

Microscopic and Macroscopic Wave-Matter Interactions in Time-Switched Space-Time Metamaterials

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The physics of natural phenomena can be explored at different scales while maintaining the same predictions unaltered. Electromagnetic wave interactions with matter, such as reflection at a spatial interface, are an excellent example of this concept. In fact, Fresnel's coefficients can be derived from macroscopic refractive indices or from the collective response of microscopic unit elements, as in the Ewald-Oseen extinction theorem. Understanding the link between small and large scales underpins modern metamaterials, where manipulating microscopic parameters achieves desired and exotic macroscopic responses.

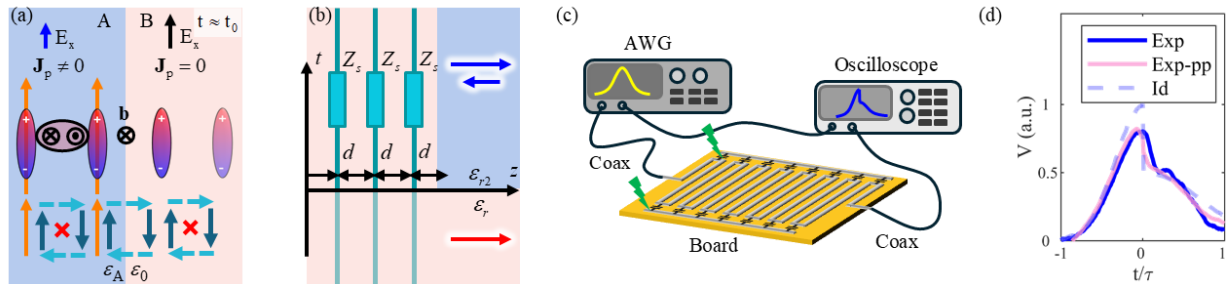


Figure 1. (a) The polarization currents generated in the materials are not balanced at the interface, resulting in a net curl. (b) A transmission line is suddenly loaded with a periodic array. Under certain conditions the response is akin to the one of a uniform medium. (c) Experimental setup for the space-time corner. (d) Comparison between the ideal response, in dashed light blue, and the experimental data, raw in solid blue and processed in solid pink.

In this contribution, we explore the connection between microscopic interactions and macroscopic response in a time-switched metamaterial. We describe the microscopic process that results in the conservation of the induction fields and show a scenario in which this is not the case. To obtain this unusual response, we make use of a space-time corner obtained at the spatial interface between a time-modulated medium and a static one, Fig. 1a. We show that the currents, generated by the injection of random dipoles, during the time interface are not balanced at the space-time corner, altering the continuity of the induction fields.

Our investigation proceeds by modelling a time interface in a periodically loaded transmission line. In this case, rather than dipoles, we consider concentrated loads connected in shunt with the line, Fig. 1b. We explain the macroscopic response of a uniform medium with the microscopic single response of each loading element and provide bounds for this connection.

Then, we experimentally prove the space-time corner in a periodically loaded transmission line where switches can connect or disconnect lumped capacitors in time, Fig. 1c. We excite the board with a broadband pulse and make use of the coaxial cable in output. When the signal is half inside the board and half inside the cable, we trigger the time interface, where the left side (board) is modulated while the right side (coaxial cable) is static. Fig. 1d reports the comparison between the ideal and experimental response, showing a good agreement compared to the dispersion present in the device.