Extreme non-linearity in ferrites: from microwave to THz.

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Electromagnetic (EM) shock waves are normally associated with nuclear explosions, and as such a rare phenomenon. Analogous to a sonic boom, it is an interference effect, resulting in a surge of EM power, propagating with a speed of light. Since early 60s there was an interest to harness the effect to make it more technologically practical. One possible way to do that is within the configuration of a magnetically loaded transmission line (e.g. coaxial line). While the coaxial design has been proven to be viable for generating high power microwaves [1], its practicality in consumer technology is less so obvious due to high voltages (typically 10-100th kV) needed in order to obtain the effect. Theoretically, this problem can be resolved by scaling down the dimensions of the transmission line. Reducing down to microscopic dimensions, it is possible to obtain the effect at voltages as low as 1-10 Volts. At this level the effect can be usefully utilised in a range of electronic devices, and particularly the high frequency communications, which are of great demand in the development of modern IC technologies. Modelling extremely non-linear EM dynamics is however a challenging problem, that can not be done by the available conventional solvers. Here we approach the problem by using a unique modelling technique allowing to solve Maxwell equations in parallel to Landau-Lifshits-Gilbert's (LLG) [2]. The unique nature of our 3D FDTD-LLG code, is in the fact that LLG equation is solved exactly, accounting for the given geometry with the presence of any type of conducting or non-conducting materials [3]. This means that all non-linear effects can be calculated precisely without any linearization or imposed constraints.

In this contribution I will demonstrate the main characteristics and parameters of the shock wave propagation in microstrip transmission line. In particular, I will show the dispersion characteristics of the wave, its dependence on the geometric and material parameters of the device and those of the source of actuation. As well as the typical effects, such as applied field dependence and anisotropy, I will demonstrate some unique features, such as tuneability with the electric field pulse, allowing to manipulate the response in a broad GHz to THz frequency range. I will also demonstrate the possibility of guiding the waves in microstripes with non-linear geometric designs, and discuss the potential for application in communication technologies.

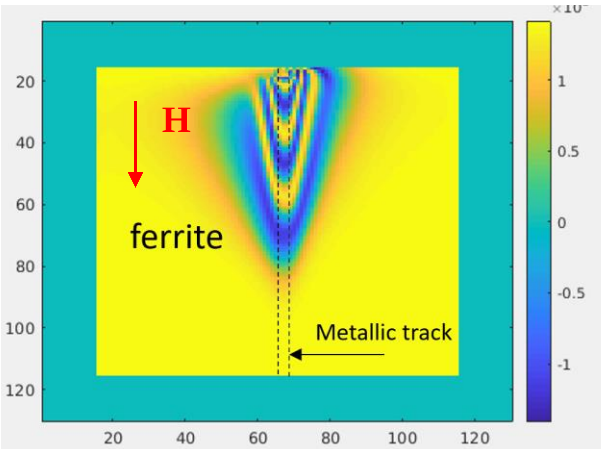

Figure 1. **Electromagnetic shock-wave propagation in a thin-film microstrip transmission line**. The wave is actuated with a short electric pulse between the microstrip (shown with dashed lines) and the base metalised plane. Ferrite thin film (10micron) extended over the base line. Shock wave propagates below the strip, but deviates also into the whole slab. Intensity map: out-of-plane magnetisation. Initial orientation of the magnetisation is parallel to the applied field (red arrow).

References

[1] Ulmasculov et al. (2017), J. Phys.: Conf. Ser. 830 012027.
[2] M. M. Aziz, Progress In Electromagnetics Research B 15, (2009) 1–29.
[3] https://www.maxllg.com/