



Project Number 500252

**METAMORPHOSE**

**Metamaterials Organized for radio, millimetre wave,  
and Photonic Superlative Engineering**

Network of Excellence

Priority 3, Nano-technologies and nano-sciences,  
knowledge-based multifunctional materials,  
and new production processes and devices

**Final Activity Report  
2004-2008**

Period covered: from: 1 June 2004 to 31 May 2008  
Start date of the project: 1 June 2004

Date of preparation: August 2008  
Duration: 4 years

Project coordinator name: Prof. Sergei Tretyakov  
Project coordinator organisation name: Helsinki University of Technology

Revision: 1

## I. Project execution

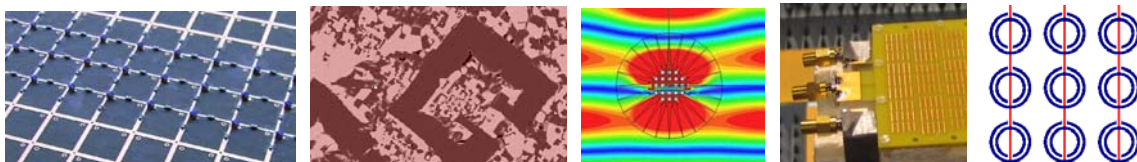
### 1. Executive summary

#### 1.1. Project objectives

The main integration objectives of the **Metamorphose NoE** project concentrated on the design and implementation of a Virtual Institute to plan and organize joint research and use and disseminate new knowledge. A mature scientific community should be established that would launch Integrated Projects, STREPS, and other joint projects in strategically targeted areas. A program for personnel mobility of researches should be created, and an international PhD program should be organized, including web-based learning tools and an information platform. In addition, the Virtual Institute should establish and maintain a mechanism for common use of research facilities and manage regular scientific conferences and workshops, as well as edit a scientific journal in its field.

The main scientific objective of the partners of this consortium was to develop new types of artificial materials, often referred to as metamaterials, with electromagnetic properties that cannot be found among natural materials. The results of this development should lead to a conceptually new range of radio, microwave, and optical technologies, based on revolutionary new materials made by large-scale assembly of some basic elements (nanoscopic and microscopic) in unprecedented combinations.

Metamaterials are artificial electromagnetic (multi-)functional materials engineered to satisfy the prescribed requirements. The prefix meta means after, beyond and also of a higher kind. Superior properties as compared to what can be found in nature are often underlying in the spelling of metamaterial. These new properties emerge due to specific interactions with electromagnetic fields or due to external electrical control.

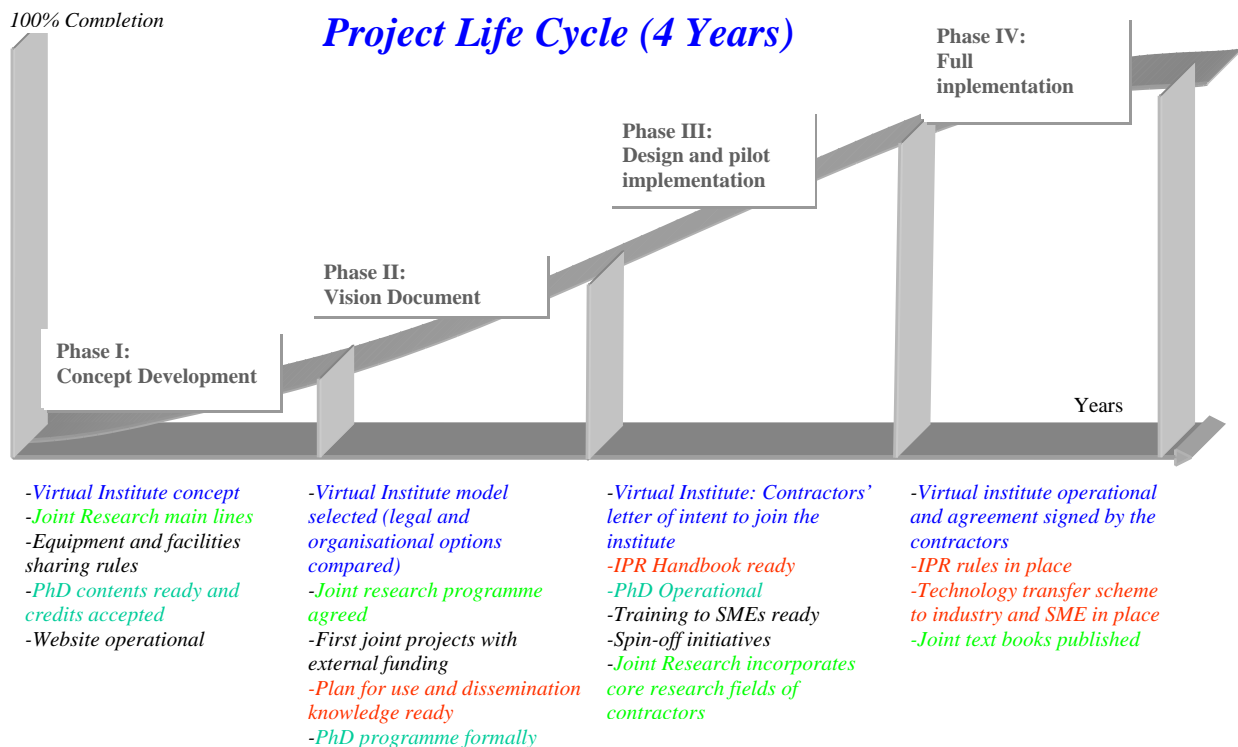


Electromagnetic metamaterials will play a key role in providing new functionalities and enhancements to the future electronic devices and components, such as high-speed circuits, multifunctional smart miniature antennas and apertures, high-resolution imaging systems, smart skins, and so forth. After all, these and other systems are built on substrates and superstrates whose electromagnetic response functions define the design and performance of the systems.

Metamaterials are, in essence, the materials of the future, since the main purpose for their study is to be able to go beyond where naturally occurring substances and current materials research have taken us. By combining different microscopic elements into large-scale designs, one will be able not only to create materials with fundamentally new properties but also to fabricate others that have properties on demand, as required by new technologies. In particular, new electromagnetic properties will allow us to control microwaves, millimetre waves, and optical light in revolutionary ways.

The integration procedure was planned in four major phases:

- I) Concept development
- II) Design Document
- III) Design and pilot implementation
- IV) Full implementation



The duration of each phase is one year. These phases lead us towards a permanent organisation, the Virtual Institute. The Virtual Institute takes care of a) Sharing of equipment and facilities, b) Joint research, c) Spreading of excellence.

## 1.2 Contractors involved

The project integrated 21 partners from 12 countries: Helsinki University of Technology, Universite Catholique de Louvain, Universidad del País Vasco / Euskal Herriko Unibertsitatea, Swiss Federal Institute of Technology, University of Southampton, Bilkent



University, Universidad Publica de Navarra, University of Glasgow, Siegen University, St. Petersburg Electrotechnical University, FORTH, Warsaw University, University Roma Tre, Loughborough University, University of Siena, Thales Research & Technology, Universitat Politecnica de Catalunya, Queen's University of Belfast, Université Paris-Sud, Universidad Autonoma de Barcelona, Institute of Electronic Materials Technology. The project was coordinated by Helsinki University of Technology (Prof. Sergei Tretyakov, Department of Radio Science and Engineering, Helsinki University of Technology, P.O. Box 3000, FI-02015 TKK, Finland. E-mail: sergei.tretyakov@tkk.fi; <http://www.tkk.fi/~sergei>).

### 1.3 Work performed and results

**During the year 1** our participants and the subcontractor CRR studied possible legal options for the future Virtual Institute (VI) and determined the preferred form – an Association. CRR has developed a detailed description of this option, outlining possible ways of financing the organization, liability of partners, etc. An additional network workshop fully devoted to the questions of integration and VI creation organized during the first year has been found to be a useful initiative. As envisaged in Annex I of the Contract, the partners saw the future VI as a new and useful tool which should help them to do research better, more efficiently and in a more co-operative way. It should work to help to get better funding, to find industrial customers, to promote results, to manage joint projects, to educate PhD students. All the partners have signed endorsement letters expressing their commitment to the present work plan and goals and their acceptance of the association model as the basis for future work.

We collected information of partner resources (equipment, facilities, software) that are available for the Network, and this information was made available on the intranet part of the web site. Usage rules have been established. Two Marie Curie proposals were finalized and submitted. One (NEWTAC) is a common effort with three other NoEs (ACE, NEWCOM, AMICOM) and two integrated projects. Discussion of future mobility scheme led to the introduction of “mobility grants” that were designed to foster short-term “seed” mobility of research fellows. Rules and procedures governing this mobility scheme have been agreed. The first model of Non-Disclosure Agreement has been proposed to be a common document and a reference for all project members. Rules within the FP6 European programme have been described and examples of IP management have been provided to the partners. Temporary web site has been developed and maintained by the coordinating institution (HUT). The web address of the Network web site is <http://www.metamorphose-eu.org/>. Draft procedure for monitoring the percentage of women in the research sector of the participants has been developed, and the first study has been conducted.

The main tool in organizing future joint research activities has been the Network Workshop. The first workshop was organized in Belgium and France by Universite Catholique de Louvain and CNRS (Lille) in November 2004. The workshop was a success, leading to new co-operations and initiated research proposals. In addition to organization of research planning workshops, the current research efforts have been analysed, and potential collaborations identified. A review of industrial needs has been compiled. Procedure for working on new joint research proposals has been developed and agreed in the network. A



few first joint proposals have been submitted and more are in the process of development. Three research workpackages prepared overviews of the current status of the respective research fields and came up with two research proposals that were considered in the Workshop as means to combine European resources in a more effective way

During the year 1 the steering committee for the future joint PhD school was created. The committee developed a draft document “Memorandum of Understanding on EU Ph.D. Mention of Excellence”, which was signed by participating partners. The first courses had well-developed plans with determined locations and teachers. The steering committee for the work on a reference book on metamaterials has been created, and the committee has finished work on planning personal involvement in writing the planned books, and planning of the book contents. Many special sessions on leading scientific conferences were organized, as well as special journal issues. Information about potential industrial partners was collected and made available to the partners. On the Network web site, we have a special section for industrial specialists.

To summarize, during the first year the Consortium developed the preliminary concept of the future Virtual Institute and had chosen its legal format. Three modules [a) sharing of equipment and facilities; b) joint research; c) spreading of excellence] of the VI were established in their preliminary form within the NoE and operated towards the cooperation goals.

**During the year 2** we developed the concept and the legal frame of the future Virtual Institute and elaborated its functionalities.

During this year and all the following years we updated the collected information of partner resources (equipment, facilities, software) available to the Network, and this undated information was made available on the intranet part of the web site.

New professional web site was developed with the help of a subcontractor. The site maintenance responsibility was moved to the coordinating institution (TKK).

Procedure for monitoring the percentage of women in the research sector of the participants was developed, and the second stage of study has been conducted. Promotional materials targeted to young women in science were produced.

The key activity in our research was the work on developing the Network research road map. In addition to organization of research planning workshops to discuss the joint research plans, the work was organized via e-mail exchanges between the partners. As a result, we produced a draft road map document, with the goal to link the global goals with particular research proposals for joint work. During the year, several research proposals were prepared. We also worked towards promotion of the new research direction of artificial electromagnetic materials as a promising topic for future FP7 research plans, within NMP and IST priority areas.



The joint PhD school was already operational. The “Memorandum of Understanding on EU Ph.D. Mention of Excellence” was updated during the second year, and conditions and rules of interaction between the PhD consortium and the future Virtual Institute were agreed.

Many special sessions on leading scientific conferences have been organized, as well as special journal issues. A focused workshop for industries was organized.

**During the year 3** the METAMORPHOSE NoE officially registered the Virtual Institute (VI) for Artificial Electromagnetic Materials and Metamaterials - METAMORPHOSE VI AISBL, and about 90 percent of the NoE partners joined the new organization as full members. Furthermore, several external organizations expressed interest in becoming associate members of the Virtual Institute.

The VI interactive database of shared resources was fully functional and accessible to all partners. Starting year 3, the partners had a possibility to update their resources and availability time slots online or by contacting the WP leader. Resource sharing was managed by the distributed European Metamaterials Research Centre (EMRC), which is a part of the Virtual Institute.

The Network restructured its Mobility Grant Scheme to better address the partners’ needs in launching new joint research directions and working on the projects coordinated with the Research Roadmap. All mobility activities were correlated with the development of joint research proposals and the Research Roadmap projects.

The Outline Virtual Institute Business Plan, developed during the 3rd year, described the products and services offered by the VI, gave an evaluation of the market for the VI services; and outlines the preliminary business strategy; financing requirements; and key financial data with financial projections. Also, we completed the work on the IPR Handbook. The handbook provided researchers and students in the METAMORPHOSE VI with a comprehensive introduction to IPR and contains guidance on protecting and licensing IP that have been generated by the work of the Virtual Institute.

We developed a reliable and effective web platform for the annual METAMATERIALS Congress. The platform is accessible via <http://www.metamorphose-vi.org>. Inexpensive e-teaching tools were found and used. The first electronic course on metamaterials was created. It is available at the VI webportal.

In the research part of the work we concentrated on the Roadmap development and the coordinated projects. Our major joint research activities were organized in form small-scale coordinated research projects within the NoE. We worked on 14 projects which covered a wide range of topics from negative refraction to beaming and cloaking. Metamorphose Scientific Workshop was held in Berlin, Germany on May 11, 2007. In that workshop, the NoE partners presented and discussed their efforts within the coordinated projects. Significant progress was reported and the results proved that the coordinated project scheme was working. The problem we have faced for our NoE is the lack of metamaterials research within the FP6 calls. This was mostly due to the fact that metamaterials were not invented





during the write-up of the FP6 work programme (WP). We were also making efforts to get projects funded at national levels.

We were quite active during the preparation of the FP7 WP. For the NMP thematic area, we had a grassroots effort where we had asked the national delegates to the NMP program committee to support our efforts to include metamaterials as a “broad R&D research topic”. We sent a letter to the NMP director, which stated this request. We hoped that the inclusion of metamaterials within FP7 WP will give further incentive to the national research funding agencies to support metamaterials research at the national level.

Our main results in spreading and dissemination of the knowledge during year 3 are listed below:

- completion of the updates to the Memorandum of Understanding containing the mutual recognition of the credits earned at the EU Doctoral Schools;
- organization of three educational events of the EU Doctoral School on metamaterials (Rovaniemi, August 2006; St. Petersburg, October 2006, Warsaw, May 2007);
- development of the plan for the next School events (Belfast, August 2007; Rome, October 2007; Barcelona, January 2008);
- release of a CD containing all the material of the 2006 School events;
- maintenance and reinforcement of the web pages of the doctoral programme;
- a document summarizing the school guidelines has been prepared, discussed and agreed by the partners;
- basic investigation on the possible realization of new web-based focused courses;
- the first web-based course has been organized in Helsinki;

The Ph.D. Consortium was linked to the Virtual Institute through a proper set of rules and it is a department of the new organization.

We prepared the following educational and dissemination events in the 3<sup>rd</sup> year:

- International Student Seminar 2006, held in Rovaniemi (August 2006) in the frame of the “Metamorphose Training Week”; organization of the Summer School 2007,
- 2007 “Metamorphose training week” to be held in Belfast (August 2007) and comprising the International Student Seminar 2007 and the Summer School 2007 on “Dielectric and plasmonic metamaterials: fabrication, properties and modelling techniques”;
- International Congress on Advanced Electromagnetic Materials for Microwaves and Optics; pre-event organization of the first Congress Metamaterials 2007 to be held in Rome (October 2007) comprising both the Conference and the School with technical support from several bodies has been received;
- Journal “Metamaterials”, jointly organized by the Metamorphose NoE and Elsevier (ISSN number 1873-1988) was launched and the first issue was published online in March 2007.

**During the year 4 METAMORPHOSE VI AISBL** was functioning on full scale. The community got experience of keeping the association in working order in terms of work planning, financial management, promotion, dissemination of the members’ results. A new website <http://www.metamorphose-vi.org/> was created. The main results are as following:

- We attracted three new Associated Members to the VI during the last year of the project.



- The database on the VI facilities is functional. The rules how to access the facilities were unchanged.
- Mobility in the NoE is on the level adequate to the current research activities.
- The VI webportal is functional, and we have got positive feedback from a number of users. New concepts for the webpages of the EU Doctoral program on metamaterials and the METAMORPHOSE office have been used.

One FP7 Coordination project originated by the VI has got its funding from the EC for a period of 3 years and started its activities in April 2008. Around 10 joint research proposals have been generated, jointly developed and submitted for the FP7 NMP Call 2 in the spring of 2008. Three of the projects have passed the 1<sup>st</sup> selection stage.

The spreading activities gave us the following results:

- EU Doctoral Programme on Metamaterials is functional. A number of doctoral schools has been organized. The Programme Memorandum has been updated.
- The 1<sup>st</sup> annual Congress on Metamaterials took place in Rome, Italy in 2007. The second Congress will take place in Pamplona, Spain in September 2008. The Congress is owned and organized by the Virtual Institute.
- The NoE-originated book on metamaterials has been finalised and sent to the publisher.
- The partners were in contacts with the related industry on the local level.

According to the results of the EC reviews the METAMOPRPHOSE NoE project has achieved all the planned objectives.



**Some pictures from the project meetings during 2004-2008**



Picture 1: NoE Advisory Board meeting, Barcelona, Spain, February, 2006. VI discussion



Picture 2. VI meeting, Barcelona, Spain, February, 2006. Coordinator's talk.



Picture 3: NoE PhD school in Rovaniemi, Lapland, Finland, August 2007. Students and teachers.



Picture 4. Discussion of the research mini-projects, Seefeld, Austria, January 2007.





Picture 5 NoE GB meeting, bus trip in Berlin, Germany, May 2007. Prof. Tomash Szoplic discusses with Sergei Tretyakov possible cooperation on nano-structured metamaterials.



Picture 6: Closing ceremony of METAMATERIALS 2007 Congress, Rome, Italy.



Picture 7: Joint event with PHOREMOST NoE: Women in Photonics (WiP 2008) event in Paris.



Picture 8: Poster session at the WiP 2008 event.