International Journal of Research Publication and Reviews, Vol 5, no 9, pp 2814-2817 September 2024

International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

Visualizing Monochromatic Plane Waves: A Hypothesis on Internal Interference Patterns and Energy Balance

Santosh Ramesh Jadhav.

HOD, Prototyping, Advandes Pvt Ltd, Pune, Maharashtra State, Bharat.

A B S T R A C T

The concept of a field is pivotal in physics, enabling the description of forces without direct physical contact. An electric charge generates an electric field in its vicinity, while a moving charge produces a magnetic field. Traditionally, Electromagnetic (EM) waves are viewed as arising from the cyclical interplay between oscillating electric and magnetic fields. As an EM wave propagates through a vacuum, its energy is distributed between these fields, with their phase relationship influencing their respective strengths. (1) In free space, the electric and magnetic fields of separate EM waves do not directly interact with one another in the context of this cyclical interplay, as demonstrated by experiments such as the dispersion of white light through a prism. Despite this, EM waves maintain their coherent identity. Instead, they superpose, forming interference patterns of constructive and destructive interference based on their relative phase angles. However, this conventional view may overlook a more fundamental mechanism governing field interaction.

EM waves consist of electrically neutral, massless photons. (1) Monochromatic plane waves are characterized by equal contributions from the electric and magnetic fields. (2) This paper proposes a novel hypothesis that, in such waves, rather than being the result of the cyclical interplay between oscillating fields, a single EM wave may emerge from the superposition and interference of its intrinsic electric and magnetic fields. Instead of one field inducing the other, the fields collaborate to maintain a dynamic equilibrium through patterns of constructive and destructive interference while oscillating independently. This model suggests that synchronized photons drive these internal interference patterns, where constructive interference in the electric field coincides with destructive interference in the magnetic field, and vice versa. As a result, only half of the total energy is detectable at any given moment, while the total energy of the wave remains conserved.

The study of EM waves typically requires devices with mass and electrical conductivity. While an observer might perceive a changing electric field as generating a corresponding magnetic field, the proposed interference pattern within the EM wave may represent the true underlying mechanism. This paper includes preliminary diagrams illustrating the relationship between the phase angle of monochromatic plane waves and the magnitudes of the electric and magnetic field components, employing a unit circle and vector representation to depict their oscillatory behaviour during propagation.

Keywords: Electromagnetic Field, Electromagnetic Wave, Internal Constructive and Destructive Interference

Introduction

Max Planck’s work on blackbody radiation introduced the concept that radiation is composed of discrete units called "quanta." Albert Einstein later extended this idea, demonstrating that light consists of these units, termed "photons." Photons are electrically neutral and massless particles, each carrying energy defined by $E=hf$, where h is Planck’s constant. Furthermore, James Clerk Maxwell developed the theory of electromagnetism, establishing the fundamental link between light and electromagnetic waves. (1)

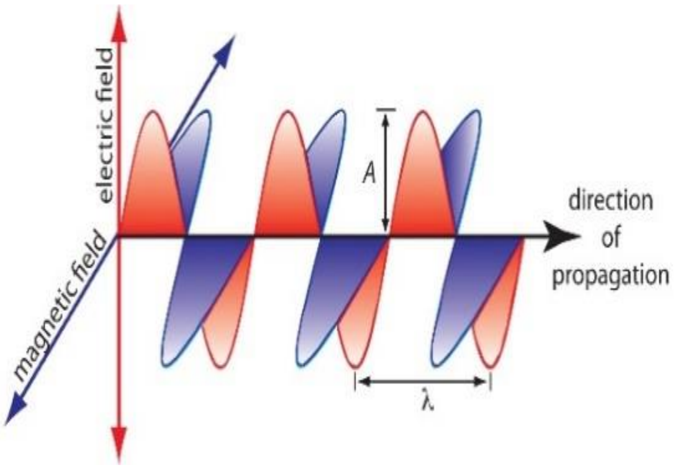

Figure 1: Electric and Magnetic Felds at Right Angles

Electromagnetic Wave:

Electromagnetic waves consist of oscillating electric and magnetic fields that propagate through space. Characterized by their frequency (f) and wavelength (λ), the frequency denotes the number of wave cycles per unit time, while the wavelength is the distance between corresponding points on adjacent waves. The relationship between wave speed (v), frequency, and wavelength is given by v=λf. For electromagnetic waves, the speed of light (c) is the constant wave speed, leading to the simplified equation c=λf. (1)

Representation: Internal Constructive and Destructive Interference Pattern

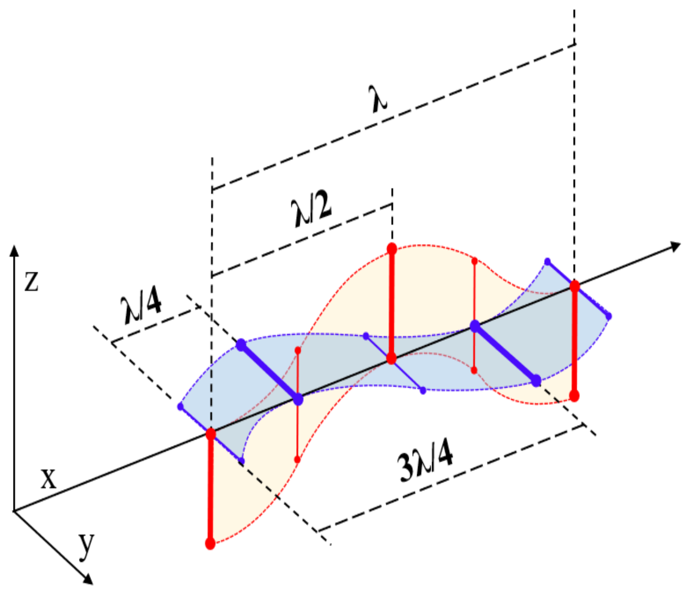

Figure 2: Representation of the Internal Constructive and Destructive Pattern on a Wavelength (λ)

- **Possitive X-axis: Direction of EM Wave Propagation**

The propagation of an electromagnetic (EM) wave is often modelled using the expression (x, t) = kx − ωt, which represents the phase of a plane wave traveling in the x-direction. This equation describes the relationship between space (x) and time (t) in terms of the wave vector (k) and angular frequency (ω). When illustrating the relationship between the phase angle of the propagating EM wave and the relative magnitudes of the oscillating electric and magnetic fields using a unit circle and vectors, the positive x-axis is selected as the direction of the wave's propagation. (1) (2)

- **Z- and Y-axis: Direction of Electric and Magnetic Fields, Respectively**

In electromagnetic wave propagation, the electric and magnetic fields are orthogonal to each other and to the direction of wave travel. The z-axis represents the electric field, while the y-axis represents the magnetic field. This arrangement is consistent with Maxwell's equations, maintaining the transverse nature of the wave. (2)

- **Right-Hand Rule in Electromagnetism and Phase Angle Measurement Interpretation**

The right-hand thumb rule is an essential principle in electromagnetism, that is used to determine the direction of the magnetic field around a current-carrying conductor. When applying this rule to EM wave propagation, the electric field vector aligns along the z-axis, while the magnetic field vector aligns along the y-axis. The phase angle is measured from the negative z-axis, ensuring alignment with the right-hand rule and maintaining consistency with the phase relations between the fields. (2)

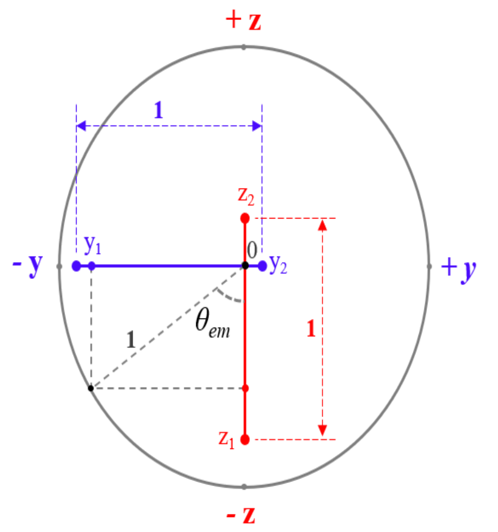

Figure 3: Phase Angle and field Components representing Vectors Orthogonality on a Unit-radius circle.

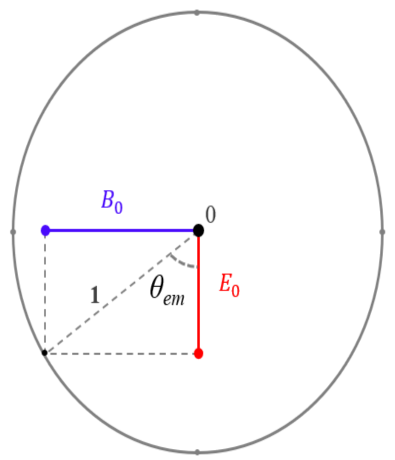

Figure 4: Sum of Respective Field's Interference Using a Unit Radius Circle

- **Figure 3: Phase Angle, Vector Orthogonality, and Energy Conservation in Electromagnetic Waves**
    - **Oscillatory Behaviour Representation**: A unit-radius circle is used to represent the oscillatory behaviour of an EM wave.
    - **Perimeter and Vector Components**: The perimeter of the circle corresponds to the wave's wavelength (λ). The electric field components (z_1, z_2) and magnetic field components (y_1, y_2) are shown as orthogonal, aligned with the z- and y-axes, respectively.
    - **Phase Angle Measurement**: The phase angle (θ_{em}) is measured from the negative z-axis.
    - **Energy Conservation Visualization**: This diagram illustrates how the total energy of an EM wave is conserved during propagation. The vectors depict how energy is distributed between the electric and magnetic fields, showing the constructive and destructive interference patterns that balance the wave's energy.
- **Figure 4: Sum of Respective Field's Interference Using a Unit Radius Circle**
    - **Representation of Interference Patterns**: This figure shows the sum of the constructive and destructive interference components for both the electric and magnetic fields, which vary with the phase angle (θ_{em}). (3)
    - **Visualization of Field Oscillations**: As the wave propagates, the unit-radius circle serves as a reference for visualizing how the magnitudes of these fields oscillate and interact at different phase angles. Constructive interference occurs when the electric and magnetic fields reinforce each other, while destructive interference happens when they partially or fully cancel each other out.
    - **Energy Conservation**: Despite the continuous interplay of interference between the two fields, the total energy of the wave remains conserved. The unit-radius circle effectively visualizes the internal interference pattern, showing how the total energy is maintained, even as the fields oscillate and interact at various phase angles.

Relating Phase Angle With Electric And Magnetic Field Component

The phase angle of an EM wave directly relates to the magnitudes of the electric and magnetic fields. Using a unit-radius circle, the Pythagorean theorem expresses how the vectors representing the magnitudes of the electric and magnetic fields can be shown as:

- **(z_1, z_2) for the electric field and (y_1, y_2) for the magnetic field**
  - (z_1, z_2)
    - $z_1 = (\cos\theta_{em} - 1)/2$,
    - $z_2 = (\cos\theta_{em} + 1)/2$
  - (y_1, y_2)
    - $y_1 = (\sin\theta_{em} - 1)/2$
    - $y_2 = (\sin\theta_{em} + 1)/2$

These vectors represent the periodic variation in the fields' magnitudes due to constructive and destructive interference, with the total energy conserved at all times.

- **Electric and Magnetic Field Component**

The magnitudes of the electric and magnetic fields at any point can be expressed as:

- $E_0 = (z_1 + z_2) = \left(\frac{\cos\theta_{em} - 1}{2} + \frac{\cos\theta_{em} + 1}{2}\right) = \left(\frac{2\cos\theta_{em}}{2}\right) = \boldsymbol{\cos\theta_{em}}$
- $B_0 = (y_1 + y_2) = \left(\frac{\sin\theta_{em} - 1}{2} + \frac{\sin\theta_{em} + 1}{2}\right) = \left(\frac{2\sin\theta_{em}}{2}\right) = \boldsymbol{\sin\theta_{em}}$

Where E_0 and B_0 represent the electric and magnetic field components, respectively.

Conclusion

The unit-radius circle in the graphical representation effectively illustrates the oscillation and interaction of the electric and magnetic fields at varying phase angles, providing a visual framework for understanding how these fields work together to maintain the energy balance of an electromagnetic (EM) wave.

Differences from conventional methodology:

In conventional electromagnetic theory, the energy of an EM wave is expressed as E=hf, where h is Planck’s constant. However, this hypothesis suggests a departure from this traditional model. Specifically, in a **monochromatic plane wave** with a 90-degree phase difference, synchronized destructive interference between the electric and magnetic fields leads to only half of the total energy being **measurable** at any given moment. According to this view, while the total energy of the wave is E=2hf, only E/2=hf is observable or extractable at any specific time.

This reinterpretation implies a potential **doubling of the coherent energy** of the EM wave when accounting for the hidden energy within the interference patterns. Such a model invites further investigation, particularly when comparing the energy associated with mass to that of an EM wave exhibiting this phase relationship.

References

1. Lala, Parag K. Quantum Computing A Beginner's introduction. 2020. Chennai : McGraw Hill, 2019. ISBN 93-90385-26-1.

2. Griffiths, David J. Introduction to Electrodynamics. [ed.] 4th Edition. Grater Noida : Cambridge University Press 2017, 2020. ISBN-978-1-108-82290-9.

3. Silverman, Joseph H. A friendly introduction to number theory. 2019 edition. Chennai : Pearson India Education Services Pvt. Ltd, 2018. ISBN 978-93-534-3307-9.