Report of the

RF-MST Cluster Workshop

Fodele / Heraklion, Crete, Greece
June 30, 2008

Michel Declercq
Introduction

The workshop gathers together partners of IP’s, STREPS and NoE projects in the field of RF-MST, funded by the European Commission in the framework of the 6th as well as the 7th F.P. A total of 15 projects have been presented, including 3 projects that are not directly related to RF-MEMS but that present a large interest for the RF-MEMS community. Some of these projects have also been displayed on posters.

The purpose of the workshop is to share the latest achievements as well as the problems and challenges, to create contacts between scientists active in the same area, and to help creating synergies between projects.

Such a workshop on RF-MST is visibly very appreciated by the participants, and appears as a unique opportunity to help pushing the state-of-the-art in the field.

This report does not intend to repeat or summarize the content of the presentations. A copy of the slides is available in the workshop pre-proceedings and will be published on the web, while a short abstract of each project and its objectives is given in annex of this report (source: CORDIS).

Topics covered in the 2008 workshop and related comments

The program of the presentations was well balanced, offering projects ranging from exploratory technologies and devices to well focused industrial projects and support services.

MEMS switches, and more specifically capacitive switches, appear in several projects such as RETINA, ARASCOM, MEMS4MMIC, and e-CUBES. They are now reaching a good level of maturity, including for power switches. Their RF applications include, for instance, reconfigurable front-ends, cognitive radios, antenna switches, matching networks and variable delay lines.

MEMS resonators and oscillators are attracting a high-level of interest and are clearly one of the next breakthrough for the MEMS technology. These devices are potential candidates for replacing ceramic filters and quartz oscillators. MEMS resonators based on a silicon resonator and electrostatic transduction are demonstrated up to the multi-MHz range (Nanotimer, MINAmi). A significant breakthrough has been obtained using the thermal oxidation of the silicon resonator for compensating the temperature drift. Dielectric charging, tunability and precision of the resonance frequency remain a challenge. Cavity resonators with high-Q and tunability feature have also been demonstrated in the microwave range (30 to 100 Ghz) (3DμTune). Results are impressive although manufacturing precision and reliability are still challenging. In the near future, new devices such as NEM-FET based resonators may create the next breakthrough as oscillators for the direct replacement of quartz.

RF-MEMS components utilizing carbon nanotubes (CNT) are actually explored for applications such as switches, tunable capacitors and resonators.
Although it is very important to explore the capabilities of CNT, results are not convincing yet, and their future for the target applications remain questionable.

Beam steering antennas are addressed in 3 projects presented at the workshop, namely RETINA, ARASCOM and TUMESA. This application seems to be very promising for automotive (car radar) and avionics (satellite communication) applications. Prototype designs providing adjustable phase shifting have been demonstrated for frequencies ranging from the X-band up to the W-band. According to the frequency of interest and the need of fine phase tuning, various techniques are actually under test. Besides the “classical” approach combining switches with MEMS tunable capacitors or MEMS microstrips, very innovative solutions are proposed that include liquid crystal layers and tunable metamaterials.

Packaging is a critical factor for a successful industrial application of MEMS products. Although packaging has already been addressed as a side problem in various projects, a project totally and specifically dedicated to RF-MEMS packaging issues is starting now in the 7th F.P. (MEMSPACK). Level-0 (wafer-level RF-MEMS encapsulation) as well as level-1 (MEMS + IC assembly & packaging) are covered in this project that is expected to address key issues in packaging technologies, including manufacturability, RF characterization and reliability.

Transversal applications and demonstrators are important for demonstrating and assessing the industrial potential of RF-MST. The important field of wireless sensor networks is addressed in e-CUBES. Challenging miniature (3-D) SiP techniques are demonstrated for very severe specifications in terms of size, weight, robustness and low-cost. On the other hand, Ambient Intelligence (AmI) applications have been developed and demonstrated in the MINAmi project, with emphasis on ultra-low power, data storage, remote powering and wireless data transmission. Most of these applications also address the important topic of energy scavenging.

Filling the gap between R&D and industrial applications and removing the existing barriers is a key issue for the industrial future of MEMS/NEMS. Besides packaging, topics such as manufacturability, reliability, testing, failure analysis and others must be addressed for establishing MEMS as credible solutions that may provide key advantages in terms of miniaturization, low-power, low-cost and enhanced performance. These parameters have been addressed in several projects presented at the workshop. A very interesting initiative covering this important domain has been presented at the workshop with the NoE PATENT – DfMM.

Finally, support to (potential) RF-MST users is mandatory for attracting SME’s that don’t have in-house capability for mastering these technologies. Organizations offering a single entry point to access information, access technology platforms and other design supports are mandatory. The NoE AMICOM has been a pioneer in this domain by structuring the RF-MST community. Their action is successfully pursued in the framework of the self-financed AMICOM Forum. The RF-Platform project, that may be considered as a spin-off of AMICOM, is a full solution provider, industry oriented, in the field of RF-MST.
Possible synergies between projects

Considering the different domain of activities covered by the projects presented in the workshop, synergies may be developed in the following areas:

“Classical” MEMS switches are intensively used in projects such as RETINA, ARASCOM, e-CUBES and MEMS4MMIC (7th FP). On the other hand, a new, high-performance switch for low-power applications is actually investigated in the NEMSIC (7th FP) project. This ohmic switch, based on an innovative NEM-FET device, may have a bright future in many applications, owing to its high on/off ratio.

Beam steering antennas are addressed by 3 projects: ARASCOM, RETINA and TUMESA. Even if the frequency range covered by these projects is not the same, there are overlaps where the performance of the different approaches may gain to be compared. Innovative technologies based on tunable meta-materials (TUMESA) or liquid crystals (ARASCOM) should particularly be compared with other more classical solutions.

Manufacturability, reliability, testing, failure analysis, packaging and other key issues for industrial applications are addressed in several projects, and potential synergies are numerous in this area.

- RETINA has intensive testing programs for RF-MEMS switches and ferro-electric capacitances, and is developing a “Design for Reliability” Software tool for RF-MEMS.
- PATENT-DfMM, although not specifically dedicated to RF-MEMS has developed a high-level expertise in reliability, testing, accelerated ageing, humidity/hermeticity monitoring, failure analysis and others. A part of this expertise may be useful for MEMSPACK.
- RF-Platform, as an industrial service/solutions provider, is directly confronted with the same issues
- E-CUBES and MINAMI, involved in industrial demonstrators have the same needs and are addressing the same topics
- MEMS4MMIC also presented a clear commitment on reliability and testing. The AMICOM Forum may play a central role in centralizing this expertise and providing a single entry point for all these reliability and testing issues.

Access to RF-MEMS platforms is actually proposed through several projects, initiatives or support actions that include:

- AMICOM
- RF-Platform
- EUROPRACTICE
- INTEGRAMPLUS
- HTA (Heterogeneous Technology Alliance) – Partners include the CEA (France), the FhG (Germany), CSEM (Switzerland) and VTT (Finland).

A unique entry point through AMICOM that could redirect customers to the right platform according to their specific needs would be very useful and help increasing confidence in RF-MST.
Summary and trends

“More than Moore”, or the combination of sensors/actuators, radio, power and interfaces with signal processing and storage, is recognized as one of the key domains where Europe can play a leadership role.

Strong drivers for the More-than-Moore domain are automotive applications, Ambient intelligence (including bio-medical) and wireless sensor networks (including environment monitoring & security).

In this framework, RF-MEMS appear as a key enabling technology for improving dramatically miniaturization, low-power, low-cost and system performance of wireless systems.

The status and trends in RF-MEMS components, systems and services can be summarized as follows:

MEMS RF-Switches and variable-Capacitors have reached maturity and are ready for industrial applications. Applications range from reconfigurable front-ends, cognitive radios, antenna switches, matching networks to delay lines and others. Research will however continue to explore new switching technologies, applicable to power management and low-power RF switching. Among the interesting candidates, the NEM-FET appears to be very attractive with a high on/off ratio.

Resonators and oscillators are the next candidates for industrial application where they could replace bulky ceramic filters, quartz oscillators and others. Full maturity is not reached yet, but interesting breakthrough are appearing in terms of precision, temperature stability and frequency range. The next breakthrough is expected from NEM-FET resonators and oscillators. Tunability, reliability and long-term stability remain challenging.

MEMS-based RF Power sensors, which have not been addressed in this workshop, are also key components for mobile telephony applications. Interesting results were already obtained in previous EC projects such as EMMA (5th FP).

Smart antennas are attracting a large interest, due to their wide field of applications in automotive and avionics. Besides the use of “classical” MEMS for generating the variable phase shift, very innovative solutions appear that are based on liquid crystal or meta-material phase-shifters. These new approaches are promising and should be carefully monitored.

Carbon nanotubes have basically very interesting features, but their technology remains rather tricky, and actual demonstrators are not really convincing today. Research should however be pursued on CNT, that may be interesting for sensors and interconnection applications.

Packaging, reliability, testing, failure analysis and other key factors for industrial applications are now seriously addressed by several groups. This trend will be confirmed and developed, reflecting the industrial interest for practical applications of RF-MEMS.
Some challenges remain in multi-physics modeling, MEMS-IC co-design and system modeling.

Several initiatives exist for providing access to technology platforms, support for design, testing and packaging, and others. A lack of correlation is however observed between these initiatives, that may raise some skepticism among potential users of RF-MST, particularly among SME’s.

It is therefore strongly recommended to develop a single entry point for helping newcomers to access the world of RF-MST. AMICOM may play a key role in this framework.

Finally, it should be pointed out that the actual trends in Microsystems (combining microelectronics and MEMS) generate new challenges in education. Engineering education should be polytechnic and cover topics that include physics, material science, components, circuit design, system architecture, hardware-software co-design, system-oriented thinking, awareness of economics, societal behavior, etc.

Michel Declercq
## AGENDA

**RF-MST CLUSTER WORKSHOP**  
Heraklion, Crete, Greece, 30th June, 2008

Chairman: Prof. H. Schumacher, University of Ulm  
Rapporteur: Prof. M. Declercq, EPFL Lausanne

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<th>Time</th>
<th>Topic</th>
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<tr>
<td>8:15</td>
<td>Registration</td>
<td>T.J. Sommer (EC – BE)</td>
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<td>8:50</td>
<td>Opening/WELCOME</td>
<td>H. Schumacher (Univ. of Ulm - DE)</td>
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<td>9:00</td>
<td>Keynote speech: RF-MST: Challenges and Opportunities</td>
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<td>9:30</td>
<td><strong>Project Session 1</strong></td>
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<td>AMICOM (NoE) / AMICOM Forum</td>
<td>R. Sorrentino (Univ of Perugia –IT)</td>
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<td>RF-PLATFORM (IP)</td>
<td>T. Vähä-Heikkilä (VTT – FI)</td>
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<td>Brief overview of posters (I):</td>
<td>J.T.M. van Beek (NL)</td>
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<td>Coffee break / Poster session</td>
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<td><strong>Project Session 2</strong></td>
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<td>e-CUBES (IP)</td>
<td>H. Roedig / W. Weber (Infineon – DE)</td>
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<td>NANORF (STP)</td>
<td>D. Tsamados (EPFL – CH)</td>
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<td>3DµTUNE (STP)</td>
<td>H. Tilmans (IMEC – BE)</td>
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<td><strong>Project Session 3</strong></td>
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<td>14:00</td>
<td>MINAMI (IP)</td>
<td>J. Baborowski (CSEM – CH)</td>
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<td>14:10</td>
<td>RETINA (STP); DG Research</td>
<td>V. Ziegler / B. Schoenlinner (EADS – DE)</td>
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<td>ARASCOM (FP7 STP)</td>
<td>L. Marcaccioli (Univ. of Perugia – IT)</td>
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<td>R. Baggen (IMST – DE)</td>
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<td>TUMESA (FP7 STP)</td>
<td>D. Chicherin (TKK – FI)</td>
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<td>16:00</td>
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<td>SMARTIEHS (FP7 STP)</td>
<td>M. Carlin (SINTEF – NO)</td>
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<td>Conclusions</td>
<td>Chairman</td>
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Closed meeting: discussion on specific issues
- End of the closed meeting

EU-project participants only
Annex-II : Abstract of the projects presented at the workshop

**AMICOM -** Advanced MEMS For RF and Millimeter Wave Communications

**Coordinator**
CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE
LAAS
FRANCE

**Project details**
- Project Reference: 507352
- Contract Type: Networks of Excellence
- Start Date: 2004-01-01
- End Date: 2007-10-31
- Duration: 46 months
- Project Status: Completed
- Project Funding: 5.5 million euro

**ABSTRACT**
The approach of the information society has resulted in a tremendous increase in the volume of wireless communication often giving rise to bottle-necks in the communication systems. To alleviate this congestion there is pressure to widen the allocated frequency bands up to millimetre wavelengths and to have terminals that are able to support many standards. It is understood that conventional components and solutions have limitations that will make it difficult to fulfil these requirements.

The last five years has seen the emergence of a technology, RF and microwave MicroElectroMechanical Systems (MEMS), that seeks to overcome these limitations. In this new technology mechanical and electrical functions are combined to improve the performance of existing devices, allow on-wafer device integration and the creation of completely new device systems called Advanced MEMS for RF and Millimeterwave Communications "AMICOM". A consortium has been assembled that believes the merging MEMS technologies with IC technologies will lead to advanced microsystems that can operate over very broad-band frequency ranges.

The microsystems will feature innovative functionalities, such as circuit redundancy, reconfigurability and power management. To realise this micro system concept, research and collaboration in many different fields is required including fabrication technology, materials, electromagnetics, mechanics, thermal and electrical modelling, characterisation, packaging and reliability. We believe that a Network of Excellence is the most appropriate vehicle with which to assemble and integrate the isolated competences that exist around Europe in this field.

In this way a powerful research body will be created that can compete with the United States and Japan. The idea is to give to the industrial partners access to a large and transparent body of European competence to help them to enhance their competitiveness.
RF-PLATFORM - Generic manufacturing and design technology platforms based on novel RF technologies

Coordinator
VTT
FINLAND

Project details
Project Reference: 027468  Contract Type: Integrated Project
Start Date: 2006-01-01  End Date: 2008-12-31
Duration: 36 months
Project Status: Execution
Project Cost: 4.89 million euro  Project Funding: 2.9 million euro

ABSTRACT
RF-PLATFORM project will develop a service concept similar to EUROPRACTICE. Companies, universities and research organisation will have access to multi-project fabrication through a central service point. This service point will provide design interfaces and design templates for platforms that are provided by consortium. Consortium will provide multiple platforms: GaAs, SiGe, MCM-D, MCM-S, IC through participants or foundries. Some of these technologies lack the user interface for external use, and aim of the project is provide unified design and logistics environment and to create a gateway to allow wider usage of these platforms.
**NANOTIMER** - Nano-technology in mechanical-electrical resonators

Coordinator
PHILIPS ELECTRONICS NEDERLAND B.V.
NETHERLANDS

**Project details**
- Project Reference: 507914
- Contract Type: Specific Targeted Research Project
- Start Date: 2003-12-23
- Project Status: Execution
- Project Cost: 4.77 million euro
- Project Funding: 2.3 million euro

**ABSTRACT**
Mechanical resonance is widely applied in high-precision oscillators for a multitude of time-keeping and frequency reference applications. In all such cases, the high-precision resonating element consists of an off-chip passive component, such as a quartz crystal. Major drawback of these off-chip resonator technologies is that they are bulky and must interface with transistor chips at the boards, posing a bottleneck against the ultimate miniaturization of e.g. wireless devices. The extraordinary small size and high level of integration that can be achieved with silicon MEMS resonators appear to open exceptional possibilities for creating miniature-scale precision oscillators to be used in e.g. mobile communication and navigation devices. The aim of the NanoTIMER project is to develop an oscillator with high-accuracy incorporating a silicon MEMS resonator generating frequencies in the 10 to 1500 MHz range.

Within the NanoTIMER project, MEMS based oscillators will be realized according to concrete specifications derived from existing applications. The MEMS oscillator will be encapsulated using a wafer-level vacuum package technology that is compatible to the oscillator manufacturing flow. An important feature of the proposed resonator manufacturing process is the realization of nanometre size (100 nm) transduction gaps, which is of prime importance for the realization of MEMS resonators functioning in the GHz range. Reliability and drift of assembled oscillators and its constituent components (resonator and package) will be assessed.

The NanoTIMER initiative is a first step towards the realization of 'vibrating' nano-electro-mechanical processors that, combined with traditional CMOS, could open new alternatives for signal processing in VLSI.
**e-CUBES -** 3-D-integrated micro/nano modules for easily adapted applications

**Coordinator**

INFINEON TECHNOLOGIES AG
GERMANY

**Project details**

Project Reference: 026461  
Contract Type: Integrated Project  
Start Date: 2006-02-01  
End Date: 2009-01-31  
Duration: 36 months  
Project Cost: 20.8 million euro  
Project Funding: 12 million euro

**ABSTRACT**

As electronic sensor systems are becoming more complex and individualised, standard state of the art approaches will not be anymore appropriate to meet the objectives (cost, reliability, time to market, etc.) of the future. The innovative approach presented here will realize e-CUBES, i.e. investigate and develop 'small sensor cubes' which are wireless communicating among each other. The e-CUBES will build-up an ad-hoc network to realize the desired system functionality.

e-CUBES addresses various multi-disciplinary applications in the important field of wireless sensor networks, with special emphasis but not limited to the following key application areas:
- Distributed smart monitoring for Aeronautics and Space applications;
- Wireless sensor networks for Health and Fitness;
- Distributed intelligent Automotive Control.
Particular focus of e-CUBES is on the following technologies:
- Individual technologies at various layer levels, suitable for 3D integration;
- Layer processing/thinning technologies for 3D integration;
- 3D assembling and packaging;
- New communication means, e.g. antennas, passive and RF integration, and communication networks;
- Power supply and power management for portable applications;
- Design methodologies for the 3D SoC and related simulation tools.

The e-CUBES technology poses particular challenges with regard to the desirable sizes (a few cubic millimetres), the need to achieve continuous operation through an integrated or external wireless power supply, and the necessity of allowing multiple e-CUBES to communicate. The system is characterized by a large number of individual interconnected e-CUBES. The "e-CUBES" vision therefore represents a new approach to systems integration that will help to develop complex, flexible and cost-efficient.
NANORF - Hybrid Carbon Nanotube - CMOS RF Microsystems

Coordinator
ECOLE POLYTECHNIQUE FEDERALE DE LAUSANNE
SWITZERLAND

Project details
Project Reference: 028158      Contract Type: Specific Targeted Research Project
Start Date: 2006-01-01        End Date: 2008-12-31
Duration: 36 months          Project Status: Execution
Project Cost: 4.52 million euro     Project Funding: 3.2 million euro

ABSTRACT
The aim of NANORF is to take advantage of the unique mechanical and electrical properties of Carbon Nanotubes (as RF NEMS) to hybridize with CMOS electronics for RF applications (1-5GHz). The project main targets are:
(i) Prospects concerning the figures of merit of CNTs as NEMS individual devices or/and as arrays (bundles) with particular focus on the following device architectures: nano-switches, nano-resonators using vertical or lateral individual and/or arrays of CNTs, tuneable varactors based on arrays of CNTs;
(ii) Develop technological pathways for carbon nanotube radio frequency electromechanical devices: modification/modulation of electrical conductivity under actuation, mechanical and electrical fundamental properties over large of temperature (from cryogenic to 2000°C);
(iii) Develop hybrid CNT-CMOS technology based on dedicated effort for mastering compatibility issues between silicon CMOS and Multi-Walled Carbon Nanotubes (thermal budget, drift of characteristics induced by complementary technology);
(iv) Propose new RF NEMS design using individual CNT and vertically and/or laterally grown arrays of CNTs in precise locations on silicon wafers;
(v) Prospect on issues of hybrid CNT-CMOS RF device and IC co-design: coupling to electrodes, dimension control at nano-scale, signal-to-noise ratio, temperature drift;
(vi) Build RF hybrid CNT-CMOS circuit demonstrators: filters and oscillators (in general, tuneable RF NEMS blocks relevant for the RF front-end for future mobile communications systems).

The proposal essentially extends the performance and functionality of standard silicon RF CMOS ICs based on hybridization with one of the most promising nanotechnologies, the Carbon Nanotubes.
**3DµTUNE** - 3-dimensional micro-machined cavity resonators for high Q and tunable mm-wave filters and oscillators

**Coordinator**

PHILIPS ELECTRONICS NEDERLAND B.V.
NETHERLANDS

**Project details**

- Project Reference: 027768  Contract Type: Specific Targeted Research Project
- Start Date: 2006-01-01  End Date: 2008-12-31
- Duration: 36 months  Project Status: Execution
- Project Cost: 5.89 million euro  Project Funding: 3.25 million euro

**ABSTRACT**

New standards for wireless communication consumer applications appeared during the last years in the so-called millimeter-wave (mm-wave) range from 30 GHz to 100 GHz. Especially the car-radar standard at 77 GHz, Satellite Communication in different frequency intervals up to 64 GHz and very recently also 60 GHz high data rate wireless local area networks (WLAN) are prominent examples of this development. The challenge is to break the technology barrier and find a mix of technologies that lead to simpler, highly integrated and reliable systems for the consumer market.

The 3DµTune project develops a generic process for reliable, high quality fixed and tunable millimeter-wave cavity resonators embedded in a 3-dimensional passive integration technology. These are combined with SiGe IC’s to a hybrid multi-technology module (3D micromachined fixed/tunable resonators, passive integration technology and SiGe IC technology).

This technology will enable simpler oscillators, high quality millimetre-wave filters and thus simpler millimetre-wave RF front-end architectures than currently available on the market. It is a generic resonator technology with impact on all applications in the millimeter-wave frequency range as all of them require an oscillator and many of them profit from high Q tunable filters.

Parallel to the technology development for the high Q and tunable 3-dimensional cavity resonators, design issues like the co-design and technology partitioning in passive integration and IC technology and hybrid packaging for millimeter-wave applications, reproducibility and reliability for communication, automotive and space applications will be addressed. As resonators for different applications are integrated into one passive integration process, system and test cost are reduced, the new oscillators and filters are very robust and can profit from the overall production up-scaling of all millimetre wave applications.
MINAMI - Micro-Nano Integrated Platform for transverse ambient intelligence applications

Coordinator
STMICROELECTRONICS SA
FRANCE

Project details
Project Reference: 034690  Contract Type: Integrated Project
Start Date: 2006-10-01  End Date: 2009-09-30
Duration: 36 months  Project Status: Execution
Project Cost: 19.62 million euro  Project Funding: 10.2 million euro

ABSTRACT
MINAMI addresses AmI applications where personal mobile devices act as a gateway to AmI. MINAMI vision makes the user progressively be in control of his AmI environment, then interact with everyday objects to monitor and control environmental or health parameters. MINAMI develops tools, methodologies and an open platform and implement these technologies into real devices/systems in demonstrators. Ethics and privacy issues linked to AmI will be strongly assessed as well as user acceptance of the solutions. MINAMI multidisciplinary and participatory design approach will reduce the time to adopt AmI disruptive concept, facilitating a constant dialogue between technology and application developers, end users and application field experts.

The open platform previously developed in MIMOSA will be enriched in MINAMI as new technologies offer more functionalities for wider applications. Micro-Nano smart devices with enhanced short range connectivity will be developed and validated through field trials in wide and transverse applications, from consumer to niche markets.

The main technical focus in MINAMI is in the development of:
- mass storage RF tags based on low power innovative technologies
- active event sensitive tag technology including new low-cost time reference
- low-cost/low-power sensors and actuators including nanosensors, 9D integrated Inertial Measurement Unit and 3D distributed vision systems

In MINAMI, a global platform taking into account the constraints of integration, industrialisation and compatibility with advanced CMOS platforms will integrate these technologies. MINAMI links demonstration, validation and exploitation.

Service providers and companies will develop and support the applications in pre-competitive products that include:
- drugs monitoring and conditioning
- health monitoring and homecare
- assistive listening device
- data downloading from passive tags
- ambient sensors for friendly home applications
- virtual optical user interface
RETINA – Reliable, Tunable Inexpensive Antennas by Collective Fabrication Processes

Coordinator
EADS DEUTSCHLAND GMBH
GERMANY

Project details
Project Reference: 516121  Contract Type: Specific Targeted Innovation Project
Start Date: 2005-02-01  End Date: 2008-01-31
Duration: 36 months  Project Status: Completed
Project Cost: 5.18 million euro  Project Funding: 3.17 million euro

ABSTRACT
The project aims at developing a reliable and low cost solution for agile beamsteering in Ku- or Ka-band onboard mobile platforms, such as planes and satellites. It is based on the global concept called ReflectArray and the industrial implementation is clearly a lower cost alternative compared to active antennas. It will allow a high data rate connection between the mobile platforms and therefore enabling: - Live TV and Internet onboard to every passenger - Internet flight monitoring using the plane-satellite link The first objective with its associated services of the web will improve passengers' comfort and support quasi uninterrupted daily services for the citizen, whether for personal or professional purposes. It is also envisioned that this system could bring an added value to ATM functions, whatever the distances from the platforms to the airport areas, by participating to in-flight monitoring of flight parameters or for safety and security (live video) related purposes to generate early warnings and advised external help to the crew. Technically, the spatial steering of the beam is based on coherent combining of elementary EM cells radiation. Such a concept has been validated since some years now by using today's low cost PIN diodes for the basic key function, the phase shifter. Although successfully applied, it still has major inconveniences that outweigh by far the initial low cost of the diodes. Therefore, two alternative solutions will be considered in parallel within the project. - High-power handling RF-MEMS technologies - High-power handling ferroelectric materials They are considered by the consortium as the best technical alternatives for phase shifters up to Ka-band today and are foreseen to levelup the performances while keeping the costs at the lowest level. The project will lead research in the two domains and has a decisive milestone to choose the most suitable technology for the final reflect array approach.
**ARASCOM (7th FP)** - MEMS and liquid crystal based, agile reflectarray antennas for security and communication (ARASCOM)

**Coordinator**
THALES ALENIA SPACE FRANCE
FRANCE

**Project details**
- Project Acronym: ARASCOM
- Project Reference: 222620
- Start Date: 2008-05-15
- Duration: 36 months
- Project Cost: 3.91 million euro
- Contract Type: Collaborative project (generic)
- End Date: 2011-05-14
- Project Status: Execution
- Project Funding: 2.6 million euro

**ABSTRACT**

Our project is focused on Research & Development for efficient use of micro-nano devices as basis of agile antennas with moderate cost, that are more and more required in advanced systems for Communication, Safety and Security. We will assess this until representative prototypes at a very large and innovative level:

- very large because the developed agile "reflectarray" antennas for Communication (to be implemented in base-stations and satellites) will comprise thousands of RF-MEMS switches integrated in the radiating board for phase-controlling the reflected waves
- innovative: first because such quantities will require both accurate & safe design, and setting-up industrial processes including on-wafer packaging and automatic assembling, to reach higher reproducibility in top-level performances (improving reliability) than previous European projects on RF-MEMS
- innovative especially because to operate at the very high frequencies suited to security imaging, safe-landing & anti-collision radar (typically around 77 GHz), will be developed new phase-shifters combining MEMS with nematic Liquid Crystals ; the latter provide variable permittivity by adjusting molecules orientation, so may be called "nano-scale control devices".

So both Micro (MEMS) & Nano (nematic LC) technologies will be deeply investigated, for their best properties in agile antennas.
MEMS-4-MMIC (7th FP) - Enabling MEMS-MMIC technology for cost-effective multifunctional RF-system integration (MEMS-4-MMIC)

Coordinator
IMST GMBH
GERMANY

Project details
Project Acronym: MEMS-4-MMIC
Project Reference: 224101
Start Date: 2008-05-01
Duration: 42 months
Project Cost: 3.8 million euro
Contract Type: Collaborative project (generic)
End Date: 2011-10-31
Project Status: Execution
Project Funding: 2.9 million euro

ABSTRACT
The MEMS-4-MMIC proposal aims at the integration of RF-MEMS switches onto Monolithic Microwave Integrated Circuits (MMIC) creating highly integrated multifunctional building blocks for high-value applications. RF-MEMS will be an essential building block of next-generation smart systems that are characterised by cost-effective and compact designs, high performance, flexibility and configurability.

MEMS-4-MMIC will consider the whole value chain of RF-MEMS MMIC components starting at the materials and suitable foundry processes, the RF-design, packaging of RF-MEMS MMIC, and last but not least, the testing and reliability which plays a very important role in the whole manufacturing/commercialisation process. For this purpose one of Europe’s leading GaAs MMIC foundries is part of the consortium. The definition of first RF-MEMS MMIC components starts with the selection of the correct requirements that are dictated by next-generation wireless smart applications, automotive radar, satellite terminals, 60 GHz WLAN and cognitive radio front-ends. As a proof-of-concept an RF-MEMS MMIC based antenna module will be realised at the end of project showing the innovative character and possibilities for commercial exploitation.

The MEMS-4-MMIC project will significantly contribute to the knowledge and competence to include RF-MEMS switches on existing GaAs MMIC foundry processes. The project aims to provide the enabling technology platform needed for the future establishment of an RF-MEMS MMIC manufacturing base within Europe.

If successful, MEMS-4-MMIC will speed-up the commercialisation of RF-MEMS MMIC components for small scale as well as large scale production (shorten time-to-market), and be accessible for all types of customers, thus turning RF-MEMS MMIC technology into pure profit for Europe wireless highway of tomorrow.
TUMESA (7th FP) - MEMS tuneable metamaterials for smart wireless applications (TUMESA)

Coordinator
TEKNILLINEN KORKEAKOULU
FINLAND

Project details
Project Acronym: TUMESA
Project Reference: 224197
Start Date: 2008-06-01
Duration: 36 months
Project Cost: 2.53 million euro
Contract Type: Collaborative project (generic)
End Date: 2011-05-31
Project Status: Execution
Project Funding: 1.85 million euro

ABSTRACT

The proposed project focuses on development of tuneable metamaterials and metasurfaces based on microelectromechanical systems (MEMS) and their integration to smart wireless systems such as radar, secure high-capacity communication systems, radio astronomy, atmospheric remote sensing, spectroscopy, etc.

MEMS allow miniaturisation of electronic components, reduce their cost in batch production and effectively compete with semiconductor and ferroelectric based technologies in terms of losses at millimetre wavelengths. Metamaterials provide a way to design devices with unique and engineered electromagnetic properties. The advantage of convergence between MEMS and metamaterials is ability to create novel miniaturized reconfigurable low-loss and cost-effective wireless devices with innovative self-adapting mechanisms.

In addition to industrial and technological objectives, a number of socio-economic challenges urge research in smart wireless applications. EU authorities have launched a program to reduce fatal road accidents by 50% by 2010, with the focus on driver assistance and on-board safety systems for accident reduction, including automotive radar. For this purpose, the European Telecommunication Standard Institute ETSI has already produced a standard for automotive radar in the 79 GHz range.

The main objectives of the proposed project are: to develop novel on-chip phase shifting and beam-steering devices based on MEMS tuneable high-impedance surfaces; to integrate developed phase shifting components in novel space-efficient antenna arrays on a single chip; to elaborate novel concepts of implementation the beam-steering devices and antenna arrays in cost-efficient radar sensor and future high-capacity wireless communication systems and evaluate fabricated prototypes at a system level.
MEMSPACK (7th FP)  - Zero- and first-level packaging of RF-MEMS (MEMSPACK)

Coordinator
IMEC
BELGIUM

Project details
Project Acronym: MEMSPACK
Project Reference: 223882
Start Date: 2008-06-01
Duration: 36 months
Project Cost: 4.47 million euro
Contract Type: Collaborative project (generic)
End Date: 2011-05-31
Project Status: Execution
Project Funding: 3.4 million euro

ABSTRACT

Future personal and ground RF communications systems and communications satellites necessitate the use of highly integrated RF front-ends, featuring small size, low weight, high performance and low cost. Off-chip, bulky passive RF components, like discrete PIN diode switches and ceramic filters, are limiting further chip scaling. MEMS technology is now rapidly emerging as an enabling technology to yield a new generation of high-performance RF-MEMS passives, like switches, high-Q resonators and tunable filters.

Today, the commercialization of RF-MEMS, is greatly hampered by two critical success factors, namely, the development of an appropriate packaging technology and solving the reliability issues. There has not been sufficient effort towards solving these issues in Europe. The proposed MEMPACK project tackles the packaging issue. The project's objective is to (further) develop and to characterize generic wafer-level (or 0-level) and 1-level packaging solutions for housing a large variety of RF-MEMS.

The project will address all relevant issues of the development chain, i.e., the design of the package (including RF design, thermomechanical design, design for reliability), the packaging technology (e.g., 0-level "chip capping" technology, 0-level "thin film capping", 1-level packaging technology), the package characterization (RF, temperature stability, hermeticity) and the package evaluation (impact of the package on the device performance, towards meeting industrial specifications).

As the potential and future for RF-MEMS is likely to be situated in the monolithic (SoC) and/or module (SiP) integration of RF-MEMS components, the impact, the constraints and the potential of the RF-MEMS packaging on the system integration will be studied as well. One of the expected outcomes of the project will be an "RF-MEMS packaging design guideline", that can effectively be used by industry for the development of RF-MEMS.
NEMSIC (7th FP) - Hybrid nano-electro-mechanical / integrated circuit systems for sensing and power management applications (NEMSIC)

Coordinator
EPFL
Switzerland

Project details
- Project Acronym: NEMSIC
- Project Reference: 224525
- Start Date: 2008-06-01
- Duration: 36 months
- Project Cost: 5.16 million euro
- Contract Type: Collaborative project (generic)
- End Date: 2011-05-31
- Project Status: Execution
- Project Funding: 3.9 million euro

Project description
NEMSIC addresses the future intelligent sensor and actuator systems in which solid-state semiconductor micro/nanodevices and micro/nano-mechanical devices are co-integrated for new functionalities and increased performance.

The project proposes the exploration and development of low power sensing micro/nanosystems based on Nano-Electro-Mechanical (NEM) structures integrated on a Silicon-On-Insulator (SOI) or Silicon-On-Nothing (SON) technological platform. The applications that drive the technological NEM-based smart system demonstrators are gas (COx, NOx, SOx) and biological sensing (DNA, proteins and other molecules), dedicated to critical environment monitoring and applications in the fields of genetics, pharmacology and drug discovery.

NEM technology will be combined with silicon CMOS technology involving novelty and scientific/technical challenges at three levels:
- system level, addressing the challenge of true nano-micro interfaces, where signals detected by arrays of nanostructures are processed by smartly designed low power CMOS circuitry,
- device level, where novel true hybrid NEM-FET devices support new highly sensitive detection scheme and power management via sleep switches and
- technology level, where nanotechnology processes (top down processed nanobeams and nanogaps, featuring sub-100nm dimensions) will be developed and combined with advanced functionalization techniques for dedicated sensing that stays compatible with CMOS in future IC-embedded or post-IC approaches.

The reliability of the NEM structures, combined with prospects for 0-level packaging are studied as key challenges for the success of such Nano-electro-mechanical-system-integrated-circuits (NEMSIC).

Finally, NEMSIC is expected to provide the end-users with flexible design methodologies based on advanced but well-controlled SOI or SON technology platforms, with predictable performances and associated cost effectiveness.
SMARTIEHS (7th FP) - Smart inspection system for high speed and multifunctional testing of MEMS and MOEMS (SMARTIEHS)

Coordinator
STIFTELEN SINTEF
NORWAY

Project details
Project Acronym: SMARTIEHS
Project Reference: 223935
Start Date: 2008-04-01
Duration: 38 months
Project Cost: 3.78 million euro
Contract Type: Collaborative project (generic)
End Date: 2011-05-31
Project Status: Execution
Project Funding: 2.85 million euro

ABSTRACT

SMARTIEHS develops a smart, high-speed, cost effective and flexible inspection system for production of Micro(Opto)ElectroMechanicalSystems (M(O)EMS). SMARTIEHS decreases the inspection time of a wafer by a factor of 100. It cuts production costs and shorten the time to market.

To achieve this, SMARTIEHS develops an innovative measurement concept: a probing wafer consisting of an array of micro optical sensors is adapted to and aligned with the wafer under test. The design and production of the micro-optical interferometer array inspects 100 M(O)EMS structures within only one measurement cycle. A multifunctional approach of the measurement concept allows the inspection of passive and active parameters within one inspection system. A novel smart pixel detector array is developed.

SMARTIEHS provides a multifunctional design with two interferometer configurations; a low coherent interferometer and a laser interferometer. The project focuses on the measurement of shape and deformation, resonance frequency and vibration amplitude distribution. The SMARTIEHS technology will be validated and demonstrated with industrial end users. The work in SMARTIEHS will be organised in eight work packages: Project management, Inspection system design, Micro-optical interferometer system design, Micro-optical wafer production, Smart pixel camera development, inspection system integration, Inspection system test and validation, Exploitation and dissemination.

The SMARTIEHS consortium has RTD partners and industrial users: SINTEF (low-coherence interferometry, micro optics), WUT (laser interferometry, micro optics), Fraunhofer (production of Diffractive Optical Elements), CNRS (production of refractive optics, micro lenses), CSEM (design and production of smart pixel detector arrays), Heliotis (exploitation), IMMS (macro design of the inspection system), and Techfab (end user and validation).

SMARTIEHS lasts 38 months and has a budget of 3,77M Euro. Requested EC contribution is 2,85 M Euro.
PATENT – DfMM - Design for micro and nano manufacture

Project URL: http://www.patent-dfmm.org/

Coordinator
LANCASTER UNIVERSITY
UNITED KINGDOM

Project details
Project Reference: 507255
Contract Type: Networks of Excellence
Start Date: 2004-01-01
End Date: 2008-06-30
Duration: 54 months
Project Status: Execution
Project Cost: .00 euro
Project Funding: 6.2 million euro

ABSTRACT

The PATENT Network of Excellence aims to establish a new technical community that will address the underlying engineering science to ensure that problems affecting the manufacture and reliability of products based on micro and nanotechnologies can be addressed before prototype and pre-production. The "theme" of the work will be defined as Design-for-Micro and Nano Manufacture and will involve teams from the fields of packaging, test engineering, reliability engineering, simulation and modelling.

PATENT will provide added value by integrating what are currently isolated and dispersed groups with valuable skills, create mass in the field of Design-for-Micro and Nano Manufacture in Europe and provide researchers with access to state-of-the-art equipment and technology.

Finally, PATENT and its associated technical community will support both industrial teams and new Projects where Micro and Nano technologies needs to be:
- deployed in harsh or demanding environments,
- where reliability or dependability must be fully validated or where
- "right first time" manufacture is critical to meet cost and time-to-market constraints.