# National Radio Science Meeting

◆ January 4-9, 2021

**Plenary Talk, January 7, 2021**

## *Four-Dimensional Spatiotemporal Metamaterials*

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**Abstract:** To control and manipulate electromagnetic waves and fields we need to use materials. Metamaterials and metasurfaces have provided interesting platforms for tailoring and functionalizing the wave-matter interaction. Most of such material-based interactions have been with spatially inhomogeneous media, utilizing three dimensions of space. However, the dimension of "time" can be added to such inhomogeneous materials, exploiting materials that can change in time, in addition to (or instead of) space-varying material parameters. Such four-dimensional (4D) spatiotemporal metamaterials offer novel electromagnetic features with exciting functionalities. This talk is divided into three parts: In the first part, I will discuss how judicious choices of spatial inhomogeneity can provide material platforms that can perform mathematical operations with waves, effectively constructing materials that can solve equations with waves with near speed of light, thus functioning as wave-based analog computing machines. In the second part, I will present the other extreme, i.e., material platforms that are homogeneous in space, but instead exhibits time-varying parameters, leading to interesting features such as anti-reflection temporal coating, temporal aiming and temporal steering, and temporal cladding. In the final section of this talk, I will show how combining spatial and temporal inhomogeneities in spatiotemporal metamaterials can offer exciting functionalities beyond those of the conventional metamaterials. As an example for the third section of the talk, I will present how we can manipulate diffusion, leading to asymmetry and trapping in diffusive phenomena, using such spatiotemporal platforms. I will present physical insights into these results and forecast future research directions in these areas.

**Biography:** Nader Engheta is the H. Nedwill Ramsey Professor at the University of Pennsylvania in Philadelphia, with affiliations in the Departments of Electrical and Systems Engineering, Bioengineering, Materials Science and Engineering, and Physics and Astronomy. He received his BS degree from the University of Tehran, and his MS and Ph.D. degrees from Caltech.

His current research activities span a broad range of areas including photonics, metamaterials, electromagnetics, nano-optics, graphene photonics, imaging and sensing inspired by eyes of animal species, microwave and optics, and physics and engineering of fields and waves.

He has received several awards for his research including the *2014 Balthasar van der Pol Gold Medal* from URSI*,* the *2012 IEEE Electromagnetics Award*, the 2020 *Max Born Award* from Optical Society, the 2019 *Ellis Island Medal of Honor,* the 2018 *Pioneer Award in Nanotechnology from IEEE Nanotechnology Council*, the 2015 *Gold Medal from SPIE,* the 2017 *William Streifer Scientific Achievement Award from IEEE Photonics Society*, induction to the *Canadian Academy of Engineering* as an International Fellow, *the Fellow of US National Academy of Inventors (NAI), the IEEE Antennas and Propagation Society Distinguished Achievement Award,* the *Beacon of Photonics Industry Award*, *the Vannevar Bush Faculty Fellowship Award* from US Department of Defense*, the Wheatstone Lecture in King's College London, 2006 Scientific American Magazine 50 Leaders in Science and Technology*, and the *Guggenheim Fellowship*.

He is a Fellow of seven international scientific and technical organizations, i.e., IEEE, URSI, Optical Society of America (OSA), American Physical Society (APS), Materials Research Society (MRS), International Society for Optics and Photonics (SPIE), and American Association for the Advancement of Science (AAAS). He has received the honorary doctoral degrees from the Aalto University in Finland in 2016, the University of Stuttgart, Germany in 2016, and Ukraine's National Technical University Kharkov Polytechnic Institute in 2017.