Chapter 13
A Design of a Material Assembly in Space-Time Generating and Storing Energy

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Abstract The paper introduces the theoretical background of the mechanism of electromagnetic energy and power accumulation and its focusing in narrow pulses travelling along a transmission line with material parameters variable in one space dimension and time. This mechanism may be implemented due to a special material geometry, namely, a distribution of two different dielectrics in a spatiotemporal checkerboard. We concentrate on practically reasonable means to bring this mechanism into action in a device that may work both as energy generator and energy storage. The basic ideas discussed below appear to be fairly general; we have chosen their electromagnetic implementation as an excellent framework for the entire concept.

Professor Jüri Engelbrecht is widely known as an outstanding scholar in various branches of mechanics and mathematical physics. Through many years, he has been one of the main contributors to the intensive development of science and academic education in his homeland Estonia and far beyond it, on the European scale. His public service is commensurate with his scientific merits. Jüri's sphere of interests is vast, and it always belonged to the cutting edge of mechanics and thermodynamics. This is the reason why we decided to submit our work to Jüri's jubilee collection of papers; we dedicate it to our dear colleague and friend with the hope that it may get along with his long-time professional aspirations.

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13.1 Introduction

This paper is about a physical implementation of a novel concept in material science and technology termed *dynamic materials* (DMs) (Blekhman and Lurie, 2000; Lurie, 2007). DM are not materials in a traditional sense. They are defined as material substances with properties that may change in *space and time*. In particular, we may speak about formations assembled from traditional material constituents with variable space-time properties. This understanding is unusual because DMs should be thought of as substances that are not fabricated once and for all, but rather brought into the scene and maintained by being properly operated in space and time. Specifically, the temporal property change is possible only due to an exchange of mass, momentum, and energy between the DM and the environment.

To put it briefly, a DM is a thermodynamically open system; only its union with the environment may be considered as closed. The very notion of a DM makes sense only when it is perceived as a spatial temporal entity, and this is the main difference between DMs and ordinary materials that exist as dead substances, i.e., their properties do not change in time. Contrary to DMs, ordinary materials appear to be thermodynamically closed.

Living tissue represents a natural example of a DM. As to a manmade implementation, this has become possible due to recent progress in technology that allows for the property tuning, specifically on a micro- and nano-scale. Some technical means towards such tuning are detailed in (Pelesko and Bernstein, 2002; Oohira et al., 2004; Rozenberg et al., 2006; Krylov et al., 2010, 2008; Krylov and Lurie, 2011). At this point we only mention that the most practical way towards it will be a *material switching*, i.e., a transfer from one material to another implemented by a suitable technical means whenever and wherever necessary.

This transfer is accompanied by energy flux brought into the system (or released from it) by an external agent. When we work with a DM, the presence of an external agent is both inevitable and critical. It serves as a necessary link with the environment, maintaining the dynamic nature of a material formation.

Once implemented, the concept of DMs offers a diversity of effects unthinkable with ordinary materials. Among them are efficient ways to control wave propagation and, in particular, options for introducing novel principles of power generation, transport, and storage of energy. DMs are also of universal significance for optimisation because they may be adjusted to fit the environment, changing in space and time, and therefore they offer a great amount of resources never stored in ordinary materials. In this capacity, they represent a natural material arena for the purposes addressed in dynamics.

These ideas belong with a core of material science today. They can be realised and verified by building dynamic materials structured as large arrays (transmission lines) of coupled and actively controlled oscillatory elements. For this purpose the LC cells in the electromagnetic implementation could be used, and the mass spring elements in mechanical implementation. In either case, the material parameters of the elements are subjected to active control by an external agent.