Research Networking Programmes

Short Visit Grant

Scientific Report

The scientific report (WORD or PDF file – maximum of eight A4 pages) should be submitted online <u>within one month of the event</u>. It will be published on the ESF website.

<u>Proposal Title</u>:

Characterization of a 4x4 Dielectric Rod Waveguide antennas array in the W band.

<u>Application Reference Nº</u>:

7082

1) **Purpose of the visit**

2) **Description of the work carried out during the visit**

3) **Description of the main results obtained**

4) **Future collaboration with host institution (if applicable)**

5) **Projected publications / articles resulting or to result from the grant (*ESF must be acknowledged in publications resulting from the grantee's work in relation with the grant*)**

6) **Other comments (if any)**

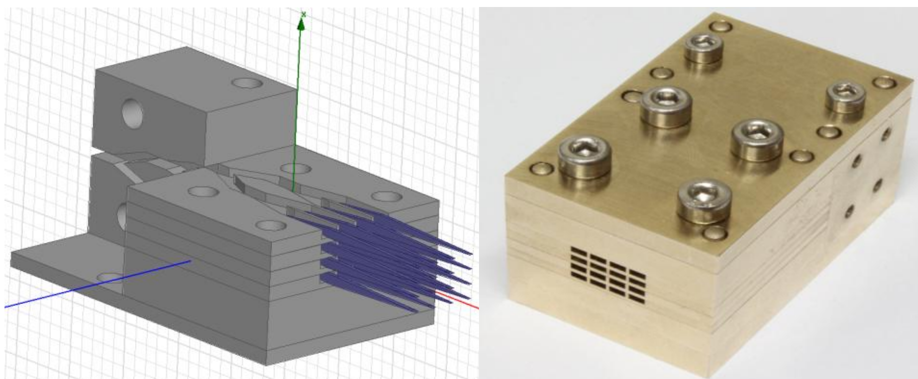
Purpose of the visit:

High permittivity Dielectric Rod Waveguide (DRW) antennas are a cost-affordable, easy to manufacture and compact alternative compared to other directive antennas for the millimeter and sub-millimeter range. They can be fed by either rectangular metal waveguides or photomixer-based terahertz sources. Good matching and an ultra-wide working band can be achieved for both feeding strategies.

For increasing available power or enabling beam steering an array of DRW antennas can be used. The performance of these devices on array configurations must be evaluated.

A 4x4 array prototype was designed for evaluating this kind of antennas in array configurations. A feeding network is designed for a central frequency of 100 GHz. WR-10 rectangular waveguide standard is used for convenience, as a more cost-affordable proof-of-concept than photomixer-based sub-millimeter power sources. Fig. 1a sketches the designed structure, simulated using different full-wave simulators (CST, HFSS and HOFEM, an in-home software from Carlos III university of Madrid). A series of power dividers distribute the power to all DRW antennas.

Fig. 1b shows the manufactured feeding network. It is fully disassemblable, which allows us to modify the feed distribution of the elements for testing the scanning capabilities.



(a) (b)

Fig. 1. 3D view of the designed prototype (a) and Manufactured feeding network for the 4x4 DRW antennas array (b).

DRW antennas were manufactured prior this research stay at Micronova's facilities using a HR-Si wafer of 0.5 mm of thickness by doing cuts with a dicing saw. Fig. 2 shows a sketch of the silicon part. It consists on one matching taper, a dielectric rod waveguide segment and the radiation taper. Matching taper is designed to be long-enough, L_TAPER 8 mm, for reducing return losses to an acceptable level (S_{11} below -10 dB) when feeding with WR-10 waveguides in the whole band. The DRW segment has a length L_DRW of 2 mm. It is considered in the design for structural purposes, since any holder placed in the radiation taper could degrade the radiation properties of the antenna. Radiation taper length L_RAD is 15 mm.

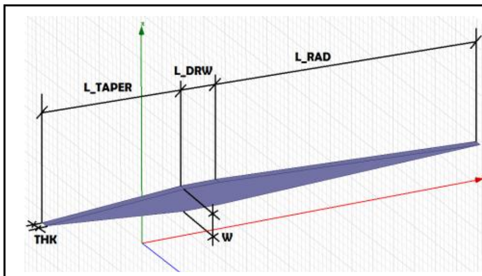


Fig. 2. Sketch of the single element.

The purpose of the visit is to characterize both the radiation pattern and return losses of the prototype.

Description of the work carried out during the visit:

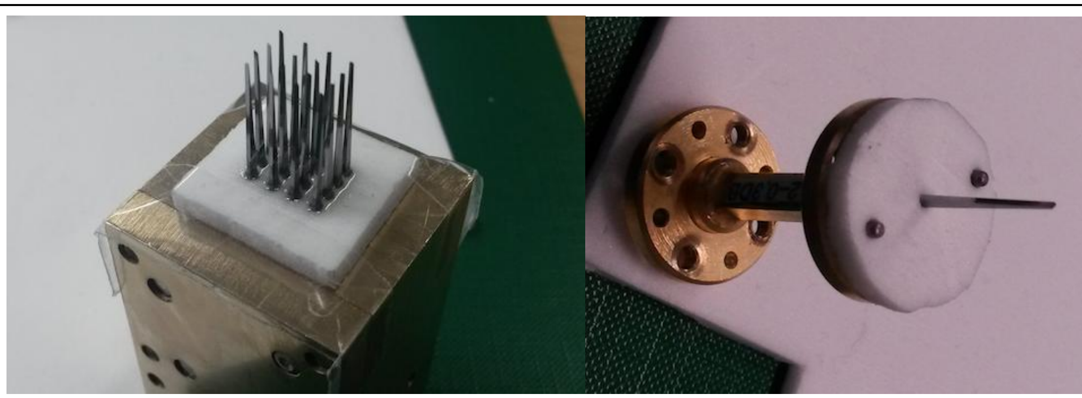
Both the single element DRW antenna and the 4x4 antennas array were characterized:

- Assembly of a single-element antenna.
- Assembly of the DRW antenna array.
- Characterization of both single-element and array prototypes. Both radiation patterns and S_{11} were measured.

Fig. 3 illustrates one step of the assembly process: all DRW antennas are glued in a holder made with a foam slab. The assembly and alignment of 16 DRW antennas is time-consuming when done in a prototyping context. This step can be easily improved in terms of costs and time by manufacturing a proper assembly holder who aligns all parts before glue them to the low-permittivity foam slab. Nonetheless, manual assembly can be reasonably precise by drilling previously an array of 4x4 holes with a milling machine.

Fig. 3. Assembly of dielectric rod waveguide antennas. They are manually placed in a foam holder, aligned and glued. Two columns are already placed.

When all DRW antennas are in place and glued, it is straightforward to align them with the metal feeder by only centering the foam (Fig. 4a). For comparison purposes, two single-element DRW antennas were manufactured. Fig. 4b shows one of them.



(a) (b)

Fig. 4. Manufactured prototypes. Both array (a) and single element (b) DRW antennas were assembled.

Description of the main results obtained:

DRW antenna array was designed to work at central frequency of 100 GHz. Reflection coefficient of the antenna was obtained with HP 8510 vector network analyzer. Measured S_{11} is below -10 dB in 95.7-103.3 GHz, as show on Fig. 5.

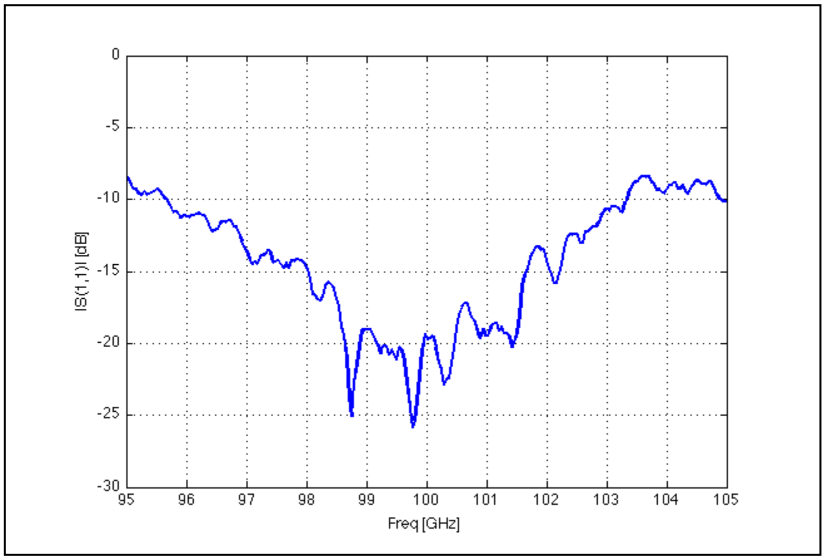


Fig. 5. Measured S_{11} of DRW antenna array prototype.

Radiation properties of the array were studied by using a NSI 2D planar scanner. Far field was directly obtained by ensuring a long-distance (200 mm) between array and probe. The measurement setup is shown on Fig. 6. Both E and H planes were studied, getting both co-polar and cross-polar components. Normalized radiation patterns are presented on Fig. 7. It clearly shows a rectangular distribution of elements. Angular beam width is narrower in the H-plane, as expected; size pith of elements is 3 mm for the H-plane and 2 mm for the E-plane. Alignment of elements seems to be accurate enough, since the radiation pattern is quite symmetric.
A comparison between simulation and measurements results will be done in the projected publications.

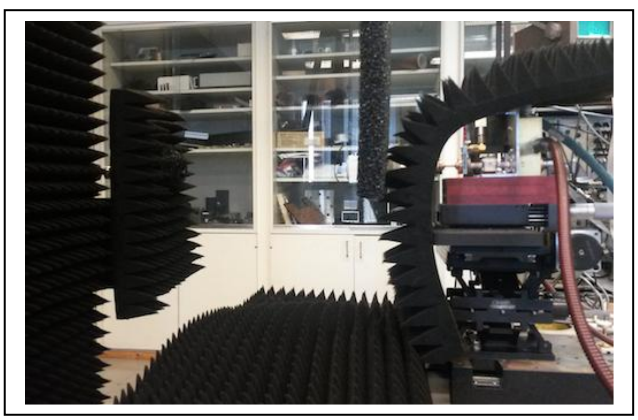


Fig. 6. Measurement setup.

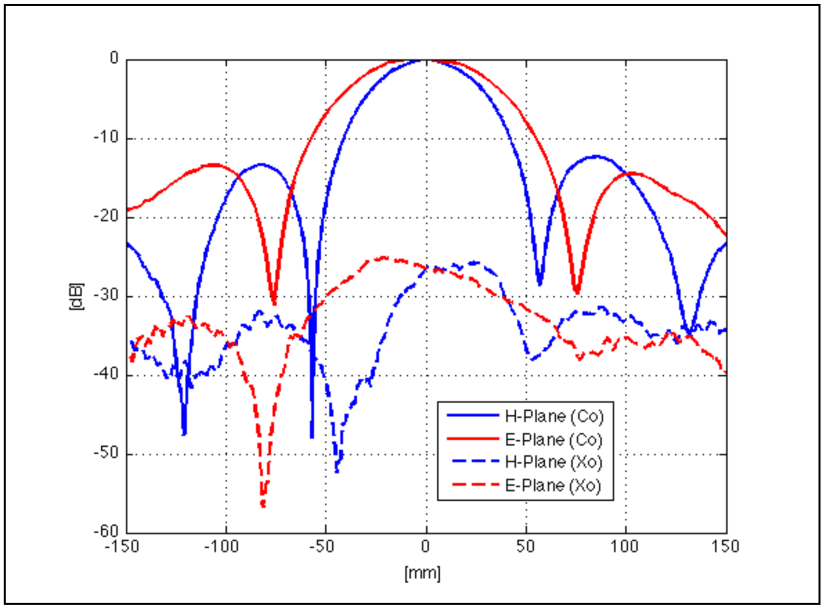


Fig. 7. Normalized radiation pattern in both H-plane (blue) and E-plane (red) at 100 GHz. Co-polar (solid) and cross-polar (dashed) components are shown.

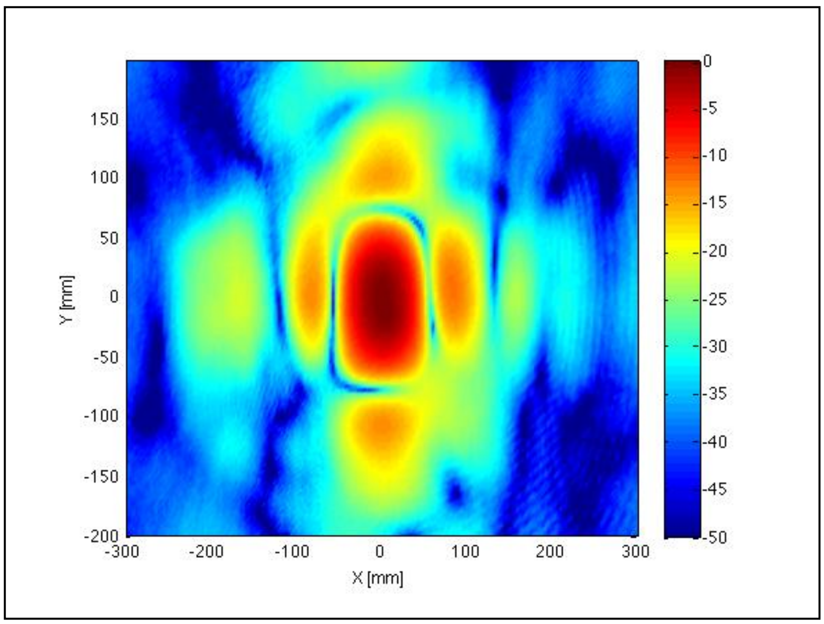


Fig. 8. Normalized radiation pattern.

Future collaboration with host institution (if applicable):

The following research lines are still opened:

- Scanning properties:

After manufacturing and characterizing the prototype, scanning properties are considered. A preliminary study will be done in Carlos III University facilities. Main beam tilt can be modified by adding dielectric into specifics paths of the power divider.

- Integration of phase shifters:

It is possible to integrate phase shifter in dielectric rod waveguides. Thin ferroelectric film technology and MEMS were proposed in the works of Dr. D. V. Lioubtchenko et al. as a two enabling technologies for electronic phase shifters. It is possible to easily integrate them in the DRW antenna array. This is an object of study nowadays.

Projected publications / articles resulting or to result from the grant (*ESF must be acknowledged in publications resulting from the grantee's work in relation with the grant*)

[1] Alejandro Rivera-Lavado, Sascha Preu, Luis Enrique García-Muñoz, Andrey Generalov, Javier Montero-de-Paz, Gottfried Döhler, Dmitri Lioubtchenko, Mario Méndez-Aller, Stefan Malzer, Daniel Segovia-Vargas, and Antti V. Räisänen, "Array of Dielectric Rod Waveguide Antennas for Millimeter-Wave Power Generation", paper accepted for the EuMW2015, 09/2015.

[2] A journal publication is now under discussion. To be submitted by 06-07/2015.

Other comments (if any)

DRW antennas were manufactured in Micronova Facilities, in Espoo (Finland).