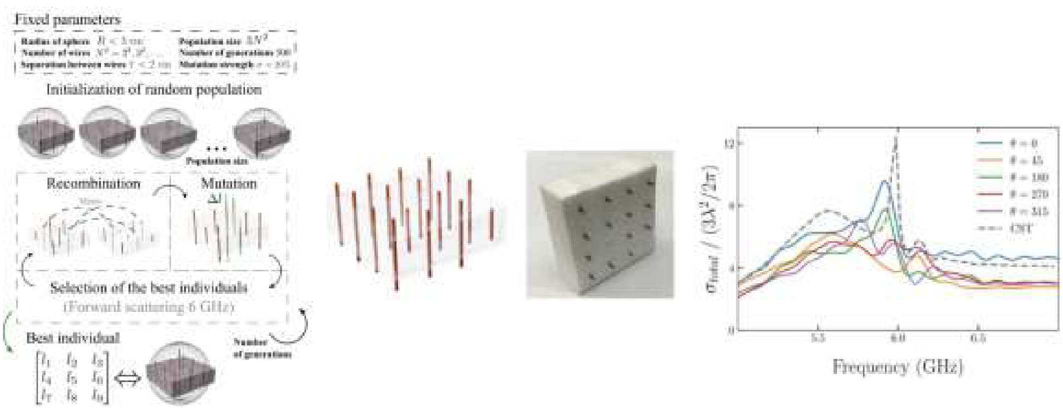
Genetically Designed Superbandwidth Superscatterers — One among a Trillion

Pavel Ginzburg, Dmytro Vovchuk, Anna Mikhailovskaya, Konstantin Grotov, Denis Kolchanov, and Dmitry Dobrykh
Tel Aviv University, Israel

Abstract— Experimental demonstration of superdirectivity and superscattering is among the longstanding challenges in electromagnetic theory. An appealing approach to increase a scattering crosssection is accommodating several spectrally overlapping resonances within a subwavelength structure. We will present several strategies to design superscatterers with the aid of generic optimization and demonstrate their state-of-the-art performances experimentally. We will formulate a new tight superradiant criterion of superscattering and demonstrate that only 1 among a trillion random structures can approach it.

The presentation is based on our recent works [1–4] and on a large set of new unpublished data (several manuscripts under review). On top of our published results, we will demonstrate novel extremely-broadband superscatterers, fabricated with the aid of additive technologies, and all-angle all-polarization corona-virus-like devices, which operation encompasses both resonant phenomena and constructively interfering creeping wave interactions.

Electromagnetic scattering on subwavelength structures has been always a subject of extensive investigations owing to fundamental challenges and applied rewards, related to its maximization or suppression. Interaction with compact structures is well approximated by a multipole series, where lower orders are typically sufficient to approach a convergence. The maximal possible scattering into a single multipole is called a channel limit. In a vast majority of cases, a dipolar single channel limit (the maximal scattering cross-section, which a small resonant lossless dipole can approach) is considered. In this case, $3\lambda^2/(2\pi)$, where λ is a free space wavelength, is the value, versus which all the assessments will be made hereafter. Compact subwavelength structures, bypassing the single channel limit, are called super-scatterers. While there is no fundamental upper bound on a scattering cross section, quite a few theoretical limits with Cho-Harrington, being the most commonly used, have been proposed to account for possible practical aspects. Bypassing those limits requires accommodating several resonant multipoles, constructively interfering at nearly the same frequency. In this case, a significant near-field accumulation in a vicinity of lossy materials, accompanied with an extremely low fabrication tolerance, are the main known factors, limiting practical demonstration of super-scatterers. Nevertheless, several promising designs have been demonstrated during the last years and will be revised hereinafter. Regardless of their particular realization, they all share the same design principles. The first one is the choice of a material platform. Since high near-field accumulation necessarily implies having high Ohmic losses, constitutive components should be carefully chosen. The second criterion is the capability



(a) (b) (c)

Figure 1: Wire bundle superscatterer. (a) Genetic algorithm for the design. (b) One of the structures — field distributions and the photograph of the device. (c) Multipolar expansion of scattering and experimental scattering cross-section of the superscatterer.

to perform extensive electromagnetic optimization. In the case of compact structures, internal resonances tend to repel each other, opening frequency gaps. In order to bypass those design challenges, optimization efforts to be performed.

In this contribution, we will demonstrate several conceptually different strategies to design and experimentally demonstrate superscattering. The following sections survey our results. Novel and conceptually different architectures will be also demonstrated at the conference.

REFERENCES

1. Grotov, K., et al., "Genetically designed wire bundle super-scatterers," *IEEE Trans. Antennas Propag.*, 2022.
2. Mikhailovskaya, A., et al., "Superradiant scattering limit for arrays of subwavelength scatters," *Phys. Rev. Appl.*, Vol. 18, No. 5, 054063, Nov. 2022.
3. Kosulnikov, S., et al., "Circular wire-bundle superscatterer," *J. Quant. Spectrosc. Radiat. Transf.*, Vol. 279, 108065, Mar. 2022.
4. Mikhailovskaya, A., D. Vovchuk, K. Grotov, D. Kolchanov, D. Dobrykh, K. Ladutenko, V. Bobrovs, A. Powell, P. Belov, and P. Ginzburg, "Coronavirus-like all-angle all-polarization broadband scatterer," *Communications Engineering*, Vol. 2, 76, 2023.