

IN THE PURSUIT OF THE FLAT LENS:

REFLECTION AND REFRACTION FROM INHOMOGENEOUS ELECTRICALLY-THIN MEDIA



Invited Talk

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Mulla Sadra Hall, School of Electrical Engineering

ABSTRACT:

Which came first, the law of refraction or lenses remain an intriguing question. How can a lens be invented or created without understanding refraction? Someone some many centuries ago could have noticed that humans or animals have lenses in their eyes to focus light but without understanding the geometry and mathematics that makes such focusing possible. Regardless, it is safe to surmise that someone must have first realized the connection between the two. The law of refraction is attributed to Snell, but historical records show that it was Ibn Sahl of Bagdad who first provided a theoretical framework for refraction of rays, later to be canonized as Snell law. Snell law is indeed the foundation for the optical phenomenon.

While humans and animals evolved to have spherically-contoured shapes to enable light transfer and hence vision, not all living things have the same, which preclude the rush to judgement that nature did not favor non-spherical geometry for light concentration and sensing. Suffice it to look at insects to understand this point. However, in this age, inexpensive manufacturing, while limited in many respects, have affected technological and scientific development. Everything now has to be “printed”. Either 2-d or 3-d. if it is not printed, manufacturers and large corporations loose interest.

Lenses, which have been historically spherically contoured, have escaped the menace (or blessing) of “printing” for years. Modern digital or non-digital cameras still rely on lenses that are spherically contoured. Can this centuries-old paradigm be altered? In recent years, several groups have been very active in developing flat lenses for optical regime. In our group, we developed flat lenses, presently for the microwaves regime, that can provide high concentration of electromagnetic waves with sufficiently less aberration that traditional gradient index lenses. Our work hinges on making the lens electrically thin, much less than the wavelength. This in turn lead to additional discoveries including the development of a new refraction “law” for electrically-thin inhomogeneous media.

BIOGRAPHY:

Omar M. Ramahi received the BS degrees in Mathematics and Electrical and Computer Engineering from Oregon State University, Corvallis, OR. He received his M.S. and Ph.D. in Electrical and Computer Engineering from the University of Illinois at Urbana-Champaign. From 1993 to 2000, he worked at Digital Equipment Corporation (presently, HP), where he was a member of the alpha server product development group. In 2000, he joined the faculty of the James Clark School of Engineering at the University of Maryland at College Park as an Assistant Professor and later as a tenured Associate Professor. At Maryland he was also a faculty member of the CALCE Electronic Products and Systems Center. Presently, he is a Professor in the Electrical and Computer Engineering Department at the University of Waterloo. He is a co-author of the book *EMI/EMC Computational Modeling Handbook, 2nd Ed.* Professor Ramahi has served as a consultant to several companies. Professor Ramahi won the Excellent Paper Award in the 2004 International Symposium on Electromagnetic Compatibility, Sendai, Japan, and the 2010 University of Waterloo Award for Excellence in Graduate Supervision. In 2012, Professor Ramahi was awarded the IEEE Electromagnetic Compatibility Society Technical Achievement Award. Dr. Ramahi is an elected IEEE Fellow. In 2009, he served as a Co-Guest Editor for the Journal of Applied Physics A Special Issue on Metamaterials and Photonics. From 2007-2015, he served as an Associate Editor for the IEEE Transactions on Advanced Packaging. From 2010-2012, he served as an IEEE EMC Society Distinguished Lecturer. In 2014, he served as a Guest Editor for the journal Sensors, special issue on Metamaterial-Inspired Sensors. He has authored and co-authored over 350 journal and conference papers.