



Dielectric and Magnetic Nonlinear Materials for NLTLs

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Abstract — Nonlinear transmission lines (NLTLs) have been the subject of several studies that have shown their suitability for a wide variety of applications as pulse compressor, phase shifter, frequency multiplier, pulsed radar, battlefield communication disruption and also as a high power microwave source, holding in this case an alternative way to generate high-power radio frequency (RF) signals without using vacuum electronic tubes, which normally requires heating filament and bias power supplies. NLTLs designed for the RF generation uses nonlinear dielectric and magnetic materials that are arranged to form a dispersive or continuous nonlinear medium. This paper presents a summary of the main research on the recent NLTLs development and provides an analysis of the influence of the nonlinear material characteristics on the performance of NLTLs, pointing out that there is a lack of nonlinear dielectric and magnetic materials that would allow the achievement of NLTLs with better RF conversion efficiency and the operation at higher frequencies even under adverse environmental conditions. The nonlinear dielectric and magnetic materials for NLTLs applications need to have characteristics such as highly nonlinear behavior, low losses, and thermal stability.

I. Types of NLTLs

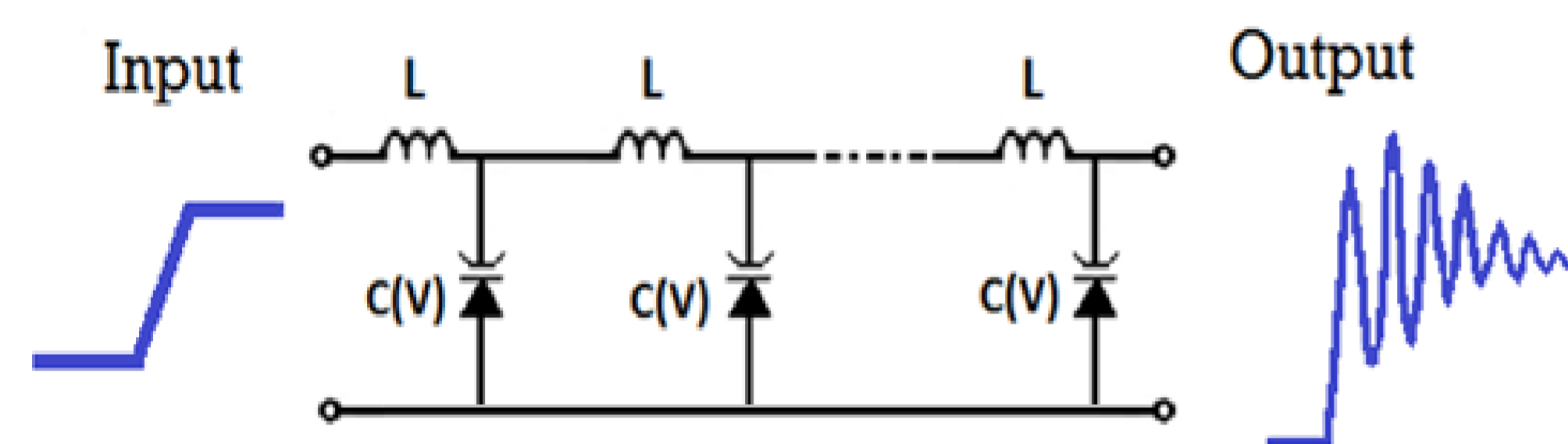


Fig. 1. Capacitive NLTL.

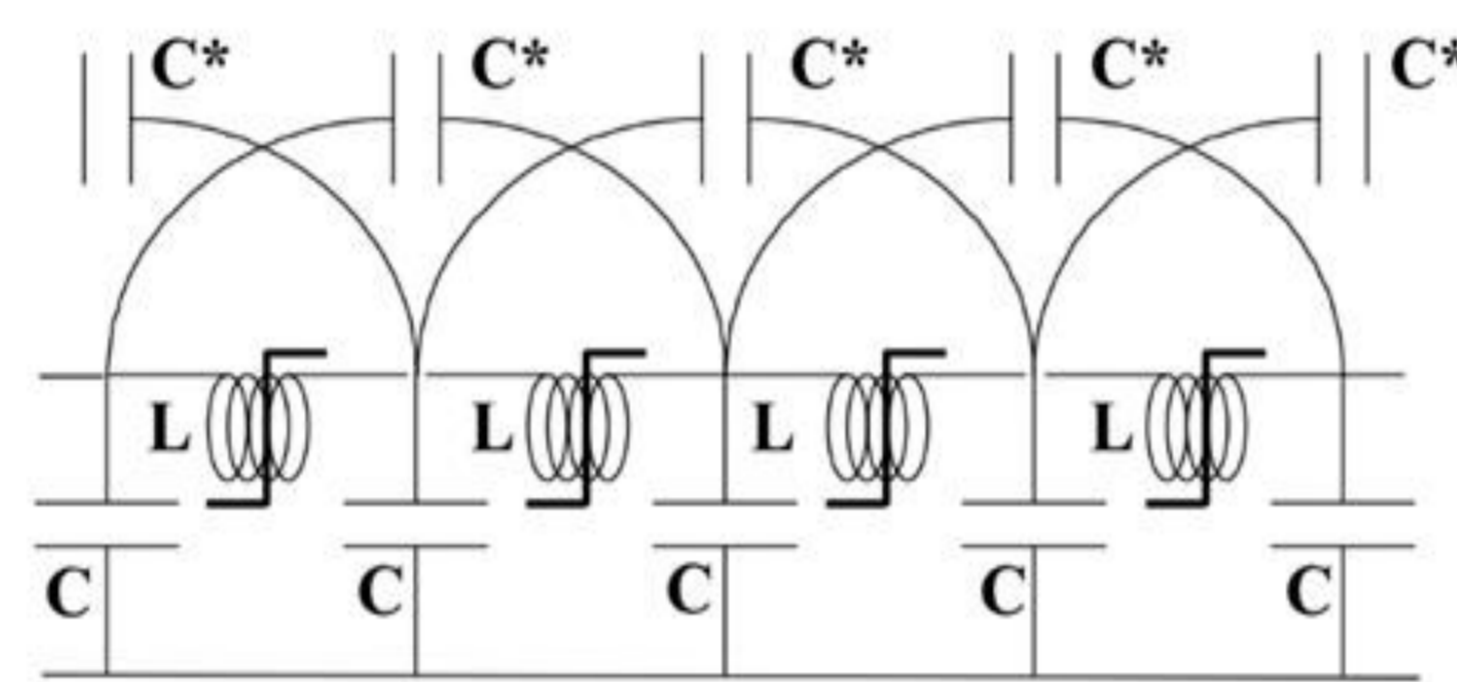


Fig. 2. Synchronous NLTL

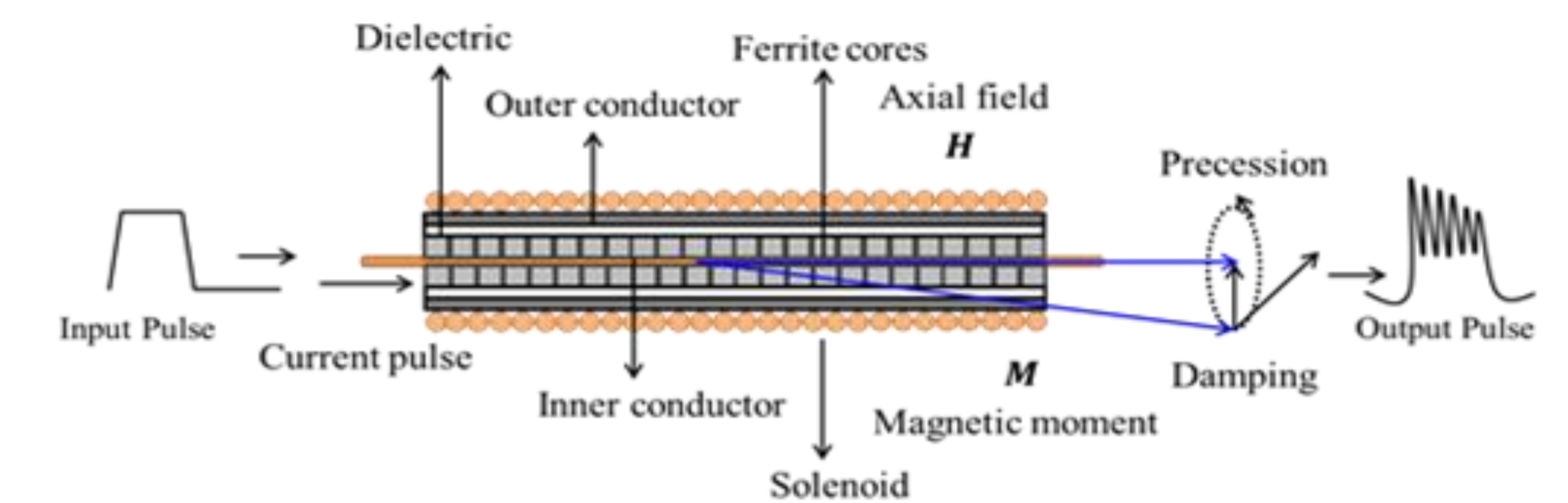
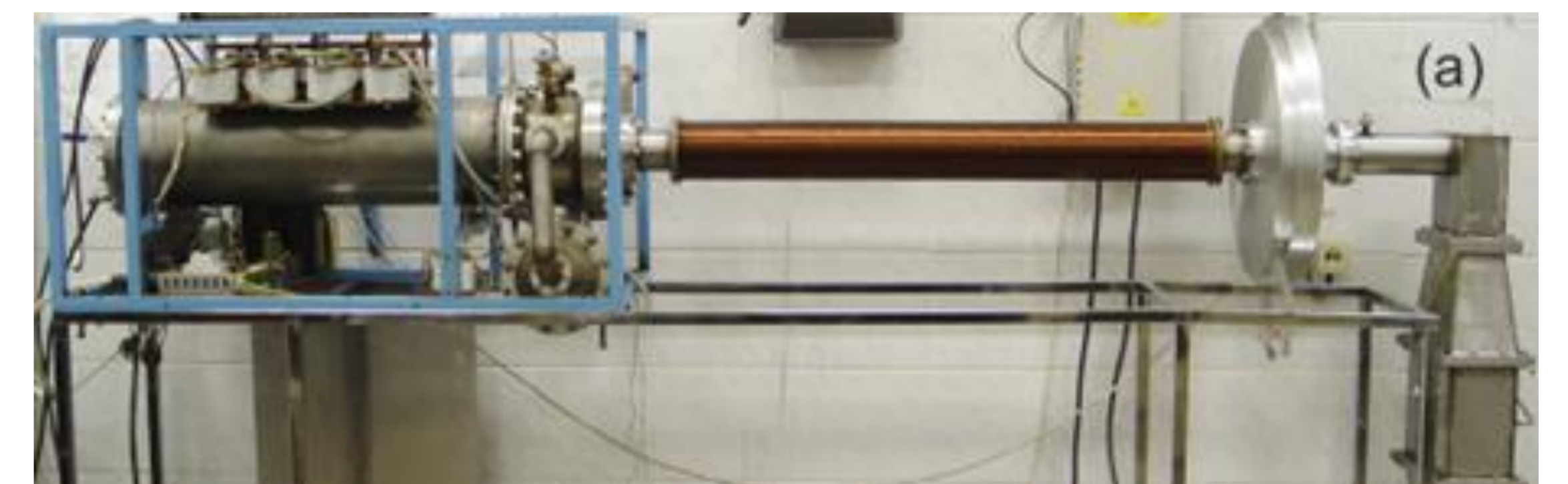
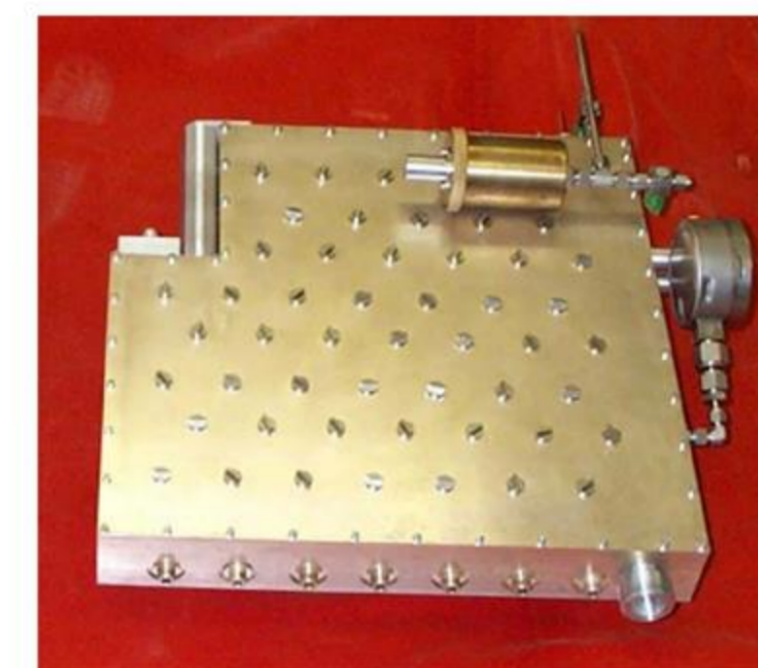
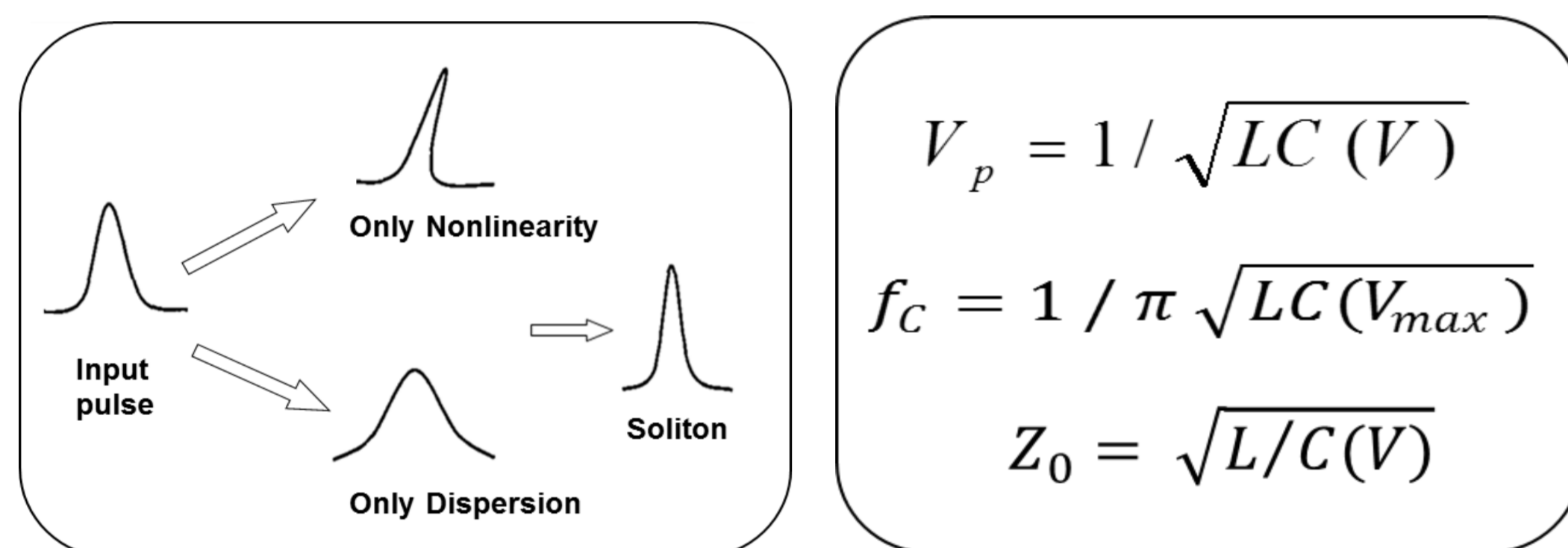


Fig. 3. Gyromagnetic NLTL



II. Relevant Experimental Results in the Literature

Structure Type	Key Material	Input Pulse (kV)	Frequency Range (GHz)	Output Power	Reference
CPW	HBV diode	0.008	231 - 247.5	10 mW	X. Mélique <i>et al.</i> - 1999
PCB	Varactor diode	0.02	0.12 - 0.25	98 W	J. Darling -2009
Parallel Plate	Blocks of $\text{Sr}_{0.4}\text{Ba}_{0.6}\text{TiO}_3$	14	0.25 - 0.40	15.6 MW	Ikezi <i>et al.</i> - 1991
PCB	Ceramic Capacitor	30	0.01 - 0.09	12 MW	J. Darling -2009
Coaxial	Ferrite	30 - 50	0.20 - 2.00	20 MW	N. Seddon <i>et al.</i> - 2007
	Ferrite (NiZn)	260	0.95 - 1.45	100 MW	D. M. French <i>et al.</i> - 2014
	Ferrite (YIG)	3 - 6	1.70 - 1.80	200 kW	D. V. Reale <i>et al.</i> - 2014
	Ferrite	30 - 50	2 - 6	1.3 MW	Bragg <i>et al.</i> - 2012
	Ferrite (NiZn)	150 - 270	0.60 - 1.00	3 GW	Romanchenko <i>et al.</i> - 2017
	Ferrite (NiZn)	200	2.0 - 2.20	200 MW	Romanchenko <i>et al.</i> - 2017

III. Materials Properties versus NLTLs Performance

PROPERTIES OF NONLINEAR DIELECTRIC MATERIALS	NLTLs PERFORMANCE
Nonlinearity of relative permittivity behavior with applied voltage ($\geq 70\%$) with medium to low values ($\epsilon_r < 100$)	Higher operation frequency
Low dielectric losses (high relaxation frequency of electric dipoles)	RF conversion efficiency
High dielectric strength (breakdown voltage)	Power handling capability

PROPERTIES OF FERRIMAGNETIC MATERIALS	NLTLs PERFORMANCE
High relative permeability	Higher operation frequency
Low magnetic loss (high resistivity, low resonance linewidth)	RF conversion efficiency
High saturation flux	Power handling capability

IV. Conclusions

- NLTLs has proven to be a robust, low cost and fully solid-state technology for many applications in high speed and wide bandwidth systems that require pulse sharpening and RF generation.
- The performance of NLTLs is related to the properties of nonlinear dielectric and ferrimagnetic materials.
- The efficiency of NLTLs is strongly affected by the energy losses in the nonlinear dielectric and ferrimagnetic materials.
- The research on high performance nonlinear dielectric and ferrimagnetic materials is a great challenge since the desired properties are subjected to the structural phase transformation at Curie temperature.
- A stable behavior over a broader operating temperature range would allow the application of NLTLs in military and aerospace areas, which can involve pulse repetition of tens of kHz.