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DOI
10.1109/IRMMW-THz.2017.8066899

Publication date
2017

Document Version
Accepted author manuscript

Published in
42nd International Conference on Infrared, Millimeter, and Terahertz Waves, IRMMW-THz 2017

A Wideband Leaky Lens Antenna with Frequency-Stable Beams for DESHIMA Spectrometer

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***Abstract*—DESHIMA (Deep Spectroscopic High-redshift Mapper) is an instrument aiming at efficiently making spectroscopic redshift measurements of sub-mm wave galaxies (SMGs), thereby providing about the formation and the evolution of stars and galaxies. The aim of this work is to provide a preliminary study into the design of a wideband leaky lens antenna coupled quasi-optical system within a 1:3 bandwidth. We propose a multi-pixel solution where the virtual sources are located on the lens focal plane. The design is able to provide frequency stable beams to achieve high Gaussian coupling efficiency within the entire bandwidth. We will evaluate the performance of the quasi-optical system design in terms of its Gaussicity and scan loss. The design is specifically targeted at the ASTE telescope located in Atacama, Chile.**

I. Introduction

DESHIMA is a direct-detection sub-mm spectrograph being developed at the Delft University of Technology, in association with the Netherlands Institute for Space Research (SRON) [1]. It aims at a frequency band from 240 up to 720 GHz. DESHIMA will host ~5000 microwave kinetic-inductance detectors (MKIDs) and is planned to be deployed at the Atacama Submillimeter Telescope Experiment (ASTE) in Chile. A quasi-optical reflector system and antenna have been designed to couple incoming electromagnetic waves of these frequencies to the MKIDs. In this work the results of a hybrid full-wave electromagnetic and physical optics simulations of a wideband leaky lens antenna coupled DESHIMA quasi-optical system will be presented. The telescope is a parabolic dish with a diameter of 10 m located at the Atacama desert in Chile: the Atacama Submillimeter Telescope Experiment (ASTE). The telescope is coupled to the antenna by a series of reflectors of which some are at room temperature (warm optics) and the others are cryogenically cooled (cold optics).

II. Design Concept

The lens antenna will be located on the focal plane of a quasi-optical system. The integrated lens antenna is coupled to the shortened end of the MKID resonator. The antenna is the key element of the DESHIMA on-chip filter-bank. It captures the incoming sub-mm wave signals within a 1:3 bandwith and must be integrated with filters and detectors. Recently, the combination of the leaky lens antennas with MKIDs has been shown to provide improved wideband antenna performances [2]. However, the antenna design provided in [2] uses a diffraction limited lens which leads to a significant beamwidth variation of the beams after the lens. Besides the design is only suitable for single feed systems. The proposed design, however, requires multi-pixel solution with providing high coupling efficiency to a fixed Gaussian beam over the full band. The beamwidth variation after the lens is not desired for such a scenario. This problem can be addressed by using a geometrically limited lens instead of using a diffraction limited one, for example a hyper-hemispherical lens. The hyper-hemispherical lens is a particular case of extended hemispherical lens [3]. Such a lens presents a broad pattern and is characterized by the absence of circular coma and spherical (aplanatic lens) aberrations [4], [5]. Using a hyper-hemispherical lens, one can create virtual sources that are located on the focal plane (See Fig. 1). The design of such an integrated lens antenna is one of the most challenging and important aspects of the instrument.

Figure 2 shows the Gaussicity of the proposed leaky lens antenna evaluated by using Physical Optics (PO) as a function of the Gaussian beamwidth, θ_0. We highlight the coupling efficiency at three different frequencies within the band. As can be seen, the results are very promising, the coupling efficiency is in the order of 80% within the band.

Starting with the lens antenna design, this work will provide the design and the evaluation of a wideband leaky lens antenna coupled quasi-optical system that is able to provide high Gaussicity and improved scan loss performance.

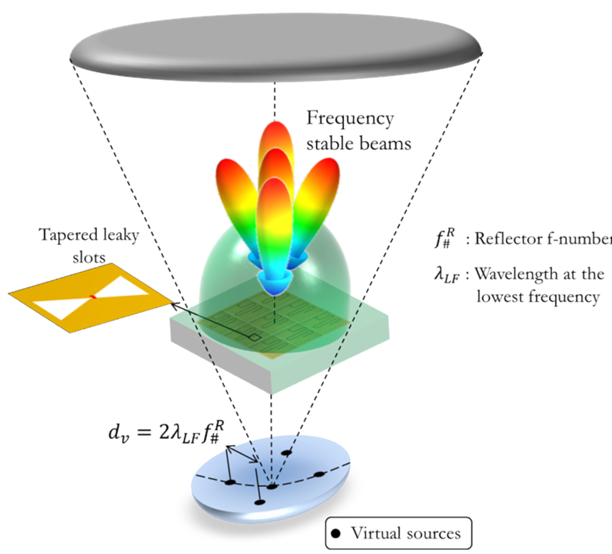

Fig. 1. Schematic of the lens antenna design fed by a 5-pixel leaky array, highlighting the virtual focuses located on the focal arc of the lens.

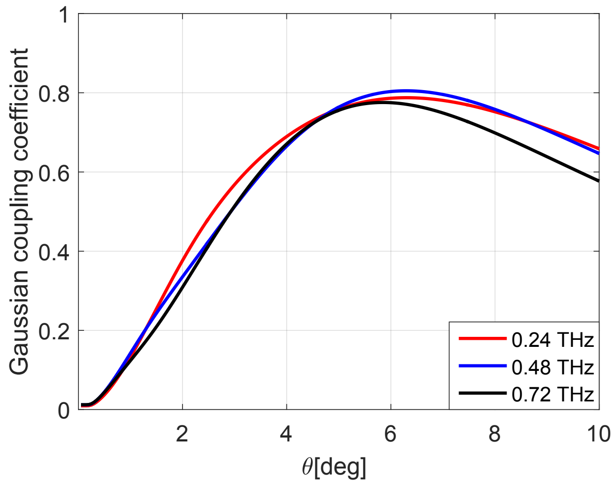

Fig. 2. Gaussian coupling efficiency as a function of the Gaussian beam width at three different frequency selected within the proposed band.

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