Hyperuniform Disordered Arrays

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Disordered hyperuniform systems are exotic amorphous states of matter that are endowed with novel physical and thermodynamic properties. Specifically, these systems have the ability to suppress large scale density fluctuations and are characterized by an exclusion region in reciprocal space, where the structure factor completely vanishes. The structure factor is a physical quantity that describes how a particular point configuration scatters incident radiation. These aperiodic element distributions have been previously used in a number of applications, such as the design of composite Luneburg lenses [1], as well as metasurfaces [2]. Due to their ability to control scattering properties, hyperuniform disordered systems have been used extensively to design complete photonic band gaps (PBG). This lead to the design of novel high-quality optical waveguides with free-form geometries [3] and to the design of the hyperuniform disordered terahertz quantum cascade laser [4].

Associating the structure factor of a point configuration with the normalized radiation pattern of an array of identical elements, allows us to design novel hyperuniform disordered antenna arrays with unique attributes. Specifically, this promising new array element distribution is able to fully suppress the undesired grating lobes when operated over large bandwidths of spanning multiple wavelengths and for large beam-steering angles and are characterized by a clear exclusion region that surrounds the main lobe rendering their behavior unique among other types of antenna arrays that have been used in the past (periodic and aperiodic). Furthermore, this kind of array distribution is scalable and can be used for the optimization of extra large arrays of thousands of elements without the need for huge amount of computational time.



Figure 1. From left right: Element distribution for an array with hyperuniform disorder of 225 elements. Corresponding array factor at 2.25 GHz. Corresponding array factor at 6.75 GHz. Top down view of the corresponding array factor at 6.75 GHz. Top down view of the corresponding array factor at 6.75 GHz. Top down view of the corresponding array factor at 6.75 GHz when the main beam is steered towards the $\theta = 30^{\circ}$, $\phi = 0^{\circ}$ direction. In all of the polar radiation plots the radial and angular coordinates correspond to the θ and ϕ angles, respectively.

References

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