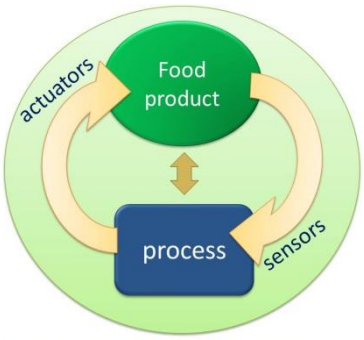
# Validation project Millimeter wave Sensors

*Monitoring of freezing and drying processes as well as the moisture content in food products*

## General project information

In a new approved IWT VIS project, called 'Sensors For Food', **Flanders' FOOD** and research partners from **IMEC, KULeuven, VUB** and **IBBT/Ghent University** join forces for four years to evaluate, optimize and validate innovative sensors for applications in the food industry. All this is 80% funded by the Flemish IWT. **Millimeter wave sensors** are among the diverse sensor system modalities tackled. They have great potential for cost-effective monitoring of **food quality, safety and processing** with improved accuracy and speed. In the following paragraphs more information is given on the broader Sensors For Food project and two specific validation projects on millimeter wave sensors. One is directed towards applications in monitoring freezing processes of food, while the other one focuses on water content determinations in food processing. As a participant in one of the validation projects you can also benefit from the services offered by the Sensors For Food Platform.

## Sensors For Food platform



Design, optimisation and control

As a result of the recently finished Intelligence For Food project, the Sensors For Food platform brings food manufacturers and technology providers together in a forum for food industry sensor systems. The aim is to improve, increase the awareness and explore the application of existing, new and upcoming sensor systems for the food industry. Activities include: a screening of needs and opportunities for the food industry, a technology watch on emerging sensor innovations, generation and support of innovative ideas, networking and partner matching between food companies and technology suppliers. Via a centralized contact point, advice is provided concerning sensor systems that are already available for the food industry. For example, assistance is offered for issues regarding sensor calibration and selection. Furthermore, a number of thematic seminars, workshops and training courses will be organized.

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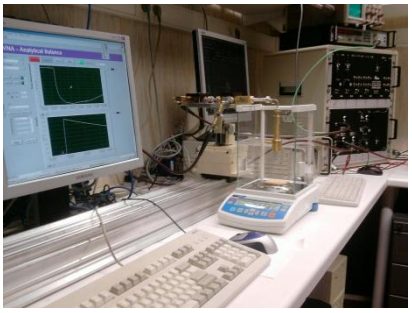
## Sensors For Food Validation projects Millimeter Wave Sensors

Freezing and freezing processes are energy consuming processes. Existing techniques do not allow for accurate and continuous monitoring of the **freezing state of food products**. By consequence, food products are nowadays often frozen harder than necessary to guarantee food safety. However, a compact sensor configuration with millimeter waves that can be installed over a production line, could allow continuous measurements of the progress of the freezing process within products and thereby enabling the direct **optimization of the freezing process**. For example, the speed of the belt in a freezing tunnel could be automatically adjusted and steered to save on **freezing time** and **energy**.



In addition to information on the freezing process, a warning can be given if the product composition changes, for example due to a mistake in dosage of one or more ingredients. This is because upon passing through a product, millimeter waves will interact with the product and generate a characteristic signal. Product deviations will result in a signal that differs from the 'standard signal'. In this way, the sensor will give a quick warning that something has changed. However, it must be remarked that it will not be able to identify what caused these changes.

Millimeter waves show a strong interaction with **water**. The free water molecules are polarized by the incident waves and consequently absorb them. The degree of absorption depends on the amount of (residual) water in the sample, e.g. in **drying processes**. In the case of **freezing**, water is transformed to ice whereby it loses its polar characteristics and hence millimeter waves are no longer absorbed. As such, the phase transition from water to ice can accurately be detected. Therefore, millimeter wave sensors can be applied in both process types. Furthermore, these sensors work **contactless** and are able to measure **into the core** of the product.

To interpret and quantify the data, dielectric mixing models will be tuned to describe the interaction between millimeter waves and the studied food products, taking into account the impact of temperature, humidity and phase status of the water. In addition, the impact of geometric factors will be added through development of more advanced models.

The Flemish food industry can take the lead in the application of this new technology. The aim of this validation project is to increase awareness of this technology in Flemish companies and lay the foundations for affordable, integrated **sensor solutions**. Within this project, the researchers will use their wide expertise in this field and bring in their infrastructure and previous developed prototypes to enable the participating companies to discover the possibilities of this technology for their company.

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## What do we offer?

The goal of the validation projects is to apply millimeter waves sensors for **online** monitoring of food products: more specifically to follow up the water content in products and to evaluate **freezing,**

**drying and other relevant processes**. These validation projects combine technical evaluations (sensitivity, detection limit, robustness, accuracy, measuring speed, …), bench marking with other measuring techniques together with cost–benefit analyses and extended knowledge transfer about the food processes monitored with millimeter waves sensors.

What are the **opportunities for you**:

The project aims to analyze and solve the specific issues that the participating companies are facing. Several tests will be designed according to the following steps:

1. Clustering of food products into categories that can be evaluated with an appropriate type of millimeter wave sensor. This includes a series of fast, preliminary laboratory experiments to reveal a number of specific characteristics of the interactions with the food products. Based on the response of these food products technical specifications for the sensor will be determined. For some products a detailed electromagnetic/dielectric model will be developed that will allow to gain information on the water molecules in the food product (e.g. water content, freezing state, …) and this in close collaboration with the companies that have expertise about the product.

2. Design, construction and assemblage of **4 prototypes** that will be applied for different clusters of food products and under different measuring conditions.

3. Testing of the different prototypes for real time monitoring of **production lines** (on-line or at-line). This will result in a significant amount of statistical data related to the production line and/or the food products on that line. This step also encompasses a comparative study with currently used measuring techniques or practices. The result of this work package will deliver insight in the achievable performance, the necessary calibration procedures and the minimal requirements of the hardware components. To make a correct assessment of these factors, specific aspects of an industrial environment will be taken into account.

4. The necessary specifications and appropriate information regarding the prototype of interest is transferred to the participating companies and, if desirable, also to their system integrator of choice (a third party) for practical conversion of the prototype to a final product for the company.

# Suggested work plan for the validation project millimeter wave sensors for freezing processes

| WP4a | Validation project : millimeter wave sensors for freezing processes | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Taak | Partner | Jaar 1 | | | | Jaar 2 | | | | Jaar 3 | | | | Jaar 4 | | | |
| 4a.1 | Modeling temperature distribution & dielectric response | ETRO | Pr | | | Sl | | | | | | | | | | | | |
| | | INTEC | | | | | | | | IA | | | | | | | | |
| 4a.2 | Experimental studies | ETRO | | | | Ra | | | | | | Ra | | | | | | |
| 4a.3 | Development Prototype-2a | ETRO | | | | | | | | P2 | | | | | | | | |
| 4a.4 | Development Prototype-2b | ETRO | | | | | | | | | | P2 | | | | | | |
| 4a.5 | Technological integration aspects | ETRO | | | | | | | | | Ra | | | | | | | |
| | | Imec | | | | | | | | | | | | | GO | | | |
| 4a.6 | Signal processing of prototype results | ETRO | | | | | | | | | | | Ra | Su | | Ra | | |
| 4a.7 | Service | ETRO | | | | | Th | | | | PcP2a | | PcP2b | | | In | Wo | Ei |
| 4a.8 | Specific user group meetings | ETRO | Sg | | Sg | | Sg | | Sg | | Sg | | Sg | | Sg | | Sg | sE |

Legend:

4.a.1 Pr = Presentation literature study and visit ETRO (Deliverable); Sl: selection food model products 2a & 2b (Strategic Milestone); Continuous Deliverable: theoretical calculations; IA = Inversion Algorithm ready for non-flat food products (Technical Milestone).

4.a.2 Ra = Report mm-wave measurements (based on Quasi-Optical ideal measurements) compared to classic sample testing (report 1 for flat food products and report 2 for non-flat food products (Deliverable).

4.a.3 P2a = demo prototype (based off-the-shelf components) for thin, flat food products (Technical Milestone).

4.a.4 P2b = demo prototype (based on off-the-shelf components) for thick, non-flat food products (Technical Milestone).

4.a.5 Ra = intermediate technical Report on compact, low-cost mm wave sensors (Deliverable); Go = Go/no Go decision moment integration compact, low-cost mm wave sensor prototypes (Strategic Milestone).

4.a.6 Ra = Reports on multi-dimensional signal processing (correlations, multivariate, PCA – regarding non-idealities and noise in real production lines) (report 1 for flat food products and report 2 for non-flat food products ) (Deliverable); Su = Substantial increase signal/noise ratio through analysis of measurement data from freeze processes ((Technical Milestone)

4.a.7 Th = Thermal simulations on case-studies (Deliverable); PcP2 = Proof of concept demo prototypes (Technical Milestone ); In = Integration demo (off- and on-line) of prototypes in industrial environment (Deliverable); Wo = Workshop mm wave sensors for freeze applications (Deliverable); Ei = Final report + Valorization document (Deliverable); Continuous Deliverable: knowledge transfer

4.a.8 Sg = Specific biannual user group meeting (Deliverable); sEv= final specific user group meeting (Deliverable)

# Suggested work plan for the validation project millimeter wave sensors for drying processes and moisture content determination

| WP4b | Validation project: millimeter wave sensors for moisture measurements | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Taak | Partner | Jaar 1 | | | | Jaar 2 | | | | Jaar 3 | | | | Jaar 4 | | | |
| 4b.1 | Modeling | ETRO | PrSI | | | | | | | | | | | | | | | |
| | | INTEC | | | | | | | | IA | | | | | | | | |
| 4b.2 | Experimental studies | ETRO | | | | | Ra | | | | Ra | | | | | | | |
| 4b.3 | Development Prototype -1a | ETRO | | | | P1a | | | | | | | | | | | | |
| 4b.4 | Development Prototype-1b | ETRO | | | | | | P1b | | | | | | | | | | |
| 4b.5 | Technological integration aspects | ETRO | | | | | | | | | Ra | | | | | | | |
| | | Imec | | | | | | | | | | | | | Go | | | |
| 4b.6 | Signal processing prototype results | ETRO | | | | | | | | | Ra | Su | | | | Ra | | |
| 4b.7 | Service | ETRO | | | | | PcP1a | | | PcP1b | | | | | | In | Wo | Ei |
| 4b.8 | Specific user group meetings | ETRO | Sg | | | Sg | Sg | | | Sg | Sg | | | Sg | Sg | | Sg | sEv |

Legend:

4.b.1 Pr = Presentation literature study and visit ETRO (Deliverable); Sl: selection food model products 1a & 1b (Strategic Milestone) 2a & 2b (Strategic Milestone); Continuous Deliverable: theoretical calculations; IA = Inversion algorithm for non-flat food products ready (Technical Milestone).

4.b.2 Ra = Report mm-wave measurements (based on Quasi-Optical ideal measurements) compared to classic random testing (report 1 for thicker flat food products with moisture content > 4% and report 2 for thin food products with moisture content < 4%) (Deliverable).

4.b.3 P1a = demo prototype (based on off-the-shelf components) for thicker, flat food products with moisture content > 4% (Technical Milestone).

4.b.4 P1b = demo prototype (based on off-the-shelf components) for thin food products with water content < 4% (Technical Milestone).

4.b.5 Ra = intermediate technical Report on compact, low-cost mm wave sensors (Deliverable); Go = Go/no Go decision moment integration compact, low-cost mm wave sensor prototypes (Strategic Milestone).

4.b.6 Ra = Reports multi-dimensional signal processing (correlations, multivariate, PCA - regarding. non-idealities and noise in a real production line); (report 1 for thicker flat food products with a water content > 4% en report 2 for thin food products with water content < 4%); Su = Substantial increase signal/noise ratio through analyses of measurement data from appropriate food processes (Technical Milestone).

4.b.7 PcP1 = Proof of concept demo prototypes in industrial environments (Strategic Milestone); In = Integration demo (off- and on-line) of prototypes in industrial environments (Deliverable); Wo = Workshop mm wave sensors for application in food processes like drying (Deliverable); Ei = Final report + Valorization document (Deliverable); Continuous Deliverable: knowledge transfer

4.b.8 Sg = Specific biannual user group meeting (Deliverable); sEv= final specific user group meeting (Deliverable)

## Financial contribution of the participating companies

The estimated project contribution per year is dependent on the size of the company, as determined by the total number of employees of the company in the concerned year and is represented in the following table:

FREEZING PROCESSES

| **Number of employees*** | Minimum project contribution (yearly, excl. VAT) | **Estimated project contribution** (yearly, excl. VAT)** | Maximum project contribution (yearly, excl. VAT) |
|---|---|---|---|
| **< 50** | 750 € | **1.000 €** | 1.500 € |
| **51-100** | 1.125 € | **1.500 €** | 2.250 € |
| **101-150** | 1.500 € | **2.000 €** | 3.000 € |
| **151-200** | 1.875 € | **2.500 €** | 3. 750 € |
| **201-250** | 2.250 € | **3.000 €** | 4.500 € |
| **> 250** | 3.000 € | **4.000 €** | 6.000 € |

MOISTURE CONTENT BASED APPLICATIONS

| **Number of employees*** | Minimum project contribution (yearly, excl. VAT) | **Estimated project contribution** (yearly, excl. VAT)** | Maximum project contribution (yearly, excl. VAT) |
|---|---|---|---|
| **< 50** | 750 € | **1.400 €** | 2.100 € |
| **51-100** | 1.125 € | **2.100 €** | 3.150 € |
| **101-150** | 1.500 € | **2.800 €** | 4.200 € |
| **151-200** | 1.875 € | **3.500 €** | 5.250 € |
| **201-250** | 2.250 € | **4.200 €** | 6.300 € |
| **> 250** | 3.000 € | **5.600 €** | 8.400 € |

*Number of employees of the largest legal entity that will have access to the results of the project.

** Based on the number of companies that had expressed their interest in the validation project upon at the submission of the Sensors for Food project application at IWT.

The real yearly project contribution can be higher or lower than the estimated contribution.
The real yearly project contribution depends on the number and size of the participating companies. The real yearly project contribution has been limited to minimum and maximum project contributions mentioned in the tables above.

Participating companies engage themselves to stay a member of the project and Flanders' FOOD for the duration of the project. (see www.flandersfood.com/lid-worden-van-flanders-food)

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