Secondment Report Form

Secondee	Lukas Jelinek	
Host Organization	Id: US	
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Research Topic(s)	A7 - Electromagnetic theory and numerical techniques	
	A14 - New materials, metamaterials, EBG structures	

ACTIVITIES DURING THE SECONDMENT

During the stay, we have been working on two major topics:

1) Surface effects in finite metamaterial samples

Effective medium theory that is used in vast majority of metamaterial structures considers in principle only unbounded systems. Of course, all real metamaterial bodies must have finite size. It is usually expected that the bodies are big enough that the presence of the surfaces does not affect the effective medium description of the system. This is certainly justified for huge systems containing probably millions of cells, but for realistic implementations (up to thousands of elements) the correctness of the description by unbounded material parameters is not self-evident. To that point we have chosen a canonical body, a cube with 10x10x10 of isotropic Split Ring Resonator cells, and analyzed it in details. The cube is schematically depicted in Fig. 1.

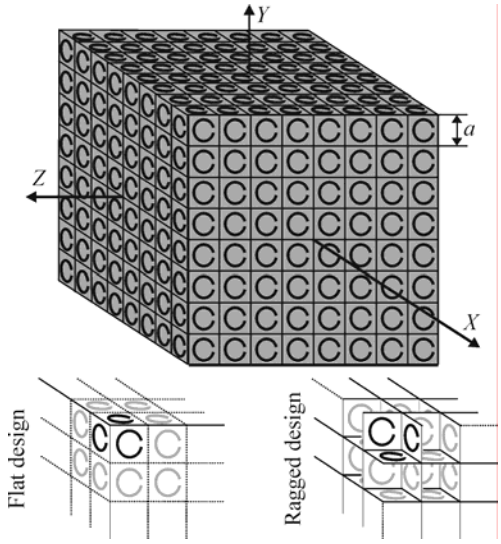

Fig. 1

For detailed analysis we have developed a code in which each ring is substituted by a perfect conducting loop with certain internal impedance. All the mutual inductances between rings were taken into account, leading to a system of linear equations (one equation for each ring) whose solution resulted in currents on the rings. From here it was straightforward to calculate the overall magnetic polarization of the cube. At the same time, we have described the cube by effective permeability (derived from unbounded system) and also calculated the overall polarization of the cube. Their comparison revealed very interesting observation: the crucial importance of the surface. Two basic possibilities of the surface design are depicted in Fig. 1 and were called “flat” and “ragged” designs. It has been very remarkable how well the ragged design copied the properties of unbounded design, while the flat structure completely failed to resemble the behavior of continuous medium. Our code further revealed that the problem resides in surface resonances that are highly suppressed in ragged case, while very strong in flat case. The results of our analysis were submitted in Journal of Physics D: Applied Physics [1].

2) Extraordinary transmission in realistic metallic screens

Since EOT was first reported, a lot of effort has been dedicated to the characterization of the phenomenon and its potential applications. Surface plasmons were soon the first explanation for EOT, but did not explain extraordinary transmission in metals at microwave frequencies or in dielectric screens. Recently analytical models for EOT from a waveguide theory perspective were developed in order to characterize EOT in the whole frequency range where it has been reported. Our major goal was to extend this analysis to the case of oblique incidence in screens perforated by a periodic 2D array of holes. We have considered oblique incidence of TE and TM waves with tangential E or H fields polarized along the main axes of the structure. The method for solving the problem was a modification of mode matching technique. The important modification has been a new set of boundary conditions on the boundary between lossy metal with holes and vacuum. First, the fields over the metal were related through a surface impedance matrix. Second, in the region of holes a standard continuity of tangential electric and magnetic field had been imposed. The surface impedance condition contained two important simplifications. One was the assumption that the overall surface impedance is unaffected by the holes. Second was the assumption that the dominant refracted modes are connected by approximately the same surface impedance matrix so that the impedance boundary condition is satisfied by the total fields. This last approximation is clearly valid for most metals where the transverse wavenumbers of the different modes are much smaller than the longitudinal wavenumber inside the metal. This leads to a determined system of linear equations for modal amplitudes. The results of our model have been compared to simulations using CST Microwave Studio. We employed 2 modes inside the holes and 8 modes in vacuum regions with CPU times of 0:5s (our model) vs CPU times of 4 min (CST) per frequency point. All has been verified for both finite conductivity metal (copper) and for Drude model metal (silver at optical frequencies). In all cases the comparison of both calculations revealed almost perfect match. The detailed description of the model and the results were published in [2].

MAIN RESULTS OF THE STAY

[1] M. Lapine, L. Jelinek and R. Marques, "Surface mesoscopic effects in finite metamaterials", *submitted to Journal of Physics D: Applied Physics (IOP)*

[2] V. Delgado, R. Marques, L. Jelinek, „Extraordinary transmission through dielectric screens with 1D sub-wavelength metallic inclusions", *Optics Express*, Vol. 19, pp. 13612 - 13617, 2011

Number of Publications: __2___

Number of Documents/ Reports: _____

Number of Case Studies & Demonstrators: _____

Other(s):

(1)____________________________________

(2)____________________________________

(3)____________________________________

* Attach all relevant documentation that specifies your results

FORECAST ACTIVITIES

The collaboration between departments of the host and the secondee is already very intense. The stay supported by this project further pushed this collaboration towards the two mentioned publications and many new ideas, which will definitely lead to another future stays in the host department.

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 ☐	2 ☐	3 ☐	4 ☒
The research topics were relevant to my work.	1 ☐	2 ☐	3 ☐	4 ☒
I benefited from being part of a wider research culture.	1 ☐	2 ☐	3 ☐	4 ☒

HOST ORGANIZATION				
I am satisfied with the quality and quantity of supervision I received.	1 ☐	2 ☐	3 ☐	4 ☒
I had access to adequate resources to support my research..	1 ☐	2 ☐	3 ☐	4 ☒

SECONDMENT PROGRAM				
I would recommend this secondment programme to others.	1 ☐	2 ☐	3 ☐	4 ☒
I believe the skills I have learned will help me to improve my job/research.	1 ☐	2 ☐	3 ☐	4 ☒
I would apply to another programme similar to CARE.	1 ☐	2 ☐	3 ☒	4 ☐
In general, how would you classify the CARE Secondment Programme?	1 ☐	2 ☐	3 ☐	4 ☒

Other questions/comments to be potentially considered: ______________________________

SIGNATURES

Candidate **LUKAS JELINEK**

Date: 2011/11/30
(year/month/day)

Signature ______________________________