"Vibrational" Electromagnetics in Metamaterials

Nader Engheta[1]

[1] *University of Pennsylvania, Philadelphia, PA, USA,*
engheta@seas.upenn.edu
https://engheta.seas.upenn.edu/

Abstract: Inspired by Kapitza's inverted pendulum problem, we have been exploring how such phenomena can be brought into the field of electromagnetic and optical metamaterials. I will present several case studies we have explored so far.

Vibrational electromagnetics in metamaterials:

The problem of an inverted pendulum with a vibrating base has been an exciting topic in mechanics since long ago [1]. It is known that a stationary inverted pendulum is at an unstable equilibrium. However, the structure becomes stable when the base is vibrated with a small amplitude but high frequency. In 1951, Pyotr Kapitza developed a comprehensive theory describing quantitatively the physics behind this mechanical problem and providing the necessary stability conditions [2, 3]. His work on this theory launched the fields of *vibrational mechanics* and *vibrational resonance* with applications in various fields of science and technology.

Inspired by Kapitza's work, in my group we have been exploring how such phenomena can be brought into the fields of electromagnetics and optics. In other words, can an "unstable" electromagnetic problem be made "stable" by adding a small-amplitude, high-frequency modulation of a parameter? We have been investigating several scenarios for this purpose. One of these scenarios is the case of LC circuit with negative (non-Foster) capacitance [4]. Such a circuit exhibits instability due to the presence of negative C. However, we have shown theoretically that a properly time-modulated inductor L(t) can indeed make the circuit stable even in the presence of negative C [4]. This problem has led us to the next scenario of "Temporal Illusion", in which a judiciously selected time-varying permittivity can imitate light-matter interaction in an object with unusual permittivity values [5]. Another case we are exploring is how monochromatic evanescent waves in Drude-negative-permittivity material can be significantly altered into monochromatic propagating waves by having periodic high-spatial-frequency distributions of positive-negative inhomogeneity. More cases are in progress now.

In this talk, I will present an overview of our most recent results and discuss some of the salient features of these phenomena inspired by the Kapitza inverted pendulum problem.

References

1. A. Stephenson, *The London, Edinburgh, and Dublin Philosophical Magazine and Journal of Science* 15, 233 (1908).
2. P. L. Kapitza*, Sov. Phys JETP*, 21, 588 (1951).
3. P. L. Kapitza, *Collected papers of P. L. Kapitza*, Volume 2 (Pergamon, Oxford, 1965).
4. A. Alex-Amor, G. Ptitcyn, and N. Engheta, "Kapitza-Inspired Stabilization of Non-Foster Circuits via Time Modulations," *ArXiv: arXiv:2410.12976. Submitted, under review*.
5. G. Ptitcyn, D. M. Solis, M. S. Mirmoosa, and N. Engheta, "Temporal Illusion", in preparation.