INNOVATIVE LENS ANTENNAS FOR MILLIMETER AND TERAHERTZ RANGE ELECTROMAGNETIC WAVE SYSTEMS

State of the art:

To increase signal capacity and security, microwave terrestrial and space communication systems are evolving into millimeter-wave ones. This also enables one to arrange a frequency re-using within a smaller indoor or urban-space area. Due to smaller wavelength, mm-wave antennas rely heavily on the quasioptical principles. Here, dielectric lens antennas take upper hand over reflectors and play a key role as components able to provide both the high density of the electromagnetic power and the integration with receivers and signal-processing circuits. E.g., such antennas have been reported for broadband point-to-multipoint distribution systems, automotive radars, and radio astronomy [G. Rebeiz, *Proc. IEEE*, 80, 1748, 1992; X. Wu, *et al*., *IEEE Trans. MTT*, 49, 431, 2001]. In the domain of even shorter waves, commonly labeled terahertz range, one can see a rapid development of various systems and instruments [P. Siegel, *IEEE Trans. MTT*, 80, 910, 2002]. Most notable of them are T-ray imaging [D. Mittelman, *et al*., *Applied Physics B*, 1999, 4], time-resolved T-spectroscopy [J. Rudd, *et al*., JOSA-B, 19, 319, 2002], and environment sensors [R. Jacobsen, *et al*., *Optics Lett.* 21, 2011, 1996]. Cylindrical and rotationally symmetric lenses are also widely used here.

Problem statement:

Dielectric lenses are crucial components of major mm-wave and all terahertz range communications and instruments systems. Their design and manufacturing would be much faster and cheaper if one could avoid costly prototyping and measurements. To minimize design delays as well as to propose innovative radiating structures, it is necessary to develop specific electromagnetic simulation tools. They will enable, not only the asymptotic and rigorous analysis of dielectric lens antennas, but also their optimization for various applications.

Computer-aided analysis and synthesis is a well-known key to succeed in this direction. However so far it has been based entirely on optical approximations. Therefore the effects of finite size, realistic material, and feed parameters on the electromagnetic performance of lens antennas still need to be accurately incorporated into the design tools. This implies a development of accurate mathematical and numerical modeling methods, writing and testing of computer codes, and investigation of the physical features of electromagnetic wave propagation, scattering and absorption. Lenses are to be considered as uniform or layered transparent scatterers having specific shape (e.g., elliptic with specially designed eccentricity, truncated elliptic, 2D or 3D arbitrarily shaped, etc.), and the size comparable to the wavelength.

Goals:

The main scope of this joint research project is the analysis and the optimization of innovative and/or compact (wavelength-size) homogeneous dielectric lens antennas. These structures can be used for various applications:

- Instruments and sensors in the terahertz range,
- Wireless communications systems for (1) the space-segment [inter-satellites communications, primary sources of Focal Array Fed Reflector, …], (2) terrestrial applications [indoor communications, high data rate outdoor communications], (3) automotive applications [intelligent transport systems, anti-collision radars, …], or (4) airborne applications [smart radomes, …].

These antennas will be used for the collimating, focusing, un-focusing, beam steering or beam forming of the electromagnetic waves radiated by a unique primary source (or a small array) whose characteristics must also be defined judiciously.

To reach these goals, the main tasks will consist in implementing and validating dedicated electromagnetic simulators for the analysis, the synthesis and the optimization of 2D and 3D dielectric lens antennas. Two complementary approaches will be investigated:

- At IETR: asymptotic methods and 3D numerical technique based on the Finite-Difference Time-Domain algorithm,
- At IRE: boundary integral equations.