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Broadband Power Distribution using Multi-Mode Leaky-Wave Lens Antennas at Submillimeter Wavelengths

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Abstract— **In this paper, we will present a novel quasi-optical power distribution technique that will allow achieving an efficient multi-pixel LO power distribution for submillimeter-wave instruments. This method can distribute the power from one antenna to a multi-pixel lens array in a hexagonal configuration with a power coupling efficiency of nearly 60%. We will present a prototype based on a transmit array of 7 pixels at WR1.5.**

I. Introduction

POWER distribution still constitutes a bottleneck for multi-pixel instruments at terahertz frequencies. The Local Oscillator power distribution among different pixels on Schottky, HEB, or SIS technology is either done using waveguide-based distribution or phase gratings [1]. Using waveguide splitters can be efficient for a small number of pixels physically close together. However, for higher frequency and more pixels, this solution becomes increasingly difficult, lossy, and costly. Another approach has been the generation of multiple beams from a single source by using phase gratings [1]. These gratings are based on a $> \lambda_0/2$ periodic reflectarray and transform the incident wave into a series of diffraction orders with different angles. This solution is narrowband and difficult to scale up in number of diffraction orders. Moreover, the claimed efficiencies, for instance, 65% for 8 pixels at 1.4 THz [1], do not include the coupling to the mixers via an antenna.

We propose a novel power distribution architecture for a modular multi-pixel heterodyne array that will provide an efficient LO signal coupling scheme. In this architecture, the radiation is efficiently coupled from one waveguide to an array of waveguides via the use of high aperture efficiency and broadband silicon lens antennas. Moreover, the proposed architectures and technologies can be scaled up to at least 2 THz due to the tolerances and surface roughness achieved in a silicon micromachining fabrication process.

II. Lens Array Coupling Architecture

The proposed quasi-optical coupling architecture is shown in Figure 1a. It is composed of one large lens antenna with a top-hat pattern coupled in the near-field to a lens array to achieve a uniform power distribution into a multi-pixel waveguide instrument. The top-hat pattern is synthesized inside the silicon medium using the multi-mode leaky-wave feed presented in [2]. To preserve this pattern when radiating towards the air medium with a collimated beam, a silicon elliptical lens, truncated at an angle θ_L is placed on top of this leaky-wave feed. The simulated collimated top-hat beam at the top of the lens, $\vec{E}^L$, is shown in Figure 1b (bottom). The proposed top-hat pattern also achieves nearly uniform phase distribution. Therefore, to couple this power into an array of waveguides, we propose to use the 7-element lens array in [2], as shown in the figure. This lens array has a periodicity of 10λ, but the proposed architecture can be easily scaled to the array's size and the number of elements. This array is characterized by a uniform aperture field distribution, $\vec{E}_i^{RX}$ (see Fig. 1b, middle) enabling an efficient power distribution scheme. The array in [2] achieved an aperture efficiency of 80% over a bandwidth of 35% at 550GHz.

To optimize this geometry, the power coupling efficiency to the waveguides has been estimated using a semi-analytical lens-to-lens near-field analysis similar to [3] as follows:

$$\eta_c^{Wg} = \frac{1}{P_{in}} \sum_{i=1}^{7} \frac{\left| \frac{2}{\zeta_0} \iint_{S_i} \vec{E}_i^{RX} \cdot \vec{E}^L dS \right|^2}{16\, P_{rad}^i}$$

The resulting coupling efficiency as a function of the lens truncation angle is shown in Fig. 1c with an overall coupling efficiency of nearly 60% that includes the coupling to a square waveguide via the lens antennas.

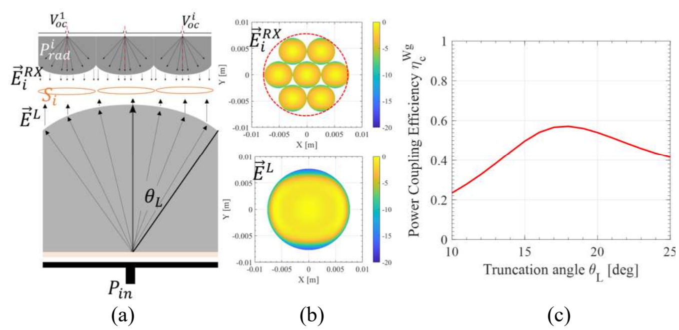

Fig. 1. (a) Proposed lens antenna array coupling architecture, composed of a top-hat pattern antenna and a lens array. (b) Field distributions from the two components. (c) Efficiency vs the lens truncation angle

The proposed quasi-optical architecture to achieve efficient power distribution can be used to excite both incoherent and coherent arrays, thanks to the excellent phase uniformity in the proposed top hat leaky-wave feed. For instance, in Fig 1a, a scanning lens phased array can be placed at the top of the power distribution architecture to achieve dynamic beam-steering [2].

A prototype of a double lens array of 7 elements in a hexagonal configuration and a top-hat pattern antenna has been developed at WR1.5 to corroborate the results. More detailed analysis and the measurements are expected to be shown at the conference.

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