

# Maxwell's Equations, Electromagnetic Waves, and Their Reading in a Multidimensional Operating Continuum

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## Abstract

This paper reformulates an earlier working analytical note into a publication-style English text suitable for ResearchGate. The first part retains the classical Maxwell system in observable space, because those equations remain the correct effective laws for macroscopic electromagnetic read-out. The second part proposes a reading in a Multidimensional Operating Continuum (MOC), in which static electric-like and magnetic-like fields, as well as propagating electromagnetic waves, are treated as observable projections of deeper closure-supported carrier regimes. In this reading, the classical field picture is preserved as an effective description, but the ontology is shifted from autonomous hard particles toward continuous carrier regimes, projection operators, and detector-resonance read-out. The wave section is expanded in detail: wave equations, plane-wave structure, energy and momentum transport, vacuum impedance, Compton and de Broglie scales, group and phase velocities, polarization and spin density, and scattering-level read-out are brought into one coherent line. The final part presents fourteen examples and paradoxes that the MOC reading addresses in a more unified way than a split vocabulary based on separate field, photon, matter-wave, and detector pictures. The paper does not claim to replace Maxwell theory or precision quantum electrodynamics. It argues instead that those highly successful observable laws may themselves be read as the projected surface of a deeper closure-governed carrier structure.

## Status and boundaries

The present text makes a strict distinction between three levels. First, Maxwell's equations in observable space remain valid effective equations and are not denied. Second, the standard quantum and high-energy literature remains the benchmark for precision data. Third, the MOC reading is offered as a structural interpretation that tries to explain why continuous fields, discrete detector events, de Broglie read-out, Compton scales, polarization, spin-like behavior, and magnetic moment laws can be placed in one analog-first carrier picture. The paper therefore does not argue against the empirical success of established physics; it argues for a deeper explanatory layer beneath it.

## 1. Classical Maxwell equations in observable space

In observable space the classical effective equations are

$$\begin{aligned}\nabla \cdot \mathbf{E} &= \rho / \epsilon_0 \\ \nabla \cdot \mathbf{B} &= 0\end{aligned}$$

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

$$\nabla \times \mathbf{B} = \mu_0 \mathbf{J} + \mu_0 \epsilon_0 \partial \mathbf{E} / \partial t$$

The integral form is

$$\oint_S \mathbf{E} \cdot d\mathbf{A} = Q_{\text{encl}} / \epsilon_0$$

$$\oint_S \mathbf{B} \cdot d\mathbf{A} = 0$$

$$\oint_C \mathbf{E} \cdot d\mathbf{l} = - d/dt \int_S \mathbf{B} \cdot d\mathbf{A}$$

$$\oint_C \mathbf{B} \cdot d\mathbf{l} = \mu_0 I_{\text{encl}} + \mu_0 \epsilon_0 d/dt \int_S \mathbf{E} \cdot d\mathbf{A}$$

The main symbols are standard:  $\mathbf{E}$  is the electric field,  $\mathbf{B}$  the magnetic induction,  $\rho$  the charge density,  $\mathbf{J}$  the current density,  $\epsilon_0$  the vacuum permittivity,  $\mu_0$  the vacuum permeability, and  $c = 1 / \sqrt{(\mu_0 \epsilon_0)}$  the propagation speed in vacuum. Maxwell's 1865 synthesis unified electricity, magnetism, and light into one field framework [1,2].

## 2. Classical wave equations and transport laws

In free space, with  $\rho = 0$  and  $\mathbf{J} = 0$ , the Maxwell system gives the standard wave equations

$$\nabla^2 \mathbf{E} - \mu_0 \epsilon_0 \partial^2 \mathbf{E} / \partial t^2 = 0$$

$$\nabla^2 \mathbf{B} - \mu_0 \epsilon_0 \partial^2 \mathbf{B} / \partial t^2 = 0$$

A monochromatic plane-wave solution can be written as

$$\mathbf{E}(\mathbf{r}, t) = \text{Re} \{ \mathbf{E}_0 \exp[i(\mathbf{k} \cdot \mathbf{r} - \omega t)] \}$$

$$\mathbf{B}(\mathbf{r}, t) = \text{Re} \{ \mathbf{B}_0 \exp[i(\mathbf{k} \cdot \mathbf{r} - \omega t)] \}$$

with the transversality conditions

$$\mathbf{k} \cdot \mathbf{E}_0 = 0, \quad \mathbf{k} \cdot \mathbf{B}_0 = 0, \quad \mathbf{B}_0 = (1/\omega) \mathbf{k} \times \mathbf{E}_0$$

The local energy density  $u$ , the Poynting vector  $\mathbf{S}$ , and the field momentum density  $\mathbf{g}$  are

$$u = \frac{1}{2} (\epsilon_0 E^2 + B^2 / \mu_0)$$

$$\mathbf{S} = (1 / \mu_0) \mathbf{E} \times \mathbf{B}$$

$$\mathbf{g} = \mathbf{S} / c^2$$

The vacuum impedance is

$$Z_0 = \sqrt{(\mu_0 / \epsilon_0)} \approx 376.730313 \Omega$$

These relations already show something important: the classical wave is not a mere visual oscillation, but a strict transport structure carrying energy, momentum, polarization, and angular momentum. Later sections will argue that this transport structure is best read as an observable projection of a deeper carrier regime rather than as a stream of tiny rigid bullets.

## 3. A comparison between the classical laws and the MOC reading

The table below summarizes the main shift in language. Nothing is removed from the classical equations. The change is interpretive: fields and waves are kept as observable laws, but are read as projection-level read-out of closure-supported carrier regimes.

Classical statement	What it means classically	MOC reading
$\nabla \cdot \mathbf{E} = \rho / \epsilon_0$	Charge sources the electric field.	Charge is the observable sign-read-out of a deeper closure-supported regime.
$\nabla \cdot \mathbf{B} = 0$	No magnetic monopoles in the observable Maxwell sector.	The magnetic-like read-out stays closed because the deeper carrier closes.
Wave equations in vacuum	The field self-propagates as a transverse wave.	The wave is the observable transport read-out of a deeper analog carrier mode.
$\Delta E = h\nu$ in matter interaction	Energy exchange appears quantized in resonant systems.	The carrier field is continuous; the discreteness belongs to detector and matter resonance.
Polarization and helicity	The field has transverse internal orientation.	Observable polarization is the projected read-out of carrier rotation and closure orientation.

#### 4. Static fields as observable continuations of closed internal regimes

In the MOC reading, static electric-like and magnetic-like fields are not autonomous primitive objects. They are the observable continuation of deeper vortical or closure-supported carrier regimes. In compact form we write

$$\mathbf{E}_{\text{obs}} = \Pi_{\text{obs}}[ \mathcal{L}_{\text{MOC}}(\Psi_{\text{cl}}) ]$$

$$\mathbf{B}_{\text{obs}} = \Pi_{\text{obs}}[ \mathcal{L}_{\text{MOC}}(\Xi_{\text{cl}}) ]$$

Here  $\Pi_{\text{obs}}$  is the projector toward the observable quantity in observer space, while  $\mathcal{L}_{\text{MOC}}$  denotes closure within the Multidimensional Operating Continuum. The meaning is simple: the detector or observer never reads the whole internal regime, only its observable projection. This is why static fields can look open in one channel and closed in another, even though both are read-out of closure-supported carrier structure.

#### 5. Electromagnetic waves: classical description and a more detailed MOC reading

This section is intentionally longer and more explicit than in the previous working note. The classical description is kept, but the explanatory layer is expanded. The key claim is that a propagating electromagnetic wave is not just a formal solution of Maxwell's equations. It is the observable transport read-out of a deeper closure-supported analog carrier mode.

##### 5.1. Vacuum propagation and transverse structure

The wave equations show that both  $\mathbf{E}$  and  $\mathbf{B}$  propagate at speed  $c$  in vacuum. Their geometry is transverse: the propagation direction  $\mathbf{k}$  is orthogonal to both field amplitudes. That transversality is not an accidental algebraic property; it is one of the signatures that the propagating observable read-out preserves an internal rotational ordering. In the MOC language, the field does not merely “wiggle”; it transports an ordered closure-supported phase front.

$$\mathbf{k} \perp \mathbf{E}_0, \quad \mathbf{k} \perp \mathbf{B}_0, \quad \mathbf{E}_0 \perp \mathbf{B}_0$$

The classical picture is fully retained, but the deeper interpretation changes: instead of postulating an independent photon object whenever the field propagates, the MOC reading treats the field itself as primary and the eventual detector click as a resonant read-out event.

## 5.2. Energy, momentum, and transport

The electromagnetic wave carries energy density  $u$ , energy flux  $S$ , and momentum density  $g$ . In a classical presentation this is already sufficient. In the MOC reading, however, these are not merely bookkeeping quantities. They are the observable transport balance of the underlying carrier mode.

$$u = \frac{1}{2} (\epsilon_0 E^2 + B^2 / \mu_0)$$

$$S = (1 / \mu_0) E \times B$$

$$g = S / c^2$$

This transport structure explains why radiation pressure exists without forcing us to imagine rigid miniature corpuscles as the only possible ontology. For perfect absorption and reflection one still has the standard laws

$$p_{\text{rad}} = I / c \quad (\text{absorption})$$

$$p_{\text{rad}} = 2I / c \quad (\text{reflection})$$

The key point is interpretive: momentum transfer can be read as a property of continuous field transport plus resonant matter response. One does not need to begin from hard photon pellets in order to recover the observable pressure law.

## 5.3. Carrier phase, Compton imprint, and de Broglie read-out

The previous note stated that the wave carries an internal Compton imprint and leaves a de Broglie read-out when the carrier moves. Here we make that statement more explicit. For a carrier regime with effective mass parameter  $m$ , the Compton scale is

$$\lambda_{\text{C}} = h / (m c)$$

$$\omega_{\text{C}} = m c^2 / \hbar$$

For a moving regime with momentum  $p = \gamma m v$ , the external kinematic read-out is

$$\lambda_{\text{dB}} = h / p$$

$$k_{\text{dB}} = p / \hbar, \quad \omega_{\text{dB}} = E / \hbar$$

In the standard language these scales are often introduced separately. In the MOC reading they are two outward manifestations of one and the same carrier: the Compton scale is the internal closure rhythm, while the de Broglie scale is the external translational read-out of that rhythm. This is one of the main unifying claims of the paper.

For a free massive carrier the standard wave-mechanical relations give

$$v_{\text{g}} = d\omega / dk = v$$

$$v_{\text{ph}} = \omega / k = c^2 / v$$

These well-known formulas are often treated as a merely formal quantum-mechanical curiosity. In the MOC reading they are natural: the group velocity belongs to the transported envelope, while the phase velocity belongs to the projected carrier phase. The two are not contradictory because they refer to different levels of read-out.

#### 5.4. Continuous field, discrete exchange, and detector clicks

One of the central conceptual tensions in electromagnetic theory is that the field propagates continuously, while atoms and detectors exchange energy in discrete quanta. The MOC reading keeps both facts but relocates the discreteness. The field remains analog and continuous. The discreteness belongs to the resonant structure of matter and to the thresholded read-out of the detector.

$$\Delta E = h \nu$$

This equation is not denied. It is reinterpreted. The relation states the spacing of resonant exchange, not necessarily the existence of a tiny rigid corpuscle flying through space as an independent solid object. In a compact detector-response form one may write

$$P_{\text{click}} \propto \left| \int \chi_{\text{det}}(\omega) \Psi_{\text{obs}}(\omega) d\omega \right|^2$$

Here  $\chi_{\text{det}}$  is the detector susceptibility and  $\Psi_{\text{obs}}$  the observable field read-out. In this language, a “click” is a resonant threshold event produced by a continuous field-carrier interaction. This makes room for a continuous carrier ontology without losing the experimentally undeniable discreteness of detection.

#### 5.5. Polarization, helicity, and spin-like content

Electromagnetic waves carry polarization and angular momentum. In the modern literature this includes both orbital and spin components. A useful monochromatic spin-density expression is

$$s = (\epsilon_0 / 2\omega) \text{Im}(E^* \times E) + (1 / 2\omega\mu_0) \text{Im}(B^* \times B)$$

For circular polarization the observable helicity is quantized in the standard description. The MOC reading does not reject that. It interprets polarization and spin-like field content as the observable projection of carrier rotation and closure handedness. The modern literature on transverse and longitudinal field spin gives an especially useful bridge here: field spin is real, measurable, and structurally richer than a simple textbook plane-wave picture [9,10].

#### 5.6. Scattering-level read-out: Compton and beyond

The Compton relation is one of the most important stress tests for any analog-first reading of the electromagnetic field. The standard formula is

$$\Delta\lambda = \lambda_C (1 - \cos \theta)$$

Historically this formula helped establish the light-quantum picture. In the MOC reading it can be preserved without taking the hard-photon ontology as the unique interpretation. The scattering event is read as a field-response restructuring in which a closure-bearing carrier transfers phase, momentum, and energy to matter in a sharply localized resonant event. The formula survives because the kinematics survive; what changes is the ontology assigned to the carrier before the interaction.

#### 5.7. A compact MOC wave law

To summarize the previous subsections, the observable wave can be written schematically as

$$\Psi_{\text{obs}}(x,t) = \Pi_{\text{obs}} [ \mathcal{L}_{\text{MOC}}(\Psi_{\text{cl}}) \exp i( k_{\text{dB}} x - \omega_{\text{dB}} t + \Phi_{\text{cl}} ) ]$$

The precise mathematical form of  $\Psi_{\text{cl}}$  is left open here, because the present goal is not to claim a fully parameterized fundamental field theory. The point is structural: the observed wave is a projection of a closure-supported carrier regime, not a primitive hard object stream.

## 6. Fourteen examples and paradoxes that the MOC reading addresses more naturally

The following list is not presented as a claim that all standard problems are “solved” in the strong mathematical sense. The claim is weaker and more precise: the MOC reading places a series of old conceptual tensions inside one carrier-and-projection framework and thereby explains why they can coexist without contradiction.

### 6.1. Why does the electric-like field look open while the magnetic-like field looks closed?

Classically, Gauss’s electric law and the divergence-free magnetic law appear asymmetrical. In the MOC reading both are observable read-outs of closed carrier structure. The electric-like sector looks open only because one sign-projection is visible, while the full closure remains partly hidden.

### 6.2. Why is $c$ fixed by $\epsilon_0$ and $\mu_0$ ?

The classical relation  $c = 1/\sqrt{(\mu_0\epsilon_0)}$  is retained exactly. The MOC reading interprets it as the observable transport speed of the carrier regime in the vacuum read-out channel rather than as an arbitrary isolated constant disconnected from structure.

### 6.3. Why can a field be continuous while atomic exchange is discrete?

The standard quantum answer uses field quantization and level structure. The MOC reading keeps the empirical  $\Delta E = h\nu$  law but places the discreteness primarily in resonant matter response and detector thresholding. This reconciles analog propagation with discrete clicks.

### 6.4. Why are de Broglie and Compton introduced as if they were unrelated?

The standard formalism often uses them in different chapters. In the MOC reading they are two projections of one carrier: the Compton scale is the internal closure clock, while the de Broglie scale is the external motion-induced read-out.

### 6.5. Why does Compton scattering look particle-like?

Compton kinematics are preserved exactly, but the ontology is softened. The event is read as a localized field-response restructuring, not necessarily as the collision of rigid miniature bullets.

### 6.6. Why does the photoelectric effect look like proof of little light pellets?

The measured threshold and frequency law remain intact. The MOC reading says that a continuous carrier field interacting with a quantized bound system can yield thresholded electron emission without requiring a rigid corpuscular ontology prior to detection.

### 6.7. Why do polarization and helicity behave like intrinsic spin?

Modern field theory assigns angular momentum and spin density to the electromagnetic field. In the MOC picture these are natural projection-level signatures of carrier rotation and handed closure, not merely abstract algebraic decorations.

### 6.8. Why does Stern–Gerlach splitting look two-valued?

The Stern–Gerlach experiment established quantized magnetic splitting for atomic beams. The MOC reading interprets the observed two-branch structure as a projected magnetic closure class rather than as evidence that the deeper internal regime itself is exhausted by the visible two-state label [7].

### 6.9. Why do magnetic moments follow simple central laws but show anomalies?

The standard relation  $\mu = g(q/2m)S$  works extremely well, while  $g - 2$  anomalies reveal fine corrections. In the MOC reading the central law comes from closure-supported internal circulation, while anomalous terms reflect small read-out corrections and interaction dressing rather than complete failure of the carrier picture [8].

### 6.10. Why can the Aharonov–Bohm phase survive where the local field is shielded?

The standard phase shift is  $\Delta\phi = (q/\hbar) \oint \mathbf{A} \cdot d\mathbf{l} = (q/\hbar)\Phi_B$ . The MOC reading naturally accepts that the observable phase can be controlled by a deeper carrier topology rather than by a naive local force picture. This is one of the strongest literature-supported examples that the observable read-out can be more global than local field force language suggests [5,6].

### 6.11. Why are near field and far field treated as very different worlds?

Engineering practice distinguishes them, but they are still parts of one field solution. In the MOC reading both are different observational zones of one carrier regime: one more stored and geometry-dependent, the other more transport-dominated.

### 6.12. Why does radiation pressure transfer momentum without requiring hard pellets?

The classical laws  $p = I/c$  and  $2I/c$  remain sufficient. The MOC reading interprets momentum transfer as a field transport balance deposited into matter through coupling, without making rigid corpuscles the only admissible ontology.

### 6.13. Why does radiation reaction look pathological?

Self-force and radiation reaction have long been conceptually difficult. The MOC reading interprets them as back-reaction of the carrier on its own closure and transport structure. This does not solve the full renormalized dynamics, but it provides a cleaner structural intuition for why self-action terms appear [11].

### 6.14. Why are Maxwell's equations so successful and yet often felt to be incomplete?

Maxwell theory is extraordinarily successful as an effective observable law. The MOC reading explains that success by treating Maxwell's equations as the correct projected read-out of a deeper carrier geometry. The equations need not be wrong in order to be structurally incomplete.

## 7. Conclusion

Maxwell's equations remain fully valid as effective laws in observable space. The present paper does not attempt to replace them. Its claim is interpretive and unifying: static fields, propagating electromagnetic waves, Compton scales, de Broglie read-out, detector discreteness, polarization, spin-like content, magnetic moment laws, and several old conceptual paradoxes can be placed in one carrier-and-projection architecture.

The MOC reading therefore does not ask the reader to abandon classical electromagnetism or precision quantum theory. It asks the reader to consider that those successful observable laws may themselves be the projected surface of a deeper closure-supported continuum. If this line is fruitful, the strongest future tests will lie not in denying established formulas, but in showing that apparently separate phenomena are in fact different read-outs of one and the same carrier structure.

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