Terahertz Reflector Antenna System for a Scanned and Multiplexed FMCW Radar

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Introduction

A Terahertz imaging radar with extremely wide bandwidth to achieve cm-scale resolution in three dimensions at a standoff range of 4 m has recently been demonstrated [1]. The driving application for this technology is the detection of weapons or contraband concealed by clothing or other material that is largely transparent to the non-ionizing THz radiation. For weapons detection, long standoff range and fast imaging acquisition are key system goals. We are currently working towards the next-generation imaging system, aiming at a 25 m standoff range and image acquisition times of few seconds per image. In order to achieve such requirements, we are relying on a mechanical scanning and a time multiplexing technique of two pixels. A much more elegant solution to the fast-imaging problem would be to fabricate a focal plane array that would acquire information from several pixels simultaneously. However, THz heterodyne detector array technology is still not available at this time [2].

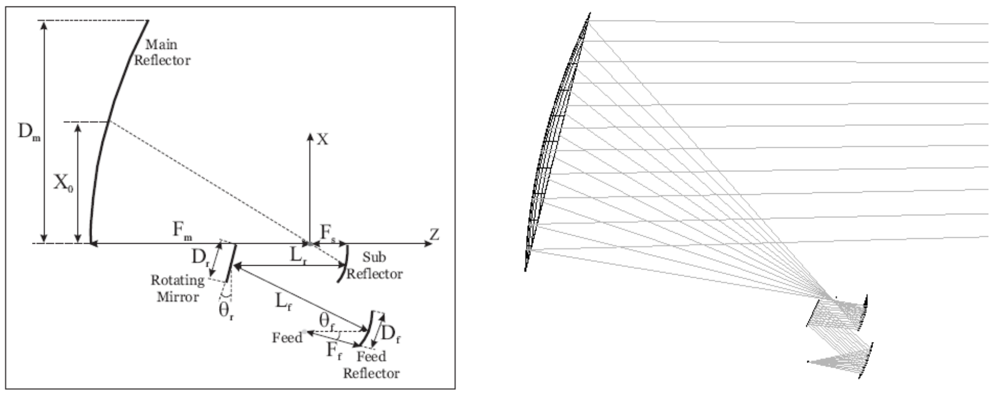
The mechanical beam scanning is done by rotating a small mirror placed in the THz radar beam path prior to the main antenna aperture. A reflector antenna system with very low distortions for scanned beams has been designed [3]. In this contribution, we describe combining such design with a time-delay multiplexing technique. We have recently proposed a new technique to multiplex two pixels [4]. Using this technique, we can simultaneously transmit and receive two spatially offset radar beams using a single heterodyne transceiver. This permits the frame rate of the imaging radar to be doubled without any additional back-end microwave or front-end THz components.

Mechanical Scanning

The scanning THz imager's design uses a near-field or confocal Gregorian reflector system (CGRS) consisting of two paraboloid reflectors sharing a common focus, see Fig. 1. This type of reflector system has been proposed for satellite applications because of its excellent scanning performance [5], a consequence of a cancellation of the coma and astigmatism aberrations that are normally present in more conventional reflector configurations.

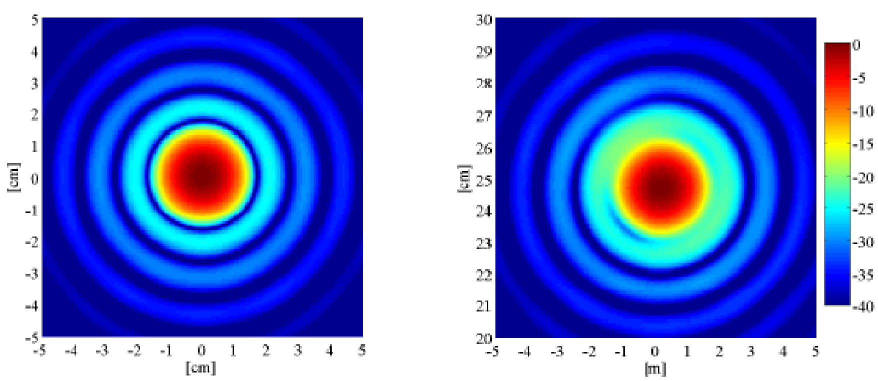
978-1-4244-4968-2/10/$25.00 ©2010 IEEE

In our configuration, we use a small rotating mirror for fast beam steering instead of phased array. This small mirror is illuminated by a parabolic sub-reflector (see feed reflector in Fig1a). The rotating mirror illuminates the confocal dual antenna geometry. A parabolic main reflector will provide focusing in the far field. However, at a 25 m standoff distance, targets are electrically very close to the antenna (in the reactive near field) for a 670 GHz radar. This means the main reflector must be an ellipsoid in order to achieve diffraction-limited focusing at 25 m. The antenna system has been simulated with the commercial software GRASP from TICRA and the results are shown in Fig.2.



(a) (b)

Fig. 1 (a) Geometry of the Confocal Antenna System, (b) Ray tracing (GRASP simulation)



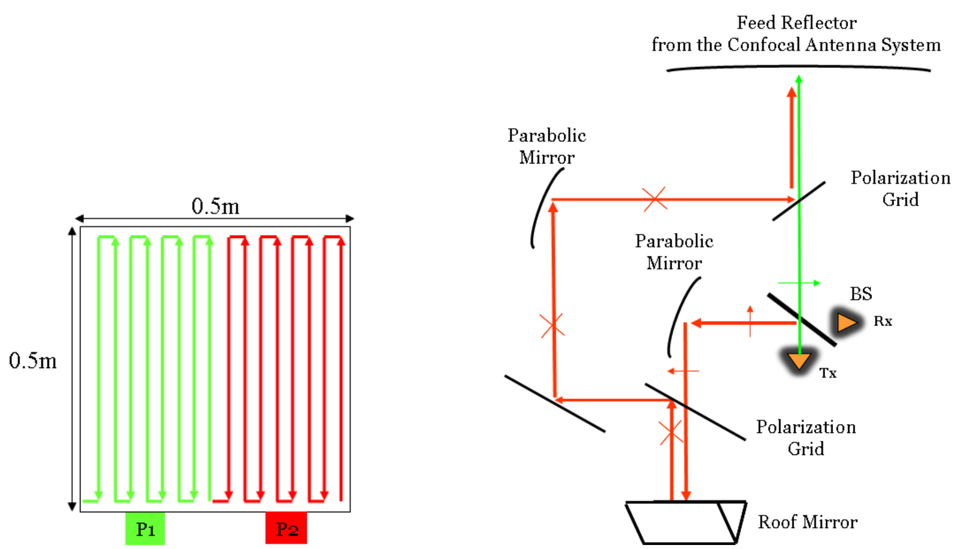
(a) (b)

Fig. 2 Simulated beam patterns at 25 m: (a) center beam and (b) beam scanned towards 25 cm. The half power beamwidth is 1.33 cm.

With such system, we are aiming to obtain 0.5 m x 0.5 m imagery in less than 10 seconds. With the mechanical scanning speed bottleneck eliminated, further improvement in acquisition time beyond about 1 second will be restricted by the finite SNR of the system.

Time Multiplexing

In [4], we have demonstrated that a quasi-optical waveguide can be used to double the number of pixels without increasing the number of Tx/Rx chains. Here, we would describe applying the same technique to the imager configuration that includes mechanical scanning. The idea is to use the multiplexing technique to divide the scanning area in half in one dimension. Starting from the confocal system of Fig. 1, we have designed a quasi-optical waveguide, shown in Fig. 3, that delays, rotates the polarization, and recombines one part of the signal at the feed reflector level. The optical system is designed in such way that both beams are displaced by 0.25 m in one plane with respect to a nominal position.



(a) (b)

Fig. 3 (a) Scanning configuration of the two multiplexed signals, and (b) Quasi-optical waveguide architecture used in the multiplexing technique. The green path corresponds to the first pixel and the red path to the second one.

The antenna system has also been simulated with GRASP. The beam patterns associated with both pixels at the nominal position of the mirror are shown in Fig 4.

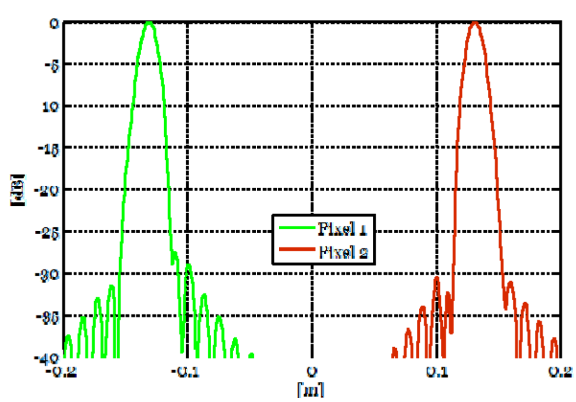


Fig. 4 Simulated beam patterns at 25 m standoff range.

Conclusions

In this contribution, we presented the antenna design and implementation of a mechanically scanned and multiplexed terahertz imaging radar. By using of a quasi-optical waveguide, we can multiplex our signal into two different beams and double the time acquisition of the image without increasing the number of transceivers. Only few additional optical components are needed.

Acknowledgments

The research described in this paper was carried out at the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration.

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