteristic toroidal geometry.

A change in field amplitude alone does not alter the direction of the Poynting vector if the spatial orientations of the fields remain unchanged. Therefore, the proposed regulating mechanism requires an energy-dependent change in field geometry or in their relative orientation.

This connection between field shape, electromagnetic energy flow, and preferred energy density forms the basis of the self-regulation mechanism developed in the following sections.

4.7. A Unified Spatial Structure

The electric and magnetic fields form a common electromagnetic structure whose properties depend on both local field intensities and their spatial organization.

The electric field is proposed to be more concentrated, with a comparatively high local energy density. The magnetic field has a broader distribution and provides the principal binding contribution.

Their overlapping regions connect the two field structures, while the Poynting vector describes their electromagnetic energy-flow dynamics.

The resulting toroidal organization provides the geometrical basis for three central features of the model: electric expansion, magnetic binding, and the regulation of electromagnetic energy density through changes in field geometry.

The next section introduces the preferred electric energy density and examines why a particular energy concentration may correspond to an equilibrium configuration of the electromagnetic torus. [3,7,8]

5. Preferred Electric Energy Density

5.1. The Concept of a Preferred Energy Density

The proposed electromagnetic torus is characterized not only by its geometrical dimensions and the distribution of its fields, but also by a preferred electric energy density.

The model introduces a characteristic value, denoted by u_{E0}, around which the electromagnetic structure tends to organize itself.

The preferred energy density is not defined as the maximum possible electric energy concentration. Instead, it represents a condition in which the spatial configurations of the electric and magnetic fields produce a preferred direction of electromagnetic energy flow.

At this condition, the electromagnetic organization is compatible with the characteristic geometry of the torus.

The existence of a preferred density is therefore associated with the direction of electromagnetic energy transfer, rather than with a prescribed upper limit on the magnitude of the electric field.

5.2. Energy Density and Field Geometry

The electric energy density is determined by the magnitude of the electric field:

$$u_E = \frac{\varepsilon_0 E^2}{2}$$

The magnitude of the magnetic energy density is:

$$|u_B| = \frac{B^2}{2\mu_0}$$

In the proposed model, the magnetic contribution has negative structural orientation:

$$u_B = -|u_B|$$

The electric and magnetic fields have different spatial distributions within the toroidal tube. Their relative concentration, orientation, and overlap determine the local electromagnetic organization.

A change in electric energy density may be accompanied by a change in the transverse distribution of the electric field, the surrounding magnetic configuration, or their relative orientation.

Such geometrical changes can modify the direction of the electromagnetic energy flux.

Consequently, the preferred energy density is considered a property of the complete field structure, rather than an isolated characteristic of the electric field alone.

5.3. Orientation of the Poynting Vector

The local electromagnetic energy flux is described by the Poynting vector:

$$S = \frac{1}{\mu_0} E \times B$$

Its direction is determined by the orientations of the electric and magnetic fields.

In the proposed torus, the electromagnetic energy flux is expected to follow characteristic paths determined by the spatial organization of the fields.

A reference direction can be defined along the preferred local path of electromagnetic energy flow. The Poynting vector may then be decomposed into a component along that path and a component directed toward the interior or exterior of the toroidal structure.

$$S = S_{\parallel e_\parallel} + S_{re_r}$$

Here, $S_\parallel$ denotes the component along the preferred path, while S_r denotes the component associated with radial energy transfer.

At the preferred electric energy density, the model proposes that the unwanted radial component vanishes in the relevant equilibrium description.

$$S_r(u_{E0}) = 0$$

This condition identifies a preferred geometrical orientation of the energy flux.

It does not imply that the magnitude of the Poynting vector must vanish. Electromagnetic energy flow may continue along the preferred path while its radial component is zero.

5.4. Field Organization Below and Above the Preferred Density

The proposed model distinguishes three characteristic situations.

Below the preferred density, the spatial organization of the fields is assumed to produce an inward-directed component of electromagnetic energy flow.

At the preferred density, the energy flux follows the equilibrium path without the corresponding radial deviation.

Above the preferred density, the modified field geometry produces an outward-directed component.

The proposed relationship can be represented as:

$$S_r(u_E < u_{E0}) < 0$$

$$S_r(u_E = u_{E0}) = 0$$

$$S_r(u_E > u_{E0}) > 0$$

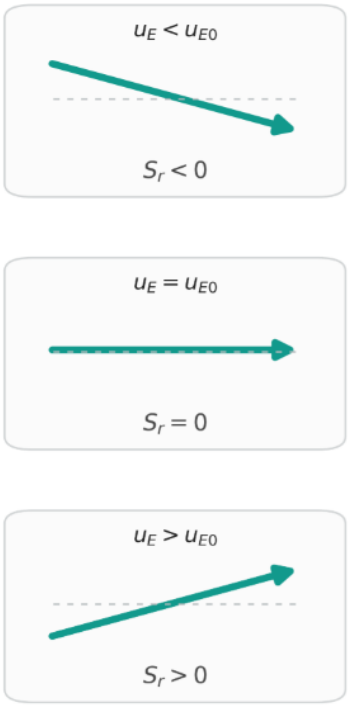


Figure 5. Preferred Electric Energy Density and Direction of Electromagnetic Energy Flow. *The diagram illustrates the proposed relationship between electric energy density and the direction of the Poynting vector. When the electric energy density is below its preferred value $u_E < u_{E0}$, the energy flow has an inward radial component $S_r < 0$, favoring energy concentration. At the preferred density $u_E = u_{E0}$, the radial component vanishes $S_r = 0$, and the energy flow follows the equilibrium path. When the density exceeds its preferred value $u_E > u_{E0}$, the energy flow develops an outward radial component $S_r > 0$, favoring energy redistribution toward the exterior. These three states illustrate the proposed self-regulating mechanism of the electromagnetic torus.*

The positive radial direction is defined toward the exterior of the toroidal tube.

These relations describe the proposed regulating orientation of electromagnetic energy flow. Their validity for a particular toroidal configuration depends on the field distributions and their electromagnetic dynamics.

The three situations are illustrated schematically in Figure 5.

5.5. Preferred Density as a Geometrical Equilibrium

The preferred energy density can be interpreted as a geometrical equilibrium condition.

If the electric energy density decreases below its preferred value, the proposed inward orientation of the energy flux tends to concentrate electromagnetic energy toward the interior.

If the density increases above the preferred value, the outward orientation tends to redistribute energy toward a larger spatial region.

At the preferred density, neither tendency produces a net radial departure from the equilibrium configuration.

For a smooth dependence of the radial flux on energy density, the behavior near the preferred value can be approximated by:

$$S_r(u_E) \approx K_S(u_E - u_{E0})$$

where K_S represents the local sensitivity of the radial energy-flow component to a change in electric energy density.

The proposed restoring orientation corresponds to a positive value of K_S, provided that outward energy transfer reduces the local density and inward transfer increases it.

This relation describes the basic regulating tendency without requiring a detailed calculation of the response to perturbations.

The mathematical stability of the complete toroidal structure, including the coupled evolution of its dimensions and electromagnetic stresses, is addressed in subsequent parts of the study.

5.6. Preferred Density and Toroidal Dimensions

The preferred electric energy density is closely related to the spatial dimensions of the torus.

The major radius R determines the characteristic scale of the closed structure, while the minor radius a influences the transverse concentration of the electric and magnetic fields.

A change in the available transverse volume can alter the electric energy density even when the total electric energy remains unchanged.

For an ideal toroidal volume:

$$V = 2\pi^2 R a^2$$

A characteristic average electric energy density can be defined as:

$$\overline{u_E} = \frac{W_E}{V}$$

However, the local electric energy density is not uniform. The electric field is concentrated more strongly in particular regions of the tube.

Therefore, the preferred density (u_{E0}) should be distinguished from the average density $\overline{u_E}$. The preferred value characterizes the local or effective field organization associated with geometrical equilibrium.

The proposed model does not require the major and minor radii to be uniquely determined by the electric energy alone. Their relationship depends on the combined spatial organization of the electric, magnetic, and displacement-related dynamics.

5.7. Physical Significance of the Preferred Density

The preferred electric energy density introduces a regulating principle into the proposed electromagnetic torus.

Rather than assuming that the toroidal geometry is externally fixed, the model associates its characteristic dimensions with the internal organization of electromagnetic energy flow.

The electric and magnetic fields interact through their spatial orientations, and these orientations determine the direction of the Poynting vector.

A preferred density corresponds to a configuration in which electromagnetic energy flow follows the characteristic equilibrium path of the torus.

Departures from this density are proposed to change the direction of the radial energy-flow component, providing a possible mechanism for returning the electromagnetic structure toward its preferred organization.

The numerical value of u_{E0} and the detailed dependence of field geometry on energy density are not prescribed in this introductory model. They are quantities to be determined from a more complete electromagnetic field description.

The following section examines how the orientation of the Poynting vector may provide a self-regulating mechanism for the energy

density and geometry of the toroidal structure. [2,3]

6. Self-Regulation Mechanism

6.1. Self-Regulation of the Electromagnetic Structure

The proposed electromagnetic torus is not assumed to maintain its geometry through an externally imposed boundary or a rigid material enclosure. Instead, its characteristic organization is attributed to the interaction of electric and magnetic fields and the resulting electromagnetic energy flow.

The model proposes a preferred electric energy density, denoted by u_{E0}, at which the spatial configuration of the fields produces a balanced electromagnetic organization.

When the local electric energy density differs from this preferred value, the relative spatial distributions and orientations of the electric and magnetic fields may change. These changes can alter the direction of the Poynting vector and introduce an inward or outward component of electromagnetic energy flow.

The proposed self-regulation mechanism is based on this relationship between energy density, field geometry, and the direction of electromagnetic energy transfer.

It does not require the instantaneous electric and magnetic contributions to be equal. Instead, it requires that the electromagnetic organization respond to deviations from its preferred configuration.

6.2. Energy-Dependent Field Geometry

The electric and magnetic fields have different characteristic spatial distributions within the toroidal tube.

The electric field is concentrated predominantly toward the inner region, while the magnetic field extends over a broader surrounding region. Their overlapping spatial structure determines the orientation of the electromagnetic energy flux.

The model proposes that these field distributions depend on the local electric energy density.

An increase in electric energy density may alter the transverse concentration, orientation, or spatial overlap of the fields. A decrease may produce a different geometrical adjustment.

Consequently, the Poynting vector may change direction even when the overall toroidal structure remains intact.

The Poynting vector is given by:

$$S = \frac{1}{\mu_0} E \times B$$

If the electric and magnetic field vectors were multiplied only by a common positive amplitude factor, the magnitude of the Poynting vector would change without changing its direction.

Therefore, the regulating mechanism requires a change in the relative orientation or spatial configuration of the fields, rather than a simple proportional change in amplitude.

This energy-dependent geometrical response is a central assumption of the proposed model.

6.3. Radial Component of Electromagnetic Energy Flow

The local Poynting vector can be resolved into components parallel and perpendicular to the preferred electromagnetic path.

Let the radial direction $\hat{e_r}$ point outward from the reference region of the toroidal tube.

The corresponding radial component is:

$$S_r = \frac{1}{\mu_0} (E \times B) \cdot e_r$$

The proposed model associates the sign of this component with the direction of energy redistribution.

Three characteristic states can be distinguished:

Electric energy density	Radial energy-flow component	Proposed response
Below u_{E0}	Inward, $S_r < 0$	Energy concentration
At u_{E0}	Balanced, $S_r = 0$	Preferred organization
Above u_{E0}	Outward, $S_r > 0$	Energy redistribution and expansion

At the preferred density, electromagnetic energy flow follows the characteristic equilibrium path without a net radial departure from the organized structure.

At a lower density, the proposed inward component tends to increase energy concentration.

At a higher density, the outward component tends to redistribute the energy over a larger region.

The resulting behavior provides a possible negative-feedback mechanism that favors the preferred energy-density condition.

For an oscillating electromagnetic field, the relevant radial component may need to be interpreted through its time average or through the net energy exchanged across a selected boundary. This distinction becomes important in a detailed dynamical treatment.

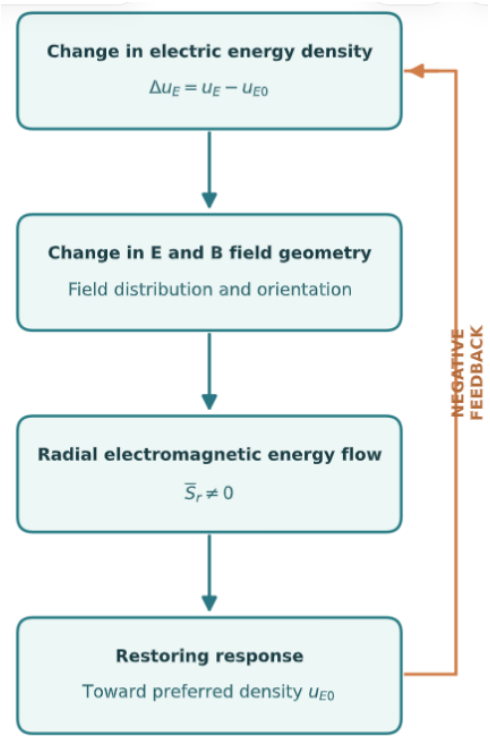


Figure 6. Self-Regulation of Electric Energy Density. *The diagram illustrates the proposed negative-feedback mechanism of the electromagnetic torus. A deviation of the electric energy density from its preferred value u_{E0} changes the spatial distribution and relative orientation of the electric and magnetic fields. This modifies the radial component of the Poynting vector, producing an inward or outward electromagnetic energy flow. The resulting energy redistribution may reduce the initial deviation and restore the preferred electromagnetic organization of the torus.*

6.4. Local Energy Redistribution

The electromagnetic energy flow is governed by the spatial and temporal behavior of the fields.

In conventional vacuum electrodynamics, the local energy balance is described by Poynting's theorem:

$$\frac{\partial u_M}{\partial t} + \nabla \cdot S = 0$$

where the conventional Maxwell energy density is:

$$u_M = \frac{\varepsilon_0 E^2}{2} + \frac{B^2}{2\mu_0}$$

The proposed toroidal model introduces an additional signed interpretation of electromagnetic energy and a displacement-related contribution. Its internal energy balance is developed separately in subsequent sections.

For the regulation mechanism, the important geometrical observation is that an inward or outward component of the Poynting vector can redistribute electromagnetic energy between neighboring regions.

Such redistribution does not necessarily imply a loss of energy from the complete toroidal structure. Energy may move between internal regions while remaining confined within the overall electromagnetic configuration.

The effect of this redistribution on the local electric energy density depends on the divergence of the energy flux, not on the direction of the Poynting vector alone.

Accordingly, the proposed regulating mechanism requires an appropriate spatial variation of the electromagnetic energy flow.

6.5. A Preferred State and Negative Feedback

Let the deviation of the local electric energy density from its preferred value be:

$$\Delta u_E = u_E - u_{E0}$$

Near the preferred state, the model proposes an approximate dependence of the radial energy-flow component on this deviation:

$$\overline{S}_r \approx K_S \Delta u_E$$

Here, $\overline{S}_r$ represents an appropriately averaged radial energy-flow component and K_S describes its local sensitivity to changes in electric energy density.

For $K_S > 0$, the proposed energy flow is outward above the preferred density and inward below it.

To produce actual negative feedback, this directional response must also reduce the deviation of local energy density from u_{E0}.

In a simplified description, such behavior can be represented by:

$$\frac{d(\Delta u_E)}{dt} = -\Gamma_E \Delta u_E$$

where $\Gamma_E > 0$ is an effective regulating coefficient.

This equation is a phenomenological representation of the proposed relaxation mechanism. It is not an independent consequence of the Maxwell equations and does not specify the detailed dynamics of the complete toroidal structure.

Its purpose is to illustrate the feedback principle: deviations from the preferred energy density are associated with responses that tend to reduce those deviations.

The detailed origin and magnitude of Γ_E depend on the electromagnetic field geometry and are reserved for subsequent analysis.

6.6. Relationship Between Energy Density and Toroidal Geometry

The preferred electric energy density is related to the characteristic dimensions of the torus.

The major radius R determines the overall scale of the closed structure, whereas the minor radius a determines its transverse spatial extent.

The volume of an ideal torus is:

$$V = 2\pi^2 R a^2$$

A change in either radius changes the geometrical volume available for electromagnetic organization.

However, electric and magnetic energies are not distributed uniformly throughout that volume. Their effective energy volumes depend on the spatial distributions of the fields.

For this reason, the relationship between energy density and toroidal dimensions cannot generally be reduced to a simple inverse proportionality between total energy and geometrical volume.

The proposed self-regulation mechanism instead involves the combined adjustment of field concentration, field orientation, and characteristic toroidal dimensions.

The preferred energy density therefore represents a condition of electromagnetic organization rather than a prescribed geometrical size.

A torus may retain its characteristic organization while its dimensions exhibit small periodic variations during electromagnetic oscillation.

The detailed magnitude of these variations and the restoring forces acting on the toroidal geometry are investigated in subsequent parts of the study.

6.7. The Role of Magnetic Binding

The model assigns opposite structural energy signs to the electric and magnetic fields.

The electric contribution is positive:

$$u_E = \frac{\varepsilon_0 E^2}{2}$$

The magnetic contribution is assigned a negative binding sign:

$$u_B = -\frac{B^2}{2\mu_0}$$

The absolute magnitude of magnetic energy is calculated using the conventional Maxwell expression.

Within the proposed interpretation, magnetic binding provides a structural tendency that opposes unrestricted expansion of the electric field.

The magnetic field also participates in determining the direction of the Poynting vector, since electromagnetic energy flow depends on the vector product of the electric and magnetic fields.

Thus, magnetic binding and electromagnetic energy-flow orientation are interconnected aspects of the proposed toroidal organization.

The negative structural energy sign is a defining postulate of the model. The actual electromagnetic forces depend on field orientation and the Maxwell stress tensor; their detailed relationship to the proposed binding interpretation is examined in subsequent parts.

6.8. Self-Regulation Without a Rigid Boundary

The principal feature of the proposed mechanism is that it does not require a material wall or a fixed mechanical enclosure.

The electromagnetic structure is envisaged as maintaining its organization through the interaction of its internal fields.

The electric field contributes to expansion, the magnetic field to binding, and their changing spatial orientations influence the direction of electromagnetic energy flow.

The preferred energy density is associated with a configuration in which these processes produce a balanced geometrical organization.

Small departures from this state may change the direction of radial energy redistribution and thereby favor a return toward the preferred field configuration.

This describes a possible self-regulating electromagnetic structure in which confinement arises from the organization of the fields themselves.

The proposed displacement field provides an additional dynamical component, particularly in the alternating phases of electromagnetic oscillation. Its role in maintaining the continuity of motion and internal energy exchange is introduced in the next section.

The present chapter establishes the conceptual mechanism of self-regulation. Its quantitative validity and stability conditions remain subjects for the subsequent mathematical development of the model. [2,3]

7. Displacement Field

7.1. The Third Dynamic Component of the Electromagnetic Torus

The proposed electromagnetic torus contains two principal field structures: the electric field, associated with expansion, and the magnetic field, associated with binding.

Their interaction produces a continuously changing electromagnetic configuration. During periodic oscillation, the electric field decreases while the magnetic field increases, and vice versa.

The proposed model introduces a third dynamic component, referred to as the **displacement field**.

The displacement field is associated with the motion and inertia of the electromagnetic structure during these transitions. Its proposed function is to preserve the continuity of internal motion and participate in the transfer of energy between the electric and magnetic contributions.

Unlike a static balance between opposing forces, this interpretation describes the torus as a continuously operating electromagnetic system.

The displacement field is therefore introduced as a dynamic component of the model rather than an additional geometrical boundary.

7.2. Maxwell's Displacement Current

Maxwell's equations introduce displacement current through the time variation of the electric field.

In vacuum, the displacement-current density is:

$$J_D = \varepsilon_0 \frac{\partial E}{\partial t}$$

Ampère's–Maxwell's equation relates it to the spatial variation of the magnetic field:

$$\nabla \times B = \mu_{0 J_D}$$

Thus, the displacement current is connected to both the temporal evolution of the electric field and the spatial structure of the magnetic field.

Faraday's equation provides the complementary relationship:

$$\nabla \times E = -\frac{\partial B}{\partial t}$$

These equations describe mutually connected electric and magnetic dynamics.

In conventional electrodynamics, displacement current is not an independent material current with its own additional energy reservoir. It is determined by the changing electric field.

The proposed toroidal model investigates a broader interpretation: a displacement-related dynamical field possessing an effective inertial role within the organized electromagnetic structure.

To distinguish this proposed field from Maxwell's displacement-current density, it is denoted by P, while J_D retains its conventional Maxwell meaning.

7.3. Inertia of the Displacement Field

The central proposed property of the displacement field is inertia.

During electromagnetic oscillation, the interaction of the electric and magnetic fields is assumed to accelerate and decelerate the displacement-related motion.

When the electromagnetic interaction supports the existing motion, energy is transferred to the displacement field.

When the electromagnetic interaction opposes that motion, the displacement field is decelerated and returns energy to the electromagnetic system.

Importantly, the direction of the electromagnetic interaction and the direction of the displacement-field motion need not be identical.

The displacement field may continue moving in its existing direction after the electromagnetic driving action has reversed.

This proposed inertial behavior is particularly important at the extrema of the electric and magnetic oscillations.

When the electric field reaches its maximum and the magnetic field momentarily vanishes, the displacement field is proposed to retain its motion and contribute to maintaining the spatial organization of the torus.

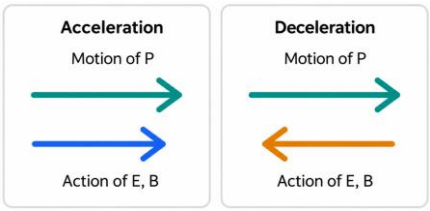


Figure 7. Displacement-Field Inertia and Electromagnetic Energy Transfer. *The diagram illustrates the proposed inertial behavior of the displacement field P during electromagnetic oscillation. During acceleration (left), the electromagnetic interaction acts in the direction of displacement-field motion, transferring energy to the field. During deceleration (right), the electromagnetic interaction acts in the opposite direction, causing the displacement field to release energy. Due to its proposed inertia, the displacement field continues moving in the same direction even after the electromagnetic driving action reverses. The figure illustrates the distinction between the direction of motion and the direction of energy transfer, which is central to the proposed mechanism of periodic electromagnetic energy exchange.*

Similarly, at the magnetic maximum, the displacement field can retain substantial motion in the opposite direction.

Its kinetic activity is therefore associated with both electromagnetic extrema, even though the directions of its motion may be opposite.

The model interprets this behavior as a possible mechanism for maintaining continuity of the toroidal structure throughout the complete oscillation cycle.

7.4. The Poynting Vector and Displacement-Field Dynamics

The electromagnetic energy flux is described by the Poynting vector:

$$S = \frac{1}{\mu_0} E \times B$$

The vector describes the direction and magnitude of electromagnetic energy transport.

The proposed model associates this energy flow with the transfer of energy to and from the displacement field.

The essential distinction is that the Poynting vector does not directly prescribe the direction of displacement-field motion. Instead, its relevant component is proposed to determine whether the displacement field gains or loses energy.

Let S_p represent the component of the Poynting vector associated with the displacement-field energy exchange.

The model introduces the phenomenological relationship:

$$\frac{dW_p}{dt} = \kappa S_p$$

Here, κ is an effective coupling coefficient with the dimensions required to convert energy flux into power.

When S_p is positive, the signed displacement-energy contribution increases. When S_p is negative, it decreases.

The physical direction of displacement-field motion may remain unchanged during either process.

This distinction between motion and energy transfer is central to the proposed interpretation.

The relationship provides an introductory description of the coupling. A complete derivation requires the spatial distribution of electromagnetic momentum and the corresponding interaction with the proposed displacement field.

7.5. Periodic Energy Exchange

Consider a simplified harmonic representation of the electric and magnetic fields at a selected location:

$$E(t) = E_0 \cos(\omega t)$$

$$B(t) = B_0 \sin(\omega t)$$

For fixed relative field orientations, the relevant component of the Poynting vector is proportional to the product of the two fields:

$$S_p(t) = S_0 \sin(2\omega t)$$

The proposed displacement-energy exchange therefore satisfies:

$$\frac{dW_p}{dt} = P_0 \sin(2\omega t)$$

Integration gives:

$$W_p(t) = C - \frac{P_0}{2\omega} \cos(2\omega t)$$

Here, C represents a constant reference contribution.

The important consequence is the phase relationship.

The displacement-energy contribution reaches a maximum or minimum whenever the relevant Poynting component passes through zero and changes sign.

These transitions occur at the characteristic electric and magnetic extrema of the simplified harmonic model.

The displacement-energy contribution therefore oscillates with twice the frequency of the electric and magnetic field amplitudes.

This relationship provides the mathematical basis for the displacement-energy curve presented in the following chapter.

The equation describes a proposed energy-transfer mechanism. Its coupling coefficient and physical realization remain to be established by a complete field model.

7.6. Direction of Motion and Sign of Energy Transfer

The direction of motion and the sign of energy transfer are different physical quantities.

A moving system may continue in one direction while the driving interaction acts against its motion.

During such deceleration, the system loses kinetic energy without immediately reversing its velocity.

The same principle is applied to the proposed displacement field.

A positive energy-transfer rate indicates that the field receives energy from its interaction with the electromagnetic structure.

A negative energy-transfer rate indicates that the field returns energy to that structure.

For an effective force acting on the displacement motion, the corresponding power can be expressed as:

$$P_p = F_{EB} \cdot v_p$$

Thus, acceleration and deceleration are distinguished by the relationship between force and velocity, rather than by the direction of velocity alone.

The kinetic energy associated with the proposed motion remains nonnegative. The signed displacement-energy contribution W_p, used in the toroidal energy balance, represents a different quantity and may take either sign.

A complete description must connect these quantities through the dynamics of the displacement field.

7.7. Continuity of the Toroidal Structure

The proposed displacement field has an additional geometrical role.

At the electric maximum, the magnetic field may momentarily vanish in the simplified harmonic description. The electric field retains its expansive structural tendency, while the usual magnetic contribution to confinement is temporarily absent.

The proposed inertia of the displacement field is expected to contribute to the continuity of the electromagnetic organization during this interval.

At the magnetic maximum, the electric field momentarily vanishes, but the displacement field may retain motion in the opposite direction.

In both cases, the toroidal structure is assumed to preserve its essential organization during the transition from one electromagnetic extreme to the other.

This does not require the toroidal dimensions to remain perfectly unchanged.

Small variations in the major and minor radii may accompany the internal oscillation while the overall structure remains organized around its characteristic dimensions.

The detailed forces and stability conditions associated with these variations are investigated in subsequent parts of the study.

In Part 1A, the displacement field is introduced primarily to explain the proposed continuity of internal electromagnetic motion.

7.8. The Displacement Field and Internal Energy Balance

The proposed toroidal model assigns positive structural energy to the electric field and negative binding energy to the magnetic field.

The displacement field contributes an additional signed energy term W_p.

The combined internal energy balance is:

$$W_j = W_E + W_B + W_p$$

The model proposes that the internal energy remains constant during periodic oscillation:

$$W_j = -W_v = \text{const.}$$

where $W_v > 0$ represents the magnitude of the residual negative binding energy.

Accordingly, the displacement-energy contribution must satisfy:

$$W_p = -W_v - W_E - W_B$$

The electric and magnetic contributions vary throughout the oscillation, while the displacement contribution is proposed to compensate their signed changes.

The resulting internal balance remains constant.

This is a defining energy postulate of the model. Its correspondence with the physical conservation of energy and the inertial properties of the complete structure requires further examination.

The following chapter illustrates this proposed energy organization through a diagram showing the electric and magnetic oscillations,

their signed energy contributions, the displacement-energy exchange, and the constant internal energy level.

7.9. Summary

The displacement field is introduced as the third dynamic component of the proposed electromagnetic torus.

Its principal role is to provide continuity of internal motion and a mechanism for exchanging energy with the electric and magnetic fields.

The model associates the sign of displacement-energy change with the corresponding direction of electromagnetic energy transfer, while the actual direction of displacement-field motion is governed by its proposed inertia.

The displacement field is therefore particularly relevant during the alternating electric and magnetic extrema, when one of the two conventional field amplitudes momentarily vanishes.

Together, electric expansion, magnetic binding, and displacement-related motion form the proposed dynamical organization of the electromagnetic torus.

The following chapter presents the complete periodic energy exchange and its graphical interpretation. [1,3]

8. Electromagnetic Oscillation

8.1. Periodic Dynamics of the Electromagnetic Torus

The proposed electromagnetic torus is a continuously oscillating structure in which the electric, magnetic, and displacement-related components participate in a common periodic process.

The electric and magnetic fields alternate between their characteristic extrema. When the electric field reaches its maximum magnitude, the magnetic field momentarily vanishes. A quarter of an oscillation period later, the electric field reaches zero while the magnetic field reaches its maximum magnitude.

The proposed displacement field participates in this process through its inertia and its interaction with the electromagnetic energy flow.

The model therefore describes electromagnetic oscillation not simply as an exchange between two field-energy magnitudes, but as the coordinated evolution of three signed energy contributions.

Its characteristic feature is that the individual contributions vary periodically while their combined internal energy remains constant.

8.2. Electric and Magnetic Field Oscillation

Consider a representative harmonic oscillation at a selected location or within an effective field description.

The electric and magnetic field amplitudes can be expressed as:

$$E(t) = E_0 \cos(\omega t)$$

$$B(t) = B_0 \sin(\omega t)$$

The two fields are phase-shifted by one quarter of a period.

The electric field reaches its extrema when the magnetic field passes through zero, and vice versa.

The corresponding energy contributions depend on the squares of the field amplitudes.

For the positive electric energy contribution:

$$W_E(t) = A \cos^2(\omega t)$$

For the negative magnetic binding contribution:

$$W_B(t) = -D \sin^2(\omega t)$$

Here, A and D are positive quantities representing the maximum magnitudes of the

corresponding integrated energy contributions.

The values of A and D are determined by the spatial distributions of the fields and need not be assumed equal within the proposed model.

In particular, the broader spatial distribution of the magnetic field may produce a greater integrated energy magnitude than the more concentrated electric field.

The example developed below uses a magnetic energy magnitude greater than the electric energy magnitude to illustrate the proposed binding-dominated organization.

8.3. The Signed Electric and Magnetic Energy Balance

The combined signed contribution of the electric and magnetic fields is:

$$W_{EB}(t) = W_E(t) + W_B(t)$$

Substituting the harmonic energy functions gives:

$$W_{EB}(t) = A\cos^2(\omega t) - D\sin^2(\omega t)$$

Using the double-angle identities, this becomes:

$$W_{EB}(t) = \frac{A-D}{2} + \frac{A+D}{2}\cos(2\omega t)$$

The expression contains a constant component and a periodically varying component.

When D exceeds A, the constant component is negative. The magnetic binding contribution then dominates the electric contribution in the time average of this simplified model.

However, the instantaneous signed balance continues to oscillate between a positive electric extreme and a negative magnetic extreme.

The negative magnetic energy is a defining structural interpretation of the proposed model. The conventional Maxwell magnetic energy density remains nonnegative.

8.4. Displacement-Field Energy Exchange

The displacement field is proposed to provide a third contribution to the electromagnetic oscillation.

Its energy changes according to the electromagnetic interaction between the electric and magnetic fields.

The Poynting vector is:

$$S = \frac{1}{\mu_0} E \times B$$

For the simplified harmonic fields, a selected component of the electromagnetic energy flux varies proportionally to:

$$S_p(t) = S_0 \sin(2\omega t)$$

The proposed displacement-field energy exchange is associated with this periodic flux.

In a phenomenological representation:

$$\frac{dW_p}{dt} = P_0 \sin(2\omega t)$$

Integration gives:

$$W_p(t) = C - \frac{P_0}{2\omega}\cos(2\omega t)$$

The displacement-energy contribution therefore reaches its extrema when the selected Poynting component passes through zero and changes sign.

When the electromagnetic energy-transfer component has one direction, the signed displacement-energy contribution increases. When its direction reverses, the contribution decreases.

The direction of the displacement field's motion does not necessarily reverse at the same instant.

Its proposed inertia allows its motion to continue while the electromagnetic interaction changes from acceleration to deceleration or vice versa.

Thus, the change in direction of electromagnetic energy transfer primarily determines the sign of the energy-transfer rate, rather than directly prescribing the direction of displacement-field motion.

8.5. Constant Internal Energy Balance

The model proposes that the signed electric, magnetic, and displacement contributions form a constant internal energy balance:

$$W_j = W_E + W_B + W_p$$

For a binding-dominated torus:

$$W_j = -W_v = \text{const.}$$

Here, W_v is a positive quantity representing the magnitude of the residual negative binding balance.

The displacement contribution required by this condition is:

$$W_p(t) = -W_v - W_E(t) - W_B(t)$$

Substituting the harmonic field-energy functions gives:

$$W_p(t) = -W_v - A\cos^2(\omega t) + D\sin^2(\omega t)$$

Equivalently:

$$W_p(t) = \frac{D-A}{2} - W_v - \frac{A+D}{2}\cos(2\omega t)$$

For the particular choice:

$$W_v = \frac{D-A}{2}$$

the expression simplifies to:

$$W_p(t) = -\frac{A+D}{2}\cos(2\omega t)$$

The resulting displacement-energy contribution has the opposite oscillating component to the combined signed electric and magnetic energies.

Their algebraic sum therefore remains constant throughout the complete period.

This relation establishes the required energy balance of the proposed model. Its interpretation as an independent conservation law and its relationship to the complete electromagnetic dynamics are investigated in subsequent parts.

8.6. Illustrative Energy Cycle

To illustrate the energy exchange, consider a normalized example in which the maximum magnitude of magnetic binding energy exceeds the maximum electric energy by a factor of 1.69.

Choose:

$$A = W_0$$

$$D = 1.69W_0$$

The electric and magnetic energy contributions are:

$$W_E(t) = W_0\cos^2(\omega t)$$

$$W_B(t) = -1.69W_0\sin^2(\omega t)$$

The constant internal balance is chosen as:

$$W_j = -0.345W_0$$

The corresponding displacement-energy contribution is:

$$W_p(t) = -1.345W_0\cos(2\omega t)$$

The six quantities are illustrated in Figure 8.

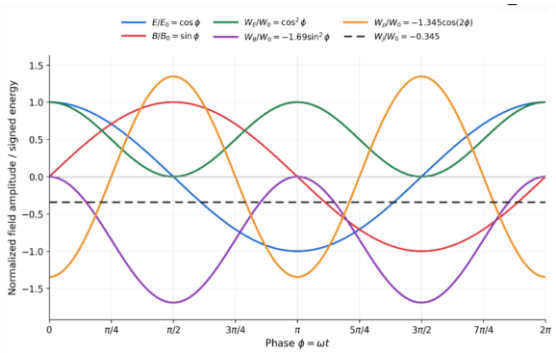


Figure 8. Electromagnetic Oscillation and Signed Energy Exchange. The diagram shows the periodic variation of electric and magnetic fields, their signed energies W_E and W_B and the displacement-energy contribution W_p. The three energy contributions vary while

maintaining the proposed constant internal balance $W_j = -0.345W_0$.

The energy contributions at representative phases are summarized in Table 1.

Phase	Electric energy	Magnetic binding energy	Displacement energy	Total
0	+1.000	0	−1.345	−0.345
π/4	+0.500	−0.845	0	−0.345
π/2	0	−1.690	+1.345	−0.345
3π/4	+0.500	−0.845	0	−0.345
π	+1.000	0	−1.345	−0.345
5π/4	+0.500	−0.845	0	−0.345
3π/2	0	−1.690	+1.345	−0.345
7π/4	+0.500	−0.845	0	−0.345
2π	+1.000	0	−1.345	−0.345

Table 1. Normalized signed energy contributions during one electromagnetic oscillation period. Energy values are expressed in units of W_o.

The table illustrates the defining feature of the proposed energy balance: the individual contributions change substantially, whereas their signed sum remains unchanged.

The numerical factor 1.69 is an illustrative geometrical energy ratio, not a universal constant derived for all electromagnetic toroidal structures.

8.7. The Role of Displacement-Field Inertia at Electromagnetic Extrema

The proposed displacement field is particularly important when one of the two conventional field amplitudes passes through zero.

At an electric-field maximum, the magnetic field is momentarily zero. In the proposed model, the displacement field retains dynamical activity acquired during the preceding part of the oscillation.

Its inertia is proposed to support the continuity of the toroidal organization while the magnetic field begins to develop again.

At a magnetic-field maximum, the electric field is momentarily zero. The displacement field may retain substantial motion in the opposite direction, again contributing to the continuity of the electromagnetic structure.

The extrema of the signed displacement-energy contribution coincide with these characteristic phases in the simplified model.

The displacement contribution W_p must nevertheless be distinguished from ordinary nonnegative kinetic energy. Its sign represents its contribution to the proposed internal energy balance, while the kinetic energy associated with any effective motion depends on the magnitude of that motion.

The detailed relationship between displacement-field motion, kinetic energy, and structural forces is examined in subsequent studies.

8.8. Local Oscillation and Spatial Continuity

The energy cycle described above represents the temporal behavior of the model at a selected location or within an effective field description.

The proposed toroidal structure is envisaged as an organized electromagnetic system in which corresponding field processes occur throughout the toroidal volume.

The model associates this organization with local transformations among electric, magnetic, and displacement-related contributions.

For a local version of the signed balance, the corresponding energy densities may be written as:

$$u_j = u_E + u_B + u_p$$

The proposed locally constant condition is:

$$\frac{\partial u_j}{\partial t} = 0$$

This condition represents the intended behavior of the expanded model. It is not automatically implied by Maxwell's equations, which describe local electromagnetic energy conservation through the divergence of the Poynting vector.

A circulating energy flux may exist within a confined electromagnetic structure without producing a net energy loss from the structure as a whole. Local constancy of energy density, however, imposes an additional requirement on the spatial organization of the energy flows.

The detailed spatial consistency of this requirement is considered separately from the introductory energy-cycle illustration.

8.9. Interpretation of the Oscillation

The proposed toroidal oscillation combines three related physical processes.

The electric field periodically develops and diminishes its expansive contribution.

The magnetic field periodically develops and diminishes its binding contribution.

The displacement field is proposed to provide inertial continuity and a signed energy contribution associated with the alternating electromagnetic energy-transfer process.

The resulting model does not depend on a static equality between electric and magnetic contributions at every moment.

Instead, the toroidal structure is represented as a dynamic organization whose internal components oscillate while the proposed combined signed energy remains constant.

The oscillation diagram is therefore not merely a graphical representation of changing field amplitudes. It illustrates the proposed relationship between electromagnetic field dynamics, displacement-related energy transfer, and the persistence of the toroidal organization.

The numerical example establishes an internally consistent algebraic energy cycle. The derivation of a complete self-confined electromagnetic field solution and the corresponding stability conditions are reserved for subsequent parts of this work. [1,3]

9. Discussion

9.1. Unified Electromagnetic Organization

The proposed electromagnetic torus combines a closed geometry, spatially differentiated electric and magnetic fields, and displacement-related dynamics within a single oscillating structure.

The electric field is predominantly concentrated toward the inner region of the toroidal tube, whereas the magnetic field occupies a broader region. Their different spatial distributions determine their integrated energy magnitudes and contribute to the proposed organization of electric expansion and magnetic binding.

The displacement field introduces an additional dynamical component associated with inertia and the continuity of internal electromagnetic motion.

The central concept is that the torus is not maintained by a static balance of opposing fields. Instead, its characteristic geometry is proposed to persist through their coordinated oscillation, electromagnetic energy redistribution, and displacement-related inertia.

9.2. Signed Energy and Dynamic Balance

The model distinguishes between electromagnetic energy magnitude and structural energy sign. Conventional Maxwell expressions determine the nonnegative magnitudes of electric and magnetic field energies, while the proposed interpretation

assigns positive energy to electric expansion and negative binding energy to the magnetic contribution.

The broader spatial distribution of the magnetic field may produce a greater integrated energy magnitude than that of the more concentrated electric field, allowing a binding-dominated configuration.

During oscillation, the electric, magnetic, and displacement-related energy contributions vary periodically. Their proposed signed internal balance is:

$$W_j = W_E + W_B + W_p = -W_v = \text{const.}$$

This formulation permits substantial periodic changes in individual contributions while preserving their algebraic sum.

The energy cycle is associated with local electromagnetic transformations rather than the progressive transport of a single energy packet around the major circumference of the torus.

The constant signed balance is a defining property of the proposed model and is distinct from conventional Maxwell energy conservation. Establishing its complete physical interpretation requires a consistent account of displacement-field energy, electromagnetic stresses, and momentum.

9.3. Preferred Energy Density and Self-Regulation

The proposed preferred electric energy density u_{E0} connects electromagnetic field geometry with the direction of energy flow.

At the preferred density, the Poynting vector is expected to follow the characteristic equilibrium path of the toroidal structure. Departures from this density are proposed to modify the spatial distributions or relative orientations of the electric and magnetic fields, producing inward or outward components of electromagnetic energy flow.

These components may redistribute energy and favor a return toward the preferred organization.

The regulating mechanism therefore depends on changes in field geometry, not merely on changes in field amplitudes. Its quantitative description requires the relationship between energy density, field orientation, and spatial energy-flow divergence.

In this interpretation, the toroidal geometry is not imposed by a material boundary but is associated with the internal organization of its electromagnetic fields.

9.4. Displacement-Field Inertia and Structural Continuity

The proposed displacement field extends the description beyond Maxwell's conventional displacement current by introducing an additional inertial role.

During electromagnetic oscillation, the interaction of the electric and magnetic fields is proposed to alternately accelerate and decelerate displacement-related motion.

A reversal of electromagnetic energy transfer does not necessarily produce an immediate reversal of that motion. The displacement field may continue moving while returning energy to the electromagnetic structure.

This distinction becomes particularly important at the electric and magnetic extrema, when one of the conventional field amplitudes momentarily vanishes.

The proposed inertia of the displacement field contributes to the continuity of the toroidal organization throughout these transitions.

Consequently, structural persistence does not require instantaneous equality between electric expansion and magnetic binding. Small periodic variations of the major and minor radii may accompany the oscillation while the overall electromagnetic organization remains intact.

The physical dynamics of the displacement field and the conditions for bounded geometrical oscillations require further quantitative analysis.

9.5. Significance and Further Development

Part A1 establishes a common geometrical and energetic framework for the proposed electromagnetic torus.

Its principal elements are the closed toroidal geometry, the different spatial distributions of electric and magnetic fields, their signed energy contributions, the preferred electric energy density, and the inertial role assigned to the displacement field.

Together, these elements describe a possible self-organized electromagnetic structure whose internal energy contributions oscillate while maintaining a proposed constant signed balance.

The subsequent parts examine the quantitative conditions for this organization, including electromagnetic stresses, restoring forces, stability under perturbations, and the interaction and merging of toroidal structures.

A further objective is to establish the relationship between internal electromagnetic dynamics, energy conservation, and inertia.

The central proposition of the model is that a toroidal electromagnetic structure may maintain its organization through the continuous interaction of electric expansion, magnetic binding, and displacement-related motion, rather than through a static equilibrium of the fields.

10. Conclusions

This paper introduces a geometrical and energetic model of a toroidal electromagnetic structure based on the coordinated interaction of electric, magnetic, and displacement-related fields.

The proposed structure is characterized by a closed toroidal geometry, with a major radius R and a minor radius a. The electric and magnetic fields have different but overlapping spatial distributions. The electric field is predominantly concentrated in the inner region of the toroidal tube, while the magnetic field extends over a broader region and is associated with the binding organization of the structure.

A central feature of the model is the distinction between electromagnetic energy magnitude and structural energy sign. The conventional Maxwell expressions are retained for calculating the magnitudes of electric and magnetic energy. The proposed interpretation assigns positive energy to the electric contribution and negative binding energy to the magnetic contribution. This signed description provides a common framework for representing electric expansion and magnetic confinement within the toroidal geometry.

The model also introduces a preferred electric energy density. Its regulating mechanism is associated with the spatial orientation of the electric and magnetic fields and the resulting direction of the Poynting vector. Changes in field geometry may redirect electromagnetic energy flow toward the interior or exterior of the torus, providing a proposed mechanism for maintaining a preferred electromagnetic organization.

A further element is the displacement field, introduced as a third dynamic component associated with inertia and internal energy exchange. Its proposed motion continues through the alternating electric and magnetic extrema, while the direction of electromagnetic energy transfer determines whether the displacement-energy contribution increases or decreases. This mechanism provides a possible explanation for the continuity of the toroidal structure throughout the oscillation cycle.

The resulting energy model combines positive electric energy, negative magnetic binding

energy, and a signed displacement-energy contribution. Their algebraic sum is proposed to remain constant, allowing the internal electromagnetic components to oscillate while preserving a characteristic internal energy balance.

Together, these elements establish a unified conceptual description of electromagnetic toroidal organization. The model connects the geometry of the fields, their energy distributions, the direction of electromagnetic energy flow, and the proposed inertia of the displacement field within a single physical framework.

Part A1 establishes this framework and illustrates its principal relationships. Subsequent parts develop the quantitative conditions for stable toroidal confinement, the response to disturbances, and the interaction and merging of electromagnetic toroidal structures.

The central proposition is that electromagnetic confinement may arise from the dynamic organization of the fields themselves, with electric expansion, magnetic binding, and displacement-related inertia forming complementary aspects of a closed electromagnetic structure.

The proposed toroidal electromagnetic structure may thus represent a fundamental building block of matter, providing a common electromagnetic foundation for the organization of material particles and light.

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