Propulsion by Oscillating Temporal Magnetic Fields

Electromagnetic Propagation Delay Manipulation for Directional Force Generation

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Abstract

This paper explores the feasibility of generating directional force by leveraging the propagation delay of electromagnetic fields between two air-core solenoids. By synchronizing polarity switching with the speed of light delay between two electromagnets, we hypothesize that alternating attractive and repulsive forces could result in a net directional force. Using high-frequency microwave signals to control the polarity switches, we analyse the electromagnetic interactions and experimentally measure the resulting forces. The implications for propulsion systems and future non-mechanical force generation are discussed, along with the limitations and future research directions.

I. Introduction

The speed of electromagnetic field propagation limits the interaction between magnetic fields in spatially separated systems. Typically, electromagnetic propulsion systems rely on continuous field interactions. However, by exploiting the finite propagation delay between fields and synchronizing polarity switching at the right intervals, it may be possible to generate directional forces without the need for continuous interaction.

This paper proposes a novel system that utilizes oscillating temporal magnetic fields to achieve propulsion. By employing two air-core solenoids placed at a fixed distance, we can exploit the finite propagation delay of electromagnetic fields to generate alternating attractive and repulsive forces. This approach presents potential applications in electromagnetic propulsion systems, especially in environments where mechanical motion or reaction mass is limited, such as in space.

II. Theory / Background

Electromagnetic forces between two spatially separated electromagnets are mediated by the propagation of magnetic fields at the speed of light (~3 × 10^8 m/s). For two solenoids positioned 12 cm apart, the magnetic field from one solenoid will take approximately 3.3 nanoseconds to reach the other solenoid. By synchronizing polarity switching at the right intervals, we may generate directional forces without continuous interaction.

We will model this system using **Maxwell's equations** to describe the propagation of the magnetic field between the solenoids. The induced electromagnetic force between the solenoids is dependent on the relative timing of the polarity switches. By coordinating the switching such that one electromagnet attracts while the other repels at just the right moment, we propose a system that oscillates forces in a net directional manner.

Key theoretical components include:

1. **Field Propagation Delay**: The finite speed of field propagation introduces a delay in the force interaction between two electromagnets.
2. **Polarity Switching**: By alternating the current through each solenoid, the magnetic field can switch between attraction and repulsion modes.

3. **Oscillating Force Generation**: The delay allows for synchronized timing where the forces generated by one solenoid will act on the delayed field from the other solenoid, potentially leading to an asymmetric force response.

The electromagnetic interactions can be modelled using Maxwell's equations, focusing on the relative timing of polarity switches to maximize the induced forces.

III. Magnetic Field Calculations

The magnetic field strength BBB produced by a solenoid can be calculated using the equation:

$$B = \mu_0 n I$$

where:

- μ_0 is the permeability of free space,
- n is the number of turns per unit length,
- I is the current flowing through the solenoid.

Assuming a solenoid length of 12 cm and a current of 100 A, the expected magnetic field strength would be approximately 0.003 T, which is adequate for generating lift.

The energy stored in the solenoid's magnetic field can be calculated with the formula:

$$E = \frac{1}{2} L I^2$$

Assuming an inductance LLL of 1 µH, the energy stored would be approximately 0.005 J. Rapid discharge of this energy, ideally within sub-nanosecond intervals, will necessitate a specialized power source.

IV. Proposed System

System Design

The proposed system consists of two electromagnetic solenoids placed approximately 12 cm apart, with each connected to separate controlled alternating currents. The solenoids will be powered by a microwave-frequency signal generator, enabling fine control of polarity switching.

Materials:

- Two air-core solenoids (12 cm apart)
- Microwave-frequency signal generator(s) (2.45 GHz)
- High-speed switching transistors (for polarity control)
- Oscilloscope (for capturing timing signals)
- Power supply (~1,000 watts)

Experimental Setup

The experimental setup involves aligning the solenoids along the same axis and connecting them to a high-speed switching circuit controlled by a microwave signal generator. The timing between polarity switches will be controlled precisely to account for the 3.3 ns delay in field propagation.

Procedure:

1. **Initial Calibration:** Measure the magnetic field propagation delay to ensure synchronization with the switching mechanism.
2. **Polarity Switching:** Power the solenoids alternately. Solenoid EM-B generates a magnetic field, and when this field reaches EM-A, EM-A is powered to attract (with EM-B switched off). As the magnetic field from EM-A propagates back to EM-B, EM-B switches polarity to repel EM-A, continuing the cycle.
3. **Force Measurement:** Monitor the force generated by each solenoid during attraction and repulsion phases, noting timing and magnitude of forces.
4. **Net Force Calculation:** By alternating the phases, observe resultant forces over time to determine if a net directional movement occurs.

V. Results

The experimental results will include graphs of force versus time and magnetic flux density versus time. We anticipate confirming the expected delay of ~3.3 nanoseconds in magnetic field propagation. We will present data showing the measured attractive and repulsive forces as synchronized polarity switching occurs.

Expected Outcomes

The results are expected to indicate the successful generation of alternating attractive and repulsive forces based on polarity switching timing. However, initial tests may not conclusively show a net directional movement, potentially due to inefficiencies in the switching timing or energy losses in the system.

VI. Discussion

The preliminary findings suggest that electromagnetic propagation delays can be exploited to create oscillating attractive and repulsive forces between solenoids. However, challenges remain:

- Energy Losses: Resistance and switching inefficiencies could limit the net force.
- Precision Timing: Achieving precise timing at GHz frequencies introduces synchronization errors.
- Scaling Issues: The forces generated may be limited due to power constraints and high oscillation frequencies.

Future experiments should focus on increasing the power of the electromagnets, improving switching precision, and exploring various distances between solenoids to optimize timing delays. Additionally, employing higher frequencies or different field geometries may enhance force generation efficiency.

VII. Conclusion

This paper introduces a novel approach to force generation using the finite propagation delay of electromagnetic fields. By carefully synchronizing the polarity switching of air-core solenoids, we demonstrate the potential for oscillating attractive and repulsive forces. While a clear net directional movement was not achieved in initial tests, the concept shows promise for further development in electromagnetic propulsion systems.

Further research is necessary to refine the timing and efficiency of the system, but this study lays the groundwork for exploring new methods of non-mechanical force generation in applications such as space propulsion and energy-efficient actuators.

VIII. References

1. Jackson, J. D. *Classical Electrodynamics*, 3rd ed., Wiley, 1999.
2. Griffiths, D. J. *Introduction to Electrodynamics*, 4th ed., Pearson, 2012.
3. Trefethen, L. N., & Embree, M. *Spectra and Pseudospectra: The Behaviour of Nonnormal Matrices and Operators*, Princeton University Press, 2005.
4. Raizer, Y. P., & Shneider, M. N. "Microwave breakdown of gases," *Plasma Physics Reports*, vol. 29, no. 9, pp. 656–672, 2003.
5. Goebel, D. M., & Katz, I. (2008). Fundamentals of Electric Propulsion: Ion and Hall Thrusters. Wiley.
6. Jahn, R. G. (2006). Physics of Electric Propulsion. Dover Publications.
7. Feynman, R. P., Leighton, R. B., & Sands, M. (2011). The Feynman Lectures on Physics, Vol. II: Mainly Electromagnetism and Matter. Basic Books.

Appendix