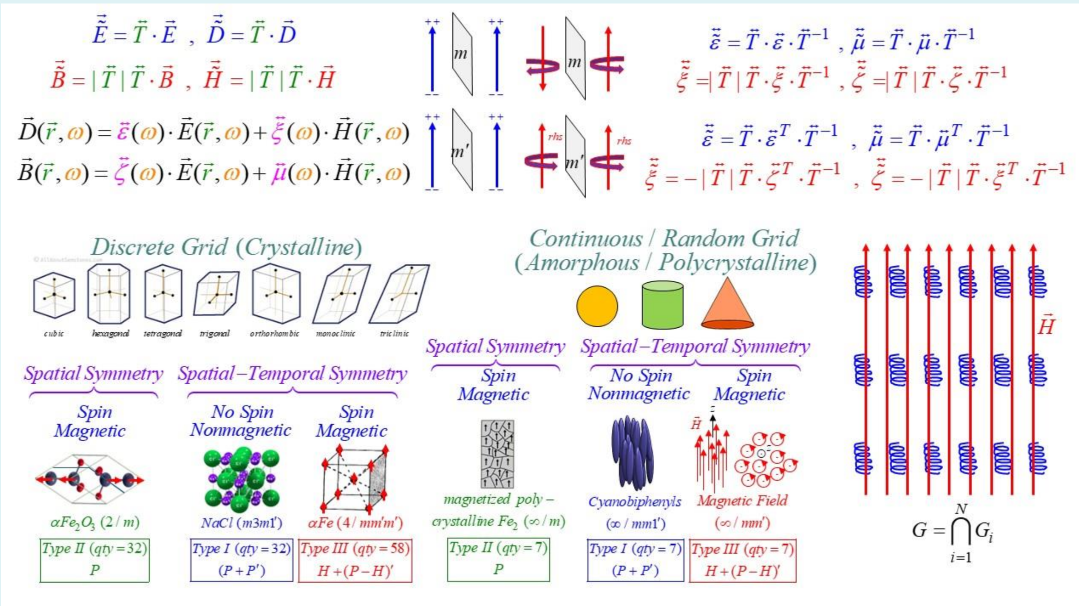
SC13 - Symmetry and symmetry breaking in complex media electromagnetics



Abstract:

The infusion of symmetry and symmetry breaking into the design and fabrication of complex media and devices is a fascinating area of research with the objective to gain ever more control over the electromagnetic field. The goal of this short course is to understand how symmetry influences the electromagnetic properties of materials, how symmetry influences scattering measurements, and how symmetry and symmetry breaking is utilized in the design of electromagnetic devices (e.g., circulators, splitters, polarization transformers, etc.). Group theory, the mathematical cornerstone of symmetry, will be discussed as well as the important concepts of Neumann's and Curie's principles. Spatial (i.e., mirror, rotation, inversion) and temporal (i.e., unrestricted and restricted time inversion) symmetries, and their corresponding influence on electromagnetic material properties and applications, will also be discussed.

Recommended pre-requisites:

The attendees should have a basic understanding of Maxwell's equations and matrix algebra. A basic understanding of group theory and symmetry would be beneficial, but is not necessary as these concepts will be discussed in the short course.

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Learning Objectives:

The primary learning objectives/goals are:

1. Understand basic principles of symmetry including spatial (mirror, rotation, inversion) and time reversal operations and how these symmetries influence material properties and measurements.
2. Be able to utilize group theory to identify the symmetry group of a given material design or measurement system.
3. Learn how to use Neumann's and Curie's symmetry principles to determine material tensor properties and symmetries of scattering parameter measurement systems and their practical importance.
4. Develop insight into how to induce symmetry breaking and how it leads to enhanced control of an electromagnetic field.
5. Discover how symmetry is used to design microwave devices, such as circulators, splitters, polarization transformers, etc.
6. Utilize symmetry in your research and future studies.

Course Outline:

Electronic pdf notes will be provided, thus a laptop is required.
The short course will be 3 hours long with a 30 minute break in between. The technical portion of the outline of the proposed tutorial short course is below:

1. Motivation for investigating symmetry and symmetry breaking in complex media electromagnetics.
2. Review spatial and temporal symmetries, including mirror reflection, rotation, inversion, and time reversal.
3. Review group theory and identify the seven basic crystal systems and the classification of the associated 122 discrete and 21 continuous point groups.
4. Use Neumann's and Curie's principles to determine the material tensor forms for all the discrete and continuous point groups. Discuss which symmetries lead to bianisotropy, non-reciprocity, ferromagnetism, antiferromagnetism, and chirality, for example.
5. Explore symmetries of various measurement systems and devices and how these symmetries influence the structure of scattering matrices and their practical importance.
6. Demonstrate how these various materials and symmetries are utilized in the design of microwave, millimeter wave, and photonic devices.
7. Conclusions and future work.

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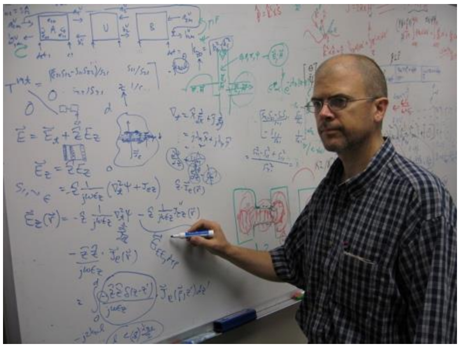
Instructor:



Michael J. Havrilla received B.S. degrees in Physics and Mathematics in 1987, the M.S.E.E degree in 1989 and the Ph.D. degree in electrical engineering in 2001 from Michigan State University, East Lansing, MI. From 1990-1995, he was with General Electric Aircraft Engines, Evendale, OH and Lockheed Skunk Works, Palmdale, CA, where he worked as an electrical engineer. He is currently a Distinguised Professor in the Department of Electrical and Computer Engineering at the Air Force Institute of Technology (AFIT), Wright-Patterson AFB, OH. He is a Fellow of the Antenna Measurement Techniques Association (AMTA), a senior member of the IEEE, a member of URSI Commission B, and a member of the Eta Kappa Nu and Sigma Xi honor societies. His current research interests include electromagnetic theory and measurement of complex media, electromagnetic propagation and radiation in anisotropic and bianisotropic materials.

Key Bibliography

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