

Secondment Report Form

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| Secondee | Marko Bosiljevac |
| Host Organization | Id: UNISI |
| | Name: University of Siena |
| Research Topic(s) | New materials, metamaterials, EBG structures |
| | Reflector and lens antennas |
| | |

ACTIVITIES DURING THE SECONDMENT

During the secondment at the University of Siena the research was focused on the analysis, design and development of a planar highly directive antenna based on the concept of surface impedance modulation. This concept has been shown to have many possible applications in the design of microwave devices and antennas. The most interesting possibility for this research lies in the idea of modulating the surface impedance of one plate of a parallel-plate waveguide structure. This way it is possible to realize different kinds of lenses that have a smooth refractive index profile, one of them being the Luneburg lens which was in the focus of our studies.

The work conducted can be divided into four segments which also describe the timeline of the research;

1. Analysis of surface impedance properties of periodic arrays of circular patches
2. Synthesis of the Luneburg lens
3. Design and optimization of an antenna based on the developed Luneburg lens
4. Construction and measurements of the designed antenna

This division will also be used in the continuation of this report.

1) Analysis of surface impedance properties of periodic arrays of circular patches

The elementary structure of interest is an infinite homogeneously filled parallel-plate waveguide with one wall replaced by an impedance surface as seen in Fig.1. From this figure the wave number in the z -direction can be written as

$$k_z = \sqrt{k^2 - k_y^2} = k \sqrt{1 - \frac{k_y^2}{k^2}} = k \cdot n_{eq}. \quad (1)$$

Here the wave number along z is interpreted as a product between the free space propagation constant and an equivalent refractive index. Through transmission line analysis and by applying the vanishing boundary conditions for the upper wall of the parallel-plate waveguide it is possible to obtain the expressions needed for the synthesis of the desired lens profile. The required impedance can be synthesized using different metamaterial surfaces, but we have chosen to use planar circular patches for symmetry reasons. The example of this surface is shown in Fig.2.

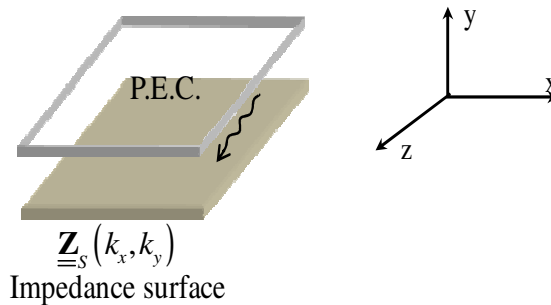


Fig. 1. Geometry of the considered parallel-plate waveguide structure

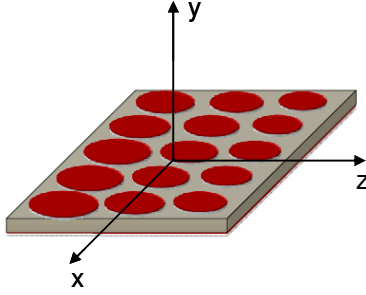


Fig. 2. Variable circular patches on a planar substrate

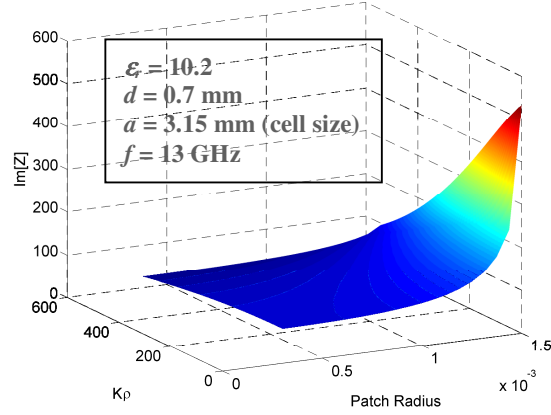


Fig. 3. Impedance values obtainable using different patch radii.

Fig. 3. shows the range of impedances realizable using the shown substrate and cell properties as a function of patch size and radial wave number k_ρ . From this result it is possible to recreate a certain lens impedance profile using the appropriate patch sizes.

2) Synthesis of the Luneburg lens

With these findings it was possible to recreate the Luneburg lens profile inside the parallel-plate waveguide using the array of variable patches. We started from the Luneburg law given by

$$n(\rho) = \sqrt{2 - \left(\frac{\rho}{R}\right)^2}, \quad (2)$$

where ρ is the radial coordinate and R the radius of the lens. This refractive index profile and the corresponding impedance profile are shown in Fig. 4. Fig. 5. shows the simulation (obtained using CST Microwave Studio) of the vertical E field plot at the design frequency (13 GHz) in the level of the patches for the synthesized lens (the waveguide height is 2.3 mm).

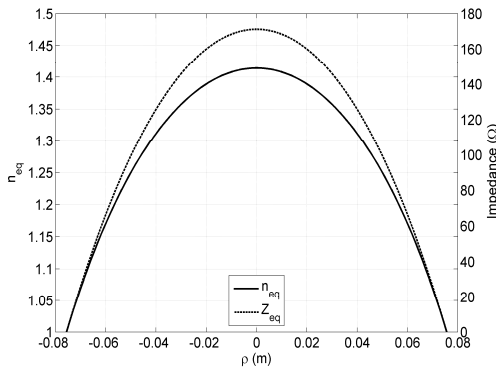


Fig. 4. Luneburg lens refractive index and impedance profile

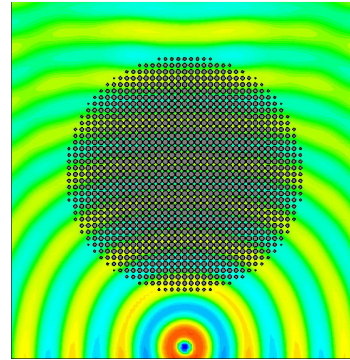


Fig. 5. Luneburg lens with the snapshot of the vertical E field

3) Design and optimization of an antenna based on the developed Luneburg lens

The main idea in this project was to build a highly directive antenna based on the developed lens. To maximally use the lens properties a small monopole source was placed on the edge of the lens backed by a $\lambda/4$ semicircular reflector. Also, to prevent field leakage on the sides of the antenna half of the lens was closed by a vertical wall as shown in Fig. 6. In Fig. 6. it is also seen that the second part of the lens differs from the first part. This second part of the lens was designed in a way to correspond to an increase in the waveguide height, which was needed to ensure better matching

of the antenna aperture to free space. Fig. 7. shows the simulated H -plane pattern of the designed antenna at 13GHz.

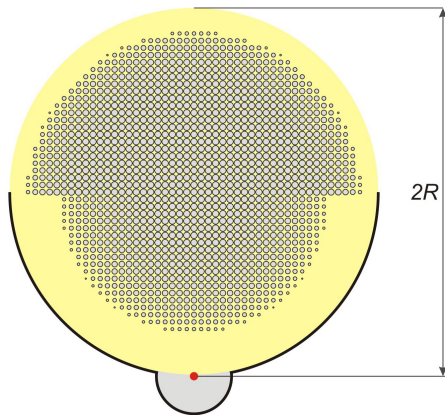


Fig. 6. Top view of the designed antenna

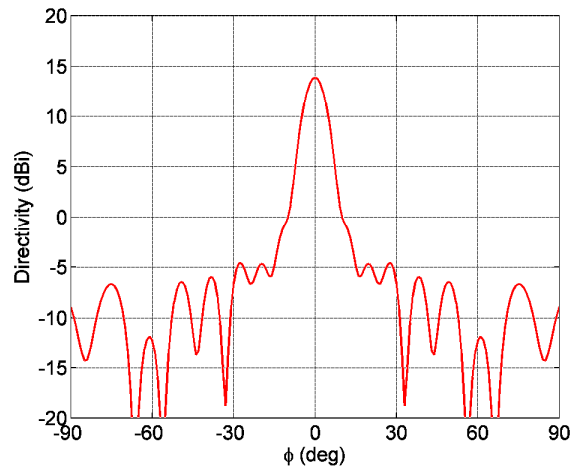


Fig. 7. H -plane pattern of the designed antenna

4) Construction and measurements of the designed antenna

The designed lens was fabricated and the photo of it is shown in Fig. 8. However the antenna plates and reflecting wall were not manufactured in time to complete the measurements.

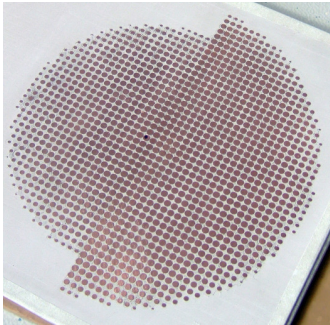


Fig. 8. Photo of the fabricated lens

MAIN RESULTS OF THE STAY

< List of the publications co-written (or in progress)>

Other(s):

Number of Publications: 1 (in progress)

(1) _____

Number of Documents/ Reports: _____

(2) _____

Number of Case Studies & Demonstrators: _____

(3) _____

* Attach all relevant documentation that specifies your results

FORECAST ACTIVITIES

<Are there any envisaged activities following this secondment project, new collaborations, co directed PhD, etc>

Due to the fact that the measurements of the designed antenna were not completed it is possible that a short follow-up to this secondment will be required. Also within that follow-up, one alternative design of the antenna with scanning capability should be investigated.

In order to improve CARE's secondment program, please fill this short questionnaire. Use the space at the end to expand your answers, if needed. Our aim is to improve the general experience for secondees in future.

Disagree < > Agree

GENERAL

| | | | | |
|--|----------------------------|----------------------------|----------------------------|---------------------------------------|
| My objectives were achieved. | 1 <input type="checkbox"/> | 2 <input type="checkbox"/> | 3 <input type="checkbox"/> | 4 <input checked="" type="checkbox"/> |
| The research topics were relevant to my work. | 1 <input type="checkbox"/> | 2 <input type="checkbox"/> | 3 <input type="checkbox"/> | 4 <input checked="" type="checkbox"/> |
| I benefited from being part of a wider research culture. | 1 <input type="checkbox"/> | 2 <input type="checkbox"/> | 3 <input type="checkbox"/> | 4 <input checked="" type="checkbox"/> |

HOST ORGANIZATION

| | | | | |
|---|----------------------------|----------------------------|----------------------------|---------------------------------------|
| I am satisfied with the quality and quantity of supervision I received. | 1 <input type="checkbox"/> | 2 <input type="checkbox"/> | 3 <input type="checkbox"/> | 4 <input checked="" type="checkbox"/> |
| I had access to adequate resources to support my research.. | 1 <input type="checkbox"/> | 2 <input type="checkbox"/> | 3 <input type="checkbox"/> | 4 <input checked="" type="checkbox"/> |

SECONDMENT PROGRAM

| | | | | |
|--|----------------------------|----------------------------|---------------------------------------|---------------------------------------|
| I would recommend this secondment programme to others. | 1 <input type="checkbox"/> | 2 <input type="checkbox"/> | 3 <input type="checkbox"/> | 4 <input checked="" type="checkbox"/> |
| I believe the skills I have learned will help me to improve my job/research. | 1 <input type="checkbox"/> | 2 <input type="checkbox"/> | 3 <input type="checkbox"/> | 4 <input checked="" type="checkbox"/> |
| I would apply to another programme similar to CARE. | 1 <input type="checkbox"/> | 2 <input type="checkbox"/> | 3 <input checked="" type="checkbox"/> | 4 <input type="checkbox"/> |
| In general, how would you classify the CARE Secondment Programme? | 1 <input type="checkbox"/> | 2 <input type="checkbox"/> | 3 <input type="checkbox"/> | 4 <input checked="" type="checkbox"/> |

Other questions/comments to be potentially considered: _____

SIGNATURES

Candidate: Marko Bosiljevac

Date: 2011/03/03
(year/month/day)

Signature Marko Bosiljevac