Electro-kinetic Potential in the Earth's A Field

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1. Introduction

The magnetic field of the Earth (here taken to be truly spherical) can be considered to emanate from a magnetic dipole of magnitude m=8.24×10^{22} Am^2 at its centre [1]. Although the magnetic field at the surface is rather weak, the same cannot be said for the magnetic scalar and vector potentials. The huge magnetic scalar potential is considered in my paper [9] where the possibility exists to use it for gaining electro-magnetic thrust, and possibly also overunity systems. This present paper looks at the magnetic vector potential.

The formula for the magnetic vector potential **A** at the (assumed) spherical Earth's surface is

$$|\mathbf{A}| = \frac{\mu_0 m \cos\theta}{4\pi r^2} \tag{1}$$

where r is the radius (6.37×10^6 m) and θ is the latitude. In this paper we use bold script to denote a vector, and the vector **A** everywhere points towards the west. At the equator **A**=203 Weber/m while at the poles **A**=0. Note that 203 Weber/m is a huge value unlikely to be seen in a laboratory (to get an appreciation of this you would find that value of **A** field at the cylindrical surface of a huge fully-magnetized piece of iron that is 400m in diameter, 4km long and weighing 4 giga-tonnes!). Surprisingly, few people are aware of this aspect of the Earth's magnetism and little attention has been given to the possibility of employing this as a useful resource. Perhaps the reason for this is current scientific dogma that the magnetic **B** and **H** fields are the primary fields responsible for magnetic effects, the **A** field being merely a mathematical artefact used for calculation purposes. This is not the only paper to challenge that position and consider possible means for extracting energy via any **A** field, but is the first to offer means for using the Earth's **A** field. For simplicity the **A** field is considered to be spatially uniform in the laboratory, its actual non-uniformity (that produces the Earth's relatively small magnetic **B** field values) is ignored.

2. The role of the A field in classical voltage induction.

Classical electrodynamics recognizes two forms of voltage induction into a conductor associated with magnetic fields, *Transformer* induction and *Motional* induction.

- *Transformer* induction occurs when both the source of the magnetic field and the conductor are stationary, but the magnetic field changes with time. In typical transformers the magnetic field is confined within a core, while the conductor is outside the core where there is no magnetic field. This absence of any magnetic field *at the conductor* demonstrates that such fields cannot be considered primary when dealing with induction effects. The induction is explained by the presence of the magnetic vector potential **A** outside the core. **A** is also changing with time giving rise to an electric field **E** where

  $$\mathbf{E} = -\frac{\partial \mathbf{A}}{\partial t} \tag{2}$$

  and it is this **E** field that actually causes the induction, that drives the mobile conduction electrons in the conductor. Because the **A** vectors (and therefore also **E** vectors) form concentric loops around the core, where for any loop the instantaneous closed path integral is equal to the instantaneous magnetic flux Φ in the core, it has become common practice to denote the induction as a voltage for a single turn which is equal to $\frac{\mathrm{d}\Phi}{\mathrm{d}t}$ (volts/turn), thus hiding the real cause for the induction, the **A** field. Note that (2) is a partial derivative that contains only time increments ∂t, there are no spatial increments.

- *Motional* induction occurs when there is relative motion between a conductor and the source of the magnetic field. This is expressed as an induction **E** field created by vector multiplication of the velocity vector **v** with the field vector **B**,

  $$\mathbf{E} = \mathbf{v} \times \mathbf{B} \quad (3)$$

  This **E** field drives the conduction electrons to produce *current* in the conductor. Most people are familiar with the case where the three vectors are all at right angles to each other as expressed by Fleming's right hand rule for induced *current*, but that teaching omits to point out that the current along the conductor is the result of an induced electric field (3). This form of induction is also called flux-cutting where the conductor is considered to "cut" the lines of magnetic force. It is unfortunate that this perception hides the role of the vector potential **A** field in this induction, see next section.

- There is much debate about a form of induction that can be derived from (2) if instead of a partial derivative it becomes a full derivative to take account of variations in **A** as "seen" by an electron moving through an **A** field. This time-variation can come from (a) variations in electron velocity magnitude, (b) variations in electron velocity direction, (c) spatial variations in **A** magnitude, (d) spatial variations in **A** direction and (e) any combinations of these. Several authors [2] [3] have shown that this full approach yields the motional induction (3) plus another term

  $$\mathbf{E} = -\nabla_A(\mathbf{v} \cdot \mathbf{A}) \text{ also written as } \mathbf{E} = -\mathbf{grad}_A(\mathbf{v} \cdot \mathbf{A}) \quad (4)$$

  where the gradient is applied only to spatial variations in **A**, i.e. any spatial variations in velocity are suppressed (hence the subscript $_A$). Here **v•A** is the scalar product of the two vectors, which is simply the product of the electron velocity value v with the component of **A** along the velocity direction. Note that **v•A** has dimensions of volts, hence it represents an electric potential that varies throughout space and, just like the well-known Coulomb potential, the spatial gradient (4) is an electric field. The fact that motional induction (3) can be derived directly from the full time-derivative of the **A** field emphasises the role of that field in *all* forms of induction: the "flux-cutting" perspective is simply a useful visual tool and not necessarily the primary aspect of that induction.

3. Why use suppressed terms?

The full Cartesian components of $\mathbf{E} = \nabla(\mathbf{v} \cdot \mathbf{A})$ (i.e. without velocity derivatives suppressed) are:

$$\begin{aligned}
E_x &= \left[v_x \frac{\partial A_x}{\partial x} + v_y \frac{\partial A_y}{\partial x} + v_z \frac{\partial A_z}{\partial x} + A_x \frac{\partial v_x}{\partial x} + A_y \frac{\partial v_y}{\partial x} + A_z \frac{\partial v_z}{\partial x} \right] \\
E_y &= \left[v_x \frac{\partial A_x}{\partial y} + v_y \frac{\partial A_y}{\partial y} + v_z \frac{\partial A_z}{\partial y} + A_x \frac{\partial v_x}{\partial y} + A_y \frac{\partial v_y}{\partial y} + A_z \frac{\partial v_z}{\partial y} \right] \\
E_z &= \left[v_x \frac{\partial A_x}{\partial z} + v_y \frac{\partial A_y}{\partial z} + v_z \frac{\partial A_z}{\partial z} + A_x \frac{\partial v_x}{\partial z} + A_y \frac{\partial v_y}{\partial z} + A_z \frac{\partial v_z}{\partial z} \right]
\end{aligned} \quad (5)$$

Note the first three terms in each parenthesis deal with spatial variations in the **A** field whilst the remaining terms deal with spatial changing velocity, and these latter terms are suppressed in (4). For an almost uniform **A** field (here to be along the *x* direction) such as that of the Earth as seen in the restricted dimensions of the laboratory, the spatial variations in **A** are all zero as are A_y and A_z, then we can simplify (5) to

$$E_x = \left[A_x \frac{\partial v_x}{\partial x} \right], \quad E_y = \left[A_x \frac{\partial v_x}{\partial y} \right], \quad E_z = \left[A_x \frac{\partial v_x}{\partial z} \right] \tag{6}$$

Only terms with velocity derivatives survive and these are the very terms that are suppressed in (4). It appears that the only reason for that suppression is that the full derivative of the **A** field is taken as

$$\frac{D\mathbf{A}}{Dt} = \frac{\partial \mathbf{A}}{\partial t} + \mathbf{v} \cdot \nabla \mathbf{A} \tag{7}$$

then (2), (3) and (4) follow from the vector identity

$$\mathbf{v} \cdot \nabla \mathbf{A} = \mathbf{v} \times \mathbf{B} - \nabla_A (\mathbf{v} \cdot \mathbf{A}) \tag{8}$$

It seems wrong to formulate EM theory to satisfy vector math identities especially when it leads to the absurd situation where a moving electron, undergoing a 180 degree change of direction within an **A** field, moves from a positive potential to a negative one (or vice versa) without the presence of an electric force-field. If the potential **v·A** has any validity then that movement must be through an effective **E** field, not as given by (4) having suppressed terms, but as given by (5), or in the case of a uniform **A** field, by (6). It remains for experiments to determine whether this is the case.

4. What evidence is there?

Sommerfeld [4] points out that in 1903 Schwarzschild introduced his "electro-kinetic potential" $L = (\phi - \mathbf{v} \cdot \mathbf{A})$ where ϕ is the Coulomb potential. Wu & Yang [8] give a historical overview of the vector potential showing that Larmor's 1895 version of the kinetic energy of a moving electron included the energy *e*(**v·A). ** So it is over 120 years since **v·A** was recognized as a potential. Schwarzschild's electro-kinetic potential *L* is really a *potential difference* (note the minus sign) which when multiplied by the charge density forms a relavistic invariant, which was important in the development of his Principle of Least Action. The mathematical intricacies of that development are of little interest to engineers, they are interested in electric and magnetic forces that can do work. The **E** field (5) is just that, hence it would be more sensible if the electro-kinetic potential capable of doing work in a fixed laboratory frame were the *sum* $(\phi + \mathbf{v} \cdot \mathbf{A})$ and not the difference. Thus, ignoring for the moment the *electric* (Coulomb) potential ϕ, an electron moving at velocity **v** through an **A** field can be considered to have an *electro-kinetic* potential **v.A**, or an *electro-kinetic energy e*(**v.A**). This is in addition to its accepted kinetic energy associated with its mass. Note this is a maximum when **v** is parallel to **A**, when the electron travels along the **A** field, and has a value *evA*.

In 1959 Aharanov & Bohm discovered that electrons moving through a static but spatially non-uniform **A** field were effected by that field. Their experiment involved an electron beam that split to travel along different paths then recombined to produce an interference pattern. The **A** field created a differential phase effect between the two beams, which became known as the Aharanov-Bohm effect. Current dogma assumes this effect is just a quantum interference effect having no significance in regard to energy extraction. However Spavieri & Rodriguez [4] have shown that this effect may have a classical origin whereby an additional force related to the static **A** field may be present on a moving electron. It is quoted as a longitudinal (along the velocity direction) force and involves the longitudinal component of the gradient of the scalar product of the vector velocity **v** and magnetic vector potential field **A** as given by

$$\mathbf{F_L} = -e\nabla(\mathbf{v}\cdot\mathbf{A}) \qquad (9)$$

This is simply the electric field (4), without any suppressed terms, applied to the electron charge to yield the force $\mathbf{F_L}$. This force creates an em phase lag that exactly accounts for the Aharonov-Bohm effect, so the Aharonov-Bohm measurements could be considered as evidence that these longitudinal forces, and the **v•A** potentials, really do exist. However in view of the fact that for any closed path travelled by an electron (9) integrates to zero its use in energy production has not been considered feasible.

Marinov [5] mentions a cathode ray experiment by Solunin Kostin where a toroidal coil was placed around the neck of a cathode ray tube. When the electron beam was given some deflection by the usual CRT means it was found possible to alter the amount of deflection by varying the DC current in the toroidal coil. Thus the electron beam velocity was altered by that current. A toroidal coil produces only an **A** field at its centre, hence here again we have a demonstration of a static **A** field applying longitudinal force to moving electrons and changing their velocity.

Carpenter [6] and Murgatroyd [7] both discuss E.G. Cullwicks "anomaly in electromagnetics" where an electric charge is fired through a toroidal coil carrying constant current where only an **A** field exists along the axis. According to current theories, as the charge moves along the axis it experiences no magnetic or induced force whatever, whereas it exerts a magnetic force of repulsion on the toroid. Where is the reaction to that force? In order to resolve this dilemma they both use (Schwartzchild's) electro-kinetic potential to calculate the changing momentum of the charge resulting in the charge enduring longitudinal forces as it moves along the **A** field, and show that overall momentum is preserved.

It can be concluded that there is a reasonable body of evidence that longitudinal forces induced by movement through an **A** field really do exist, but they have been considered to be of no importance because they come from the gradient of a scalar potential where for any closed path they integrate to zero. That null is a mathematical certainty, it cannot be challenged, but the next section highlights the difference between a closed path of moving electrons and a closed circuit.

5. Closed paths and closed circuits.

When dealing with closed path integrals through a scalar field there is a subtle difference between that for the Coulomb potential ϕ and that for the scalar product $(\mathbf{v}\cdot\mathbf{A})$. For a given source, the potentials ϕ will have set values at any point in space, those values will not depend on any characteristic of the device used to sense them. It therefore makes sense to consider the presence of a "field" of those scalar values throughout space. It is the math for this scalar "field" that cannot be challenged. Such a "field" of scalar values is not true for $(\mathbf{v}\cdot\mathbf{A})$ since its value at any point depends on the velocity of the observer. If the observer is not moving there is no potential.

In our considerations the observer is an electron. In both cases, if the electron follows a closed *path* the net force on it integrates to zero, we have a closed *circuit* that cannot extract electrical energy from the potentials. This identification of a mathematical *closed path* with an electrical *closed circuit* is the invisible stumbling block that we have unwittingly stumbled over. *A closed electrical circuit does not necessarily require electrons to traverse the full closed path.* For example if part of that path involves Maxwell's displacement current we can have current flowing around a closed circuit but the electron flow is discontinuous. In the case of the scalar potential $(\mathbf{v}\cdot\mathbf{A})$ we have the ability to use a discontinuous path where the moving electron gains potential from the **A** field along one part of its path, then transfers some of that energy via electromagnetic means to another electron that can follow a different path that includes the load. *That different path need not negate the potential gained from the* ***A*** *field in the first place.*

Consider electrons at their maximum EK potential, i.e. they are travelling along the **A** field. To extract energy from a moving electron via its EK potential it is important that the electron does not lose that potential before it reaches the transfer point. That loss of potential occurs if (a) the electron loses velocity when it reaches a capacitor plate to then become some quasi-static charge, or (b) the electron moves onto a take-off path at right angles, where in both cases $(\mathbf{v} \cdot \mathbf{A})$ drops to zero. Overcoming this problem requires careful consideration of the circuit geometry and could lead to the use of unusual and seemingly strange three-terminal capacitors, where two terminals connect to opposite ends of the same electrode so that current can be maintained along that electrode. Then the surfeit of electrons that represent the charge on that capacitor plate are not stationary, they retain their velocity hence also their $\mathbf{v} \cdot \mathbf{A}$ potential. The third terminal of course would take connection from the other electrode where, because of the deliberate conductor orientation with respect to the **A** field, change of velocity would not be a consideration. However such schemes would use only the relatively small drift velocity of conduction electrons.

A more exciting aspect is the use of electrodes on an insulating disc spinning within the Earth's **A** field. The spinning action creates velocities much greater than typical drift velocities of conduction electrons, we can achieve velocities of meters per second as opposed to fractions of a mm per second. In the Earth's **A** field, which can be as high as 200 Weber/m, the $\mathbf{v} \cdot \mathbf{A}$ electro-kinetic potential obtained from those velocities can be kilovolts! Thus an electrode at the outer periphery of a spinning disc would undergo a significant alternating electro-kinetic potential which could lead to interesting apparently anomalous effects. This hitherto neglected aspect might explain the mysteries of the Testatika machine [10] as well as the more recent device offered by Innova Tehno1943 [11].

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