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Non-periodic phase gratings

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Abstract— **For heterodyne array receivers, phase gratings are useful to divide the local oscillator (LO) signal into several beams to pump the mixers of an array. We have developed a computer model to compute general phase profiles that can be non periodic. The model allows to set many input parameters and constraints so that the output can be optimized for any specific case. The phase profiles can be used to design phase gratings that can be used in transmission or in reflection.**

I. INTRODUCTION

Early heterodyne systems concentrated on high spectral resolution and large bandwidth (i.e. many spectral channels), but usually only one spatial pixel. Recently, arrays of heterodyne receivers have been developed to simultaneously measure spectra at several positions in the sky. Heterodyne receivers at terahertz frequencies do not have many pixels (1 pixel for HIFI (1.9THz), 1 pixel for the first version of GREAT (2.5THz), arrays of 7 pixels in development for upGREAT (2.5THz and 4.7THz)). Pumping each pixel with enough LO power is a challenge. Usually, one LO is used to pump several pixels and its beam is divided optically into several beams using phase gratings.

Dammann gratings [1] have been widely used in the past decades because they are simple to design and to manufacture. A Dammann grating is a binary phase grating realized using steps able to shift the phase of the signal by π rad. Fourier gratings (or mirrors, when they are used in reflection) [2] use a spatial phase modulation given by Fourier series expansion. They are smoother than Dammann gratings and can usually reach higher efficiency.

II. SIMULATIONS

To design a more general kind of gratings, we decided to start from the desired far field beam pattern and to use an iterative method based on far-field to near-field transformation. At each iteration the following steps are performed: -the actual radiation pattern is mapped into the aperture field on the grating via an inverse FFT; the physical realization constraints are imposed (as for example the minimum step size of the grating); the modified aperture field is mapped into the corresponding radiation pattern via an FFT; the constraints on the radiation pattern are imposed (shape of the beam, Side Lobe Level, etc.). These iterations are repeated until the convergence to a physically realizable profile with the desired radiation properties. This method produces a phase grating design that is not periodic, unlike the Fourier and Dammann gratings. The main advantage is that the grating can be totally adapted to the shape (intensity and phase profiles) of the incoming beam and can reach a very high efficiency. As this method allows us to adapt the grating to the incoming beam, it should be possible to focus and divide the beam directly at the output of the LO with a single grating.

III. PRELIMINARY RESULTS

An interesting test is to calculate a grating profile able to divides the LO beam in 4 symmetric beams at 1.4THz. To do so, we considered, first, the grating in one dimension, then in two dimensions.

A. *1D grating*

We consider a phase grating able to divide an incoming beam into 2 output beams at an angle of +20° and -20°, respectively. Without imposing any physical constrains, we can obtain side lobes below -50dB, as shown in fig 1 (the desired beams are the peaks at 0dB). The desired output beams contain 99.99% of the input LO power. The phase profile (fig 2) gives us the profile of the grating we need to machine to obtain this far field beam pattern.

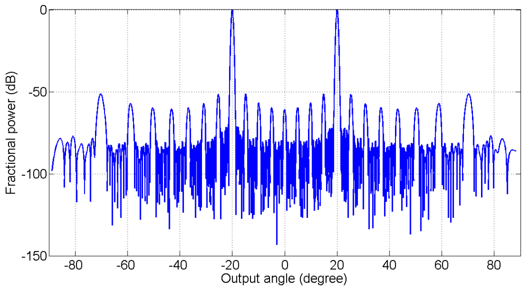

Figure 1 : Far field beam pattern

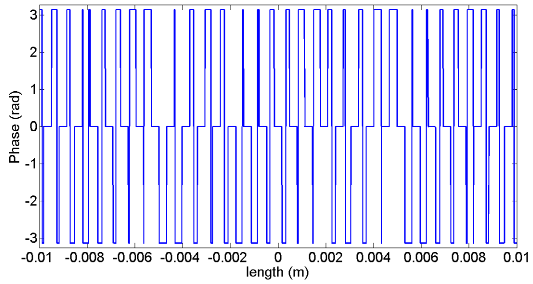

Figure 2 : Continuous phase profile

To study a more realistic case (with a limited resolution of the machining), we set a minimum step size of 50µm for the x axis and a step of π/2 for the y axis of the phase profile. This produced a discrete phase profile (fig 4).

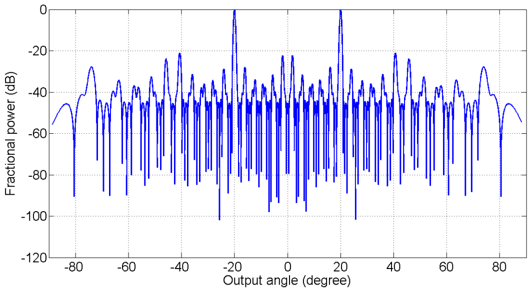

Figure 3 : Far field beam pattern

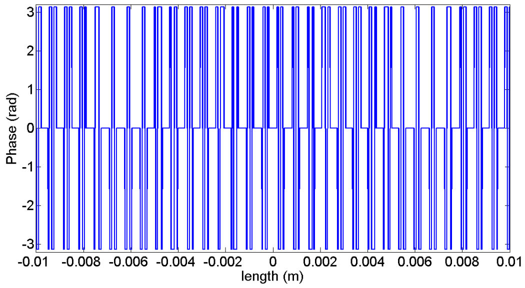

Figure 4 : Discrete phase profile

As a result, the corresponding far field beam pattern (fig 3) presents side lobes up to -21dB. The two wanted output beams contain 97.15% of the input LO power. The efficiency is worse than with a continuous phase profile, but still quite good. Changing some of the input parameters should enable us to improve these results.

B. 2D grating

As the method, in general, converges after a few iterations, the computational time needed in the case of 2D gratings will be very short. Thus, we apply the same algorithm to simulate the phase profile needed to divide the LO beam in 4 symmetric beams as shown in fig 5.

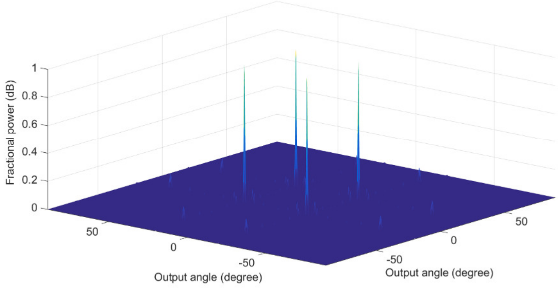

Figure 5 : Far field beam pattern with 4 pixels

The corresponding grating phase profile resembles that of figure 2, but in two dimensions. Such a grating would produce 4 beams as seen in figure 5. Without imposing any physical constrains to the phase profile, the power in the 4 beams corresponds to 99.99% of the input LO power, according to the simulations. The highest side lobes are below -50 dB. When we impose the same physical constraints as in 1D, the power in the 4 beams corresponds to 88.60% of the input LO power. The highest side lobes are at -21 dB.

IV. PERSPECTIVES

The next step is to design and manufacture a prototype phase grating. The required phase profile can be obtained in transmission with a transparent material (HDPE, Silicon) or in reflection with a mirror. Different manufacturing methods and materials have to be tested to realise a prototype. This prototype will then be tested and the measurements will be compared to our simulations.

V. CONCLUSION

Non periodic phase gratings promise a powerful tool for dividing a single LO beam into multiple beams for future heterodyne array receivers. They can be designed and optimised for many different situations, for example:

- Turn a non Gaussian beam (i.e. QCL) into a Gaussian beam
- Refocus and divide a beam with one element
- Generate a custom made beam to adapt to any output configuration

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