Electromagnetic absorption beyond the Rozanov bound via time-varying and time-switched lossy layers

Matteo Ciabattoni(1) and Francesco Monticone(1)

(1) School of Electrical and Computer Engineering, Cornell University, Ithaca, New York 14853, USA

An electromagnetic absorber is a device used to absorb incoming electromagnetic waves for the purpose of stealth, energy harvesting and more. Such devices have been designed in various forms and modes of operation; examples of that are the Salisbury screen [1], which is a resistive layer placed a quarter of a wavelength above a perfect electric conductor (PEC), or the Dallenbach Layer [2], which is a lossy material of quarter-wavelength thickness followed by a PEC. Despite the various designs developed over the years, the absorption performance of any Linear, Time-Invariant (LTI) absorber is bound by the Rozanov bound [3], which establishes a fundamental tradeoff between the reflection coefficient of a metal-backed LTI electromagnetic absorber, the bandwidth over which a desired reflection reduction can be achieved, and the absorber thickness.

In this talk we will show that, by lifting the time-invariance assumption in the design of an electromagnetic absorber through the use of a time-varying lossy layer, we can introduce frequency-wavevector transitions allowing for strong destructive interference between each of the generated harmonics of the incoming pulse. This results in enhanced absorption beyond the maximum allowed by the Rozanov bound. As a proof-of-concept experiment, we designed and tested a transmission-line-equivalent absorber incorporating a time-varying resistance implemented with a single-pole double-throw switch, and we showed that this device can overcome the Rozanov bound for a short pulse having a very broad bandwidth, 8 – 80 MHz [4] [5], with modulation frequencies spanning the range 10 – 50 MHz. Our experimental results show that the improved absorption of the time-varying absorber is dependent on its modulation frequency and, especially, on its modulation phase, highlighting that in a practical scenario a time-varying absorber would require a control system to change its modulation parameters to operate optimally.

To further improve upon this work, we will show some preliminary results of an electromagnetic absorber comprising a self-biased time-switched layer that can enhance destructive interference between different components of the incoming pulse. The absorber is implemented as a frequency selective surface and can operate beyond the Rozanov bound while having a thickness that is less than a quarter of the length of the incoming pulse.

In conclusion, in this talk we will show how the addition of time-varying and time-switched lossy layers can enable electromagnetic absorbers able to not only operate beyond the Rozanov bound but also to significantly reduce the absorber's physical footprint. These findings open new avenues for the design of compact, high-performance electromagnetic absorbers (and, more broadly, wave absorbers), paving the way for advancements in stealth technology, energy harvesting, and beyond.

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[2] W. Dallenbach and W. Kleinsteuber, "Reflection and absorption of decimiter-waves by plane dielectric layers," *Hochfreq. u. Elektroak,* vol. 51, pp. 152-156, 1938.

[3] K. N. Rozanov , "Ultimate thickness to bandwidth ratio of radar absorbers," *IEEE Transactions on Antennas and Propagation,* vol. 48, no. 8, pp. 1230-1234, 2000.

[4] M. Ciabattoni, Z. Hayran and F. Monticone, "Observation of broadband superabsorption of electromagnetic waves through space-time symmetry breaking," *Science Advances,* vol. 11, no. 3, 2025.

[5] F. Monticone, D. Sounas and M. Ciabattoni, "Time-periodic (Floquet) systems in classical wave physics and engineering: opinion," *Optical Materials Express,* vol. 15, no. 3, pp. 362-367, 2025.