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Core-Shell Leaky-Wave Lens Antenna for 150GHz Fly's Eye Communication Systems

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Abstract— **This work presents a novel lens antenna architecture based on a core-shell lens design with a leaky-wave in-packaged antenna at 150GHz. An electrically small core lens made of dense dielectric material is used to enhance the radiation of the in-packaged antenna. A low-loss dielectric shell lens with electrically large dimensions is then added to provide high directivity. A microstrip feeding network for connection to a 150GHz chipset is then also discussed. The proposed lens antenna provides good quality patterns with aperture efficiencies above 80% over a bandwidth of 20%.**

I. INTRODUCTION

HIGHLY dense scenarios requiring broadband multiple access with large connection density still present a demanding use case which is not properly addressed by today's technologies [1]. The Fly's Eye concept [2] proposes to combine quasi-optical beam forming with mm-wave broadband operation to enable a single base station more than Tbit/sec overall (front-end) capacity to a dense environment with tens of thousands of users.

For the Fly's Eye concept to work, there is a need for scalable integrated lens antennas with gains larger than 30dBi, bandwidths over 20% and a field of view in the order of 50°. To reach directivities >30dBi, lenses with diameters >3 cm will be needed. However, panels of such large lenses will be either too costly (silicon) or lossy (PREPERM). Low permittivity plastic lenses are commonly used for their reduced costs, low loss, and lightweight properties, but their small critical angle requires more directive feeding antennas compared to larger permittivities [3]. This critical angle thereby reduces the lens scanning ability. Dielectric gratings combined with leaky-wave waveguide feeds have been proposed to increase the scanning range up to 25° in [4], but the poor front-to-back ratio (F/B) of low permittivity lenses requires a non-scalable waveguide block implementation.

This work presents a new core-shell lens antenna concept based on a leaky-wave antenna in-package with a 140-170GHz front-end. The simulated performance shows that directivities >30dB and $\eta_{ap} > 80\%$ can be achieved over bandwidth of 20%. The total simulated losses are below 1dB. In this contribution, we present the architecture and summarize the simulation performance of this core-shell lens antenna.

II. CORE-SHELL LENS ANTENNA DESIGN

The lens architecture is shown in Fig. 1, and consists of three parts. First, a double slot is lithographically printed on a fused silica wafer enabling the integration with the electronic front-end. A high permittivity medium is then added on top. The half-wavelength wafer and high permittivity medium form a structure that allows the propagation of leaky-waves. This leaky-wave feed radiates a nearly Gaussian beam into the dense medium. This beam will couple well to an integrated lens and will lead to high radiation performance of the Fly's Eye panel arrays. Furthermore, the dense medium improves the antenna F/B with respect to low permittivity lenses.

A core lens is added with a diameter of $3\lambda_s$ ($\sim 4mm$) that acts as a transition between the dense $\varepsilon_r = 12$ medium and the $\varepsilon_r = 2.3$ medium. A matching layer is included to limit reflections. This core lens is spherically shaped to limit the impact on the antenna patterns and impedance. The bottom right of Fig. 1 shows the E-field propagating through the core lens, indicating a good conservation of pattern shape and no visible reflections. The wavelength changes as the wave propagates from the dense medium to the $\varepsilon_r = 2.3$ medium.

Finally, the $\varepsilon_r = 2.3$ electrically large shell lens is placed above the core lens for the generation of highly directive beams in free space using low loss plastic materials. Using the GO/FO tool of [5], the core-shell lens performance can be analyzed using the patterns in the infinite $\varepsilon_r = 2.3$ medium. The far field radiated by the proposed core-shell lens antenna is shown in Fig. 2. The field presents very low side lobe and cross polarization levels, as well as very good azimuthal symmetry. The achieved directivity over frequency, also derived using the GO/FO tool [5], is shown in Fig. 3, presenting a value higher than 31dBi over the bandwidth of 140-170GHz. Simulated losses are less than 1dB, bringing the gain >30dBi. This makes the simulated design suitable for Fly's Eye applications.

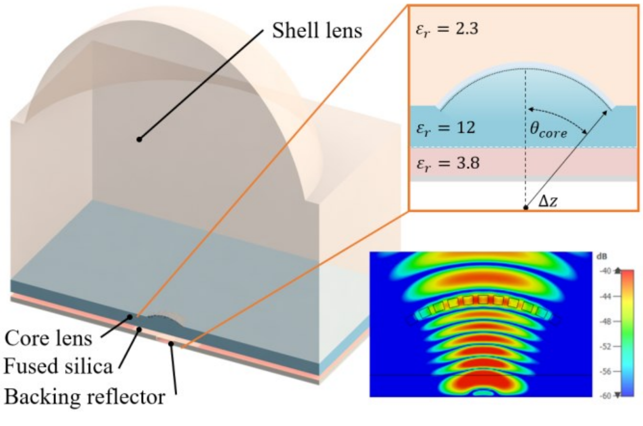

Fig. 1. Core-shell lens antenna geometry. A large shell lens is placed on top of an electrically small core lens. The inset shows a detailed view of the core lens stratification. On the bottom right the E-field at 155GHz is shown as it transitions through the core lens surface.

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At the time of writing, this antenna architecture is under fabrication. First measurement results are expected during the conference.

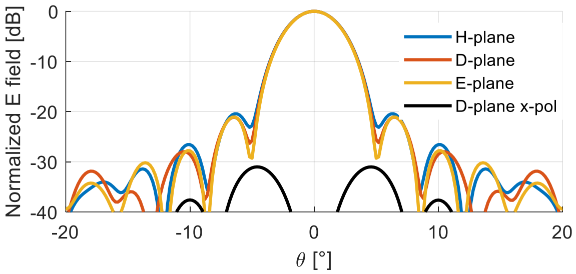

Fig. 2. Free-space patterns at the central frequency of 155GHz.

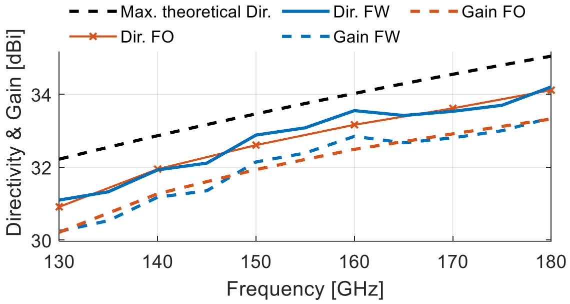

Fig. 2. Core-shell lens antenna directivity and gain as a function of frequency. These are compared to the maximum achievable directivity in the black dashed line.

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