COMBITECH

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# TECH TUESDAY MJÄRDEVI

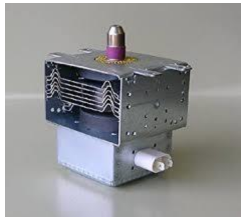
*- 22 SEPT 2020*

# TEAM PRESENTATION

**COMBITECH** has a team of former Whirlpool MWO product development engineers from the Norrköping plant which closed down in 2014. They have long experience, 30+ years, of developing microwave ovens with market leading performance.

**The team is involved in several initiatives in research, development and training in Microwave Heating systems for Domestic and Industrial applications**

related to MWO equipped with **Magnetrons** or **Solid State Technology**



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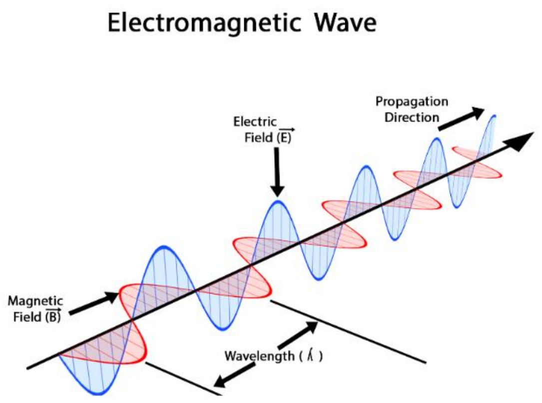
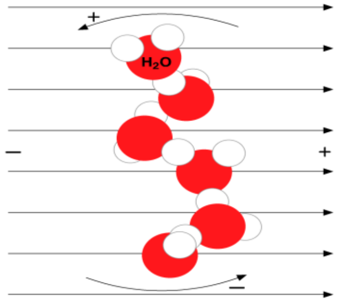
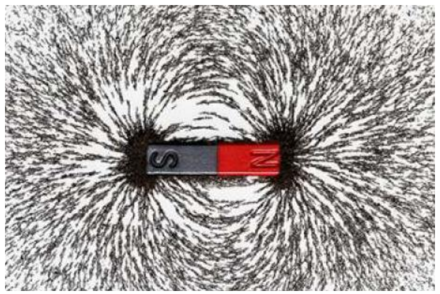
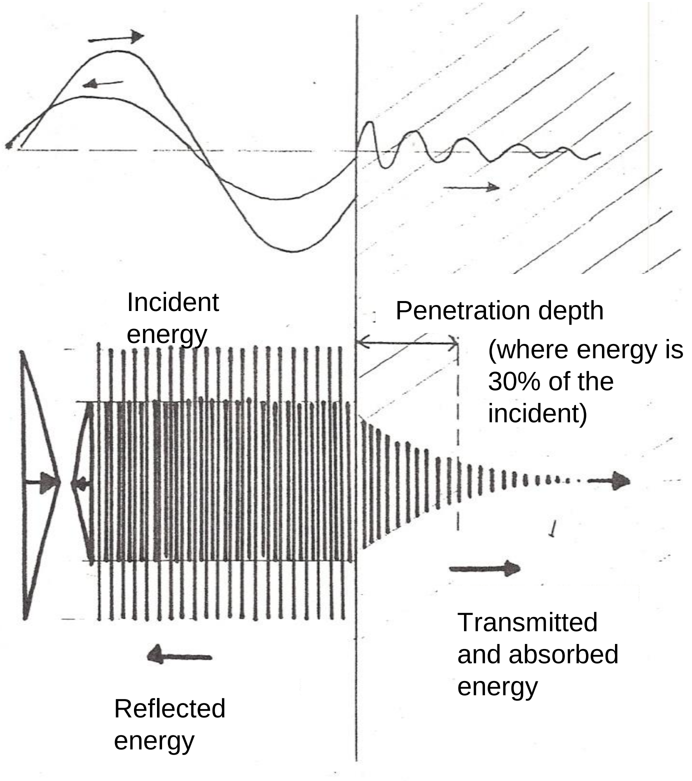
# BASICS – WHAT IS MICROWAVE HEATING?

- Microwaves are **electromagnetic waves**
- They consist of an alternating **electrical and magnetic field** which are perpendicular to each other.
- The electrical field make the **water molecules** (when present) to move which generate heat.
- The magnetic field makes a frequent realignment in a magnetic material which causes **molecule mobility** and thus heat.
- They travel with the **speed of light**
- The **wavelength** in vacuum (and air) is in the centimeter range at the frequency of 2,45 GHz
- Their behavior is fully described by **Maxwell's equations**
- When reaching an object, they are either reflected, absorbed or transmitted – or a combination of these
  - ✓ **Dielectric Constant** ($\varepsilon'$) - how "dense" a material is to the microwaves
  - ✓ **Loss Factor** ($\varepsilon''$) – how much the material absorbs and gets heated by the microwaves.




**Radiation of MW energy on a flat surface of absorbing material**

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# BASICS – ADVANTAGES & CHALLENGES

**ADVANTAGES**

- Selectiv heating
- Volumetric Heating
- Energy Saving
- Instantaneous Control
- Reduced Process Times
- High Temperatures
- Clean Energy Transfer
- Chemical Reactions Driven
- Reduced Equipment Size

**CHALLENGES**

- Field complexity
- Temperature uniformity
- Temperature Measurements
- R & D activities needed

Source: Professor Howard K. Worner

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# SOLID STATE TECHNOLOGY
## - A NEW WAY OF COOKING….

- https://www.youtube.com/watch?v=5XQ_9LPtPZY

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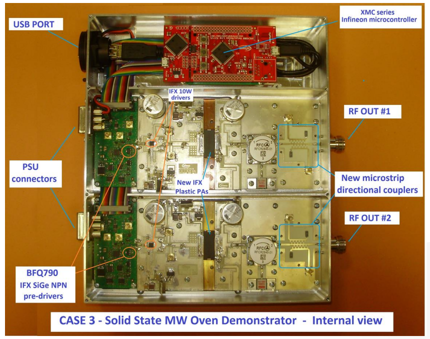
# Reference Case – Development
# Solid State Microwave Oven Demonstrator

- A joint project between Combitech, Infineon and Greenwaves.

- Purpose:
  - To show the benefits of using Solid State technology versus magnetrons for microwave heating and drying applications.
  - In particular to demonstrate selective and even heating without any moving parts by controlling frequency and phase.

- Demonstrator based on household microwave oven, but concept is also applicable on industrial heating and drying processes

- The demonstrator was presented at EUMW 2016



[Electronics Weekly 20161012]

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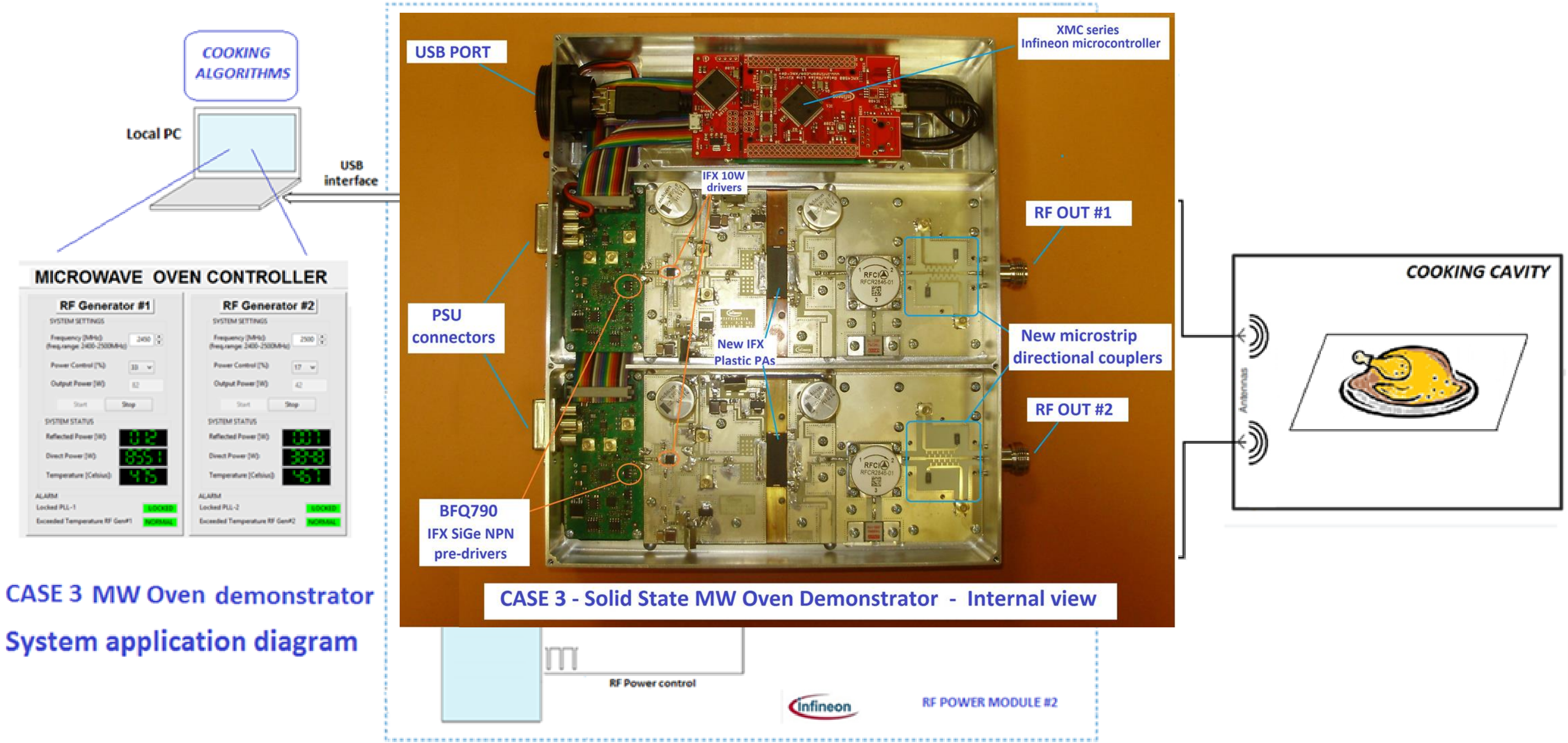
# SOLID STATE GENERATORS

## ❑ Generator and multi-feeding

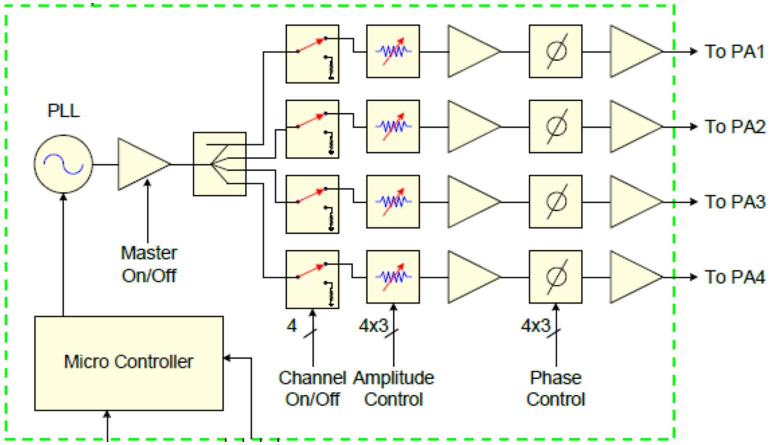
- Within the international ISM band 2400MHz to 2500MHz, each generator has a limitation in output power. Combining several will provide sufficient power for pure MW heating or MW as assistant heating source.



# ADVANTAGE OF SOLID STATE TECHNOLOGY

- **Advantages in control capability**

- The frequency can be chosen within the ISM band. Each channel can be individually controlled for amplitude and phase difference.

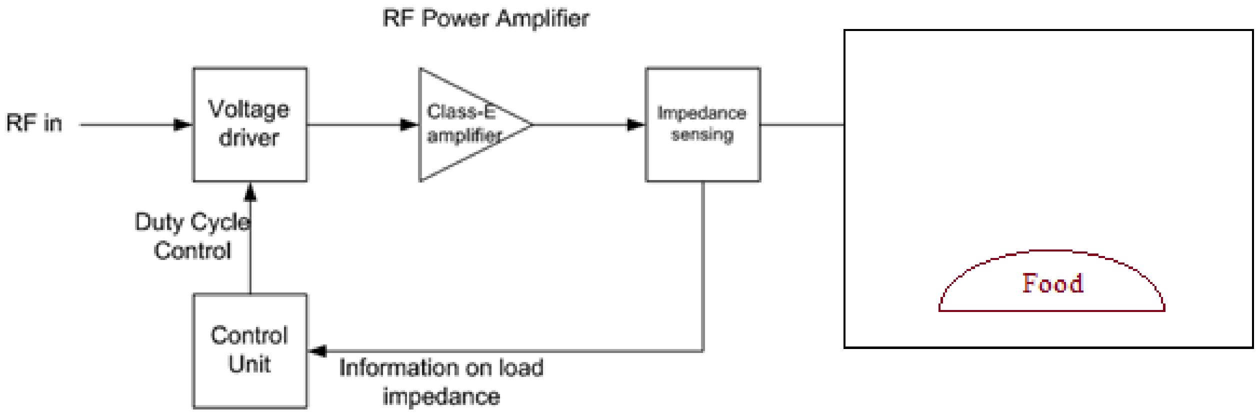

- A triplet of parameters, F/P/A, such unique setting can be optimized towards performance criteria like efficiency and/or heating

- The total heating algorithms are built up with a number of settings of the F/P/A with controlled duration time. This gives 4 parameters for the control, which is not possible for magnetron applications.

- Note: All generators are preferably operating on identical frequency to minimize risk for interference with mixing frequencies.

# ADVANTAGE OF SOLID STATE TECHNOLOGY

- **Load sensing**
  - The efficiency can be controlled by closed loop regulation by measuring the reflection to each generator, including cross-talk. The reflections, do not include any information about evenness and food type, leading to that other parameters need to be used, e.g. IR, humidity/gas, optical or user inputs.

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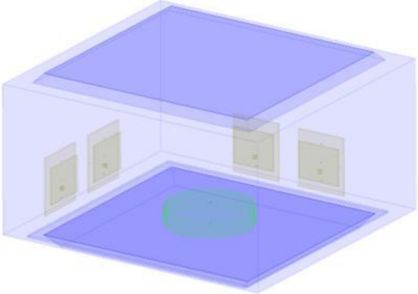
# ADVANTAGE OF SOLID STATE TECHNOLOGY - TEAM EXPERIENCES

## Cavity selection and feeding

- Several cavity types have been studied,
  - Resonator boxes (small and big)
  - Circular resonators
  - Applicators

Based on this analysis, it was concluded that any cavity geometry could be selected, no preference from technical perspective. The triplets, F/P/A, plus time can provide sufficient control parameters.

- Several feeding has been studied,
  - Waveguide apertures
  - Patch antennas
  - Slot antennas
  - Helix antennas
  - Monopole antenna
  - E-probes
  - Dipole antennas
  - Loop antennas



Most experience with waveguide apertures since these have a relatively good efficiency.

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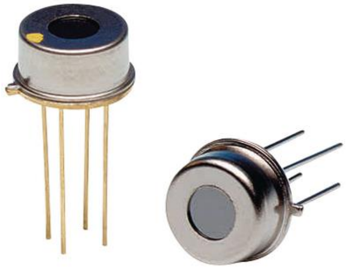
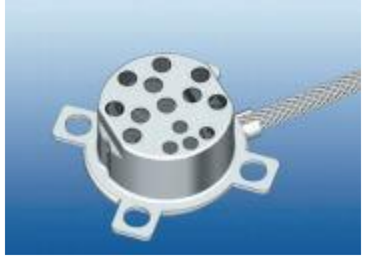
# ADVANTAGE OF SOLID STATE TECHNOLOGY - TEAM EXPERIENCES

## Load Sensing

- Load monitoring technologies that have the potential to give useful information and in different ways to achieve **optimized efficiency** are:
  - Dynamic impedance measurement in the feeding line between each generator and cavity
  - IR sensors / Arrays, measuring inside cavity
- Load monitoring technologies that have the potential to give useful information and in different ways helps to achieve improved **heating evenness** are:
  - IR sensors / Arrays, measuring inside cavity
  - Image recognition, measuring inside cavity



- Other sensor options
  - Humidity, sensing evaporation
  - RFID, identification of food items prior to heating
  - Weight sensors
  - E-field sensors



- Consumer input of important load parameters
- Several of such parameters shall be used to determine "FOOD READY", i.e. **Cooking time**

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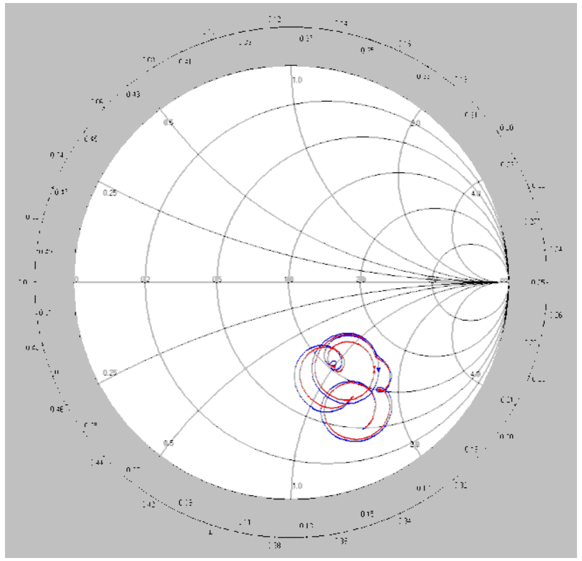
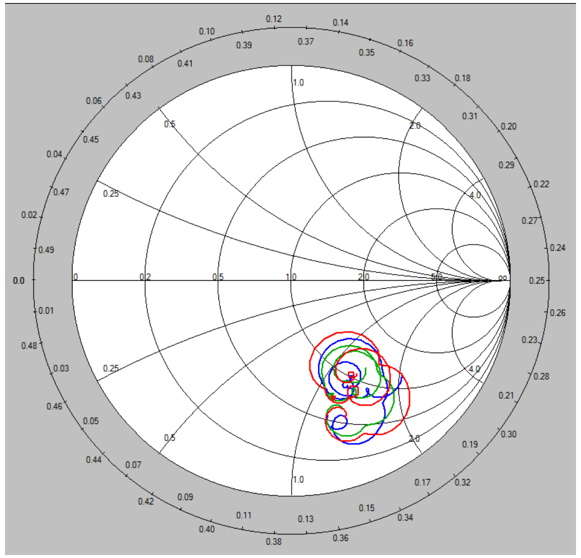
# ADVANTAGE OF SOLID STATE TECHNOLOGY - TEAM EXPERIENCES

***Load Sensing***

- *One food-load gives one unique impedance,* while, *One impedance can represent several food-loads.*



1000g water at 2 different temperature



500g minced meat at 3 different temperature

Antennas and cavities have a big impact on the total impedance, seen by the generators, in relation to the impedance of the food-load. This finding is limiting the use of reflection to be the single parameter in a closed loop regulation.

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# ADVANTAGE OF SOLID STATE TECHNOLOGY - TEAM EXPERIENCES

**Load Sensing**
A simplified equivalent scheme can help describe 2 different approaches.

- Measurements close to the generator, point A, are appropriate to “guard” the generator, while the detection of food properties is difficult due to the “distance” in the scheme.

- Measurements close to food, point B, are in the same way beneficial for the food but less useful for the generator. Measurements cannot differentiate properties of the cavity from properties of the Food-Load.

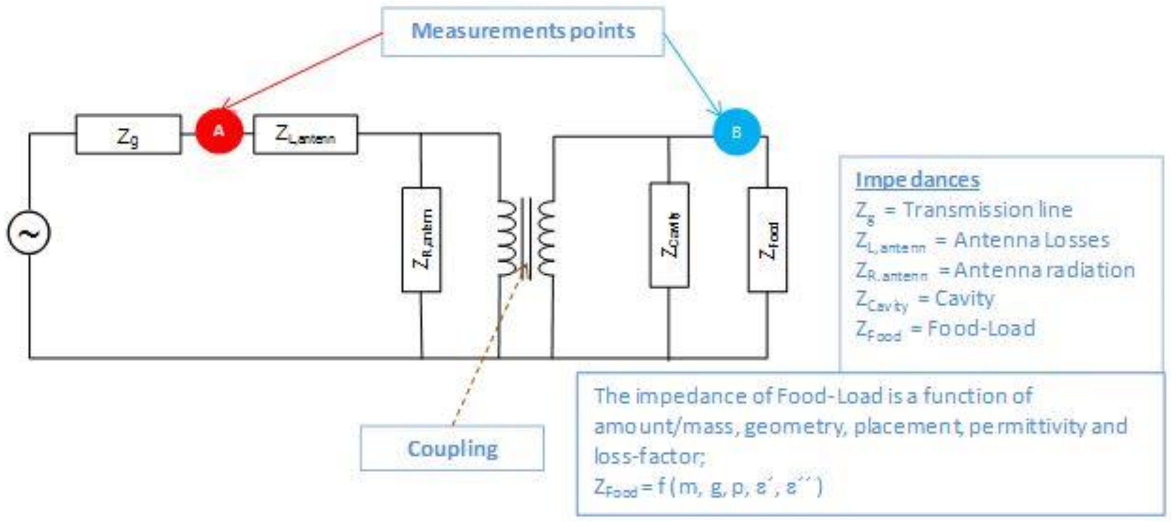


Fig1 A simplified equivalent scheme for one generator

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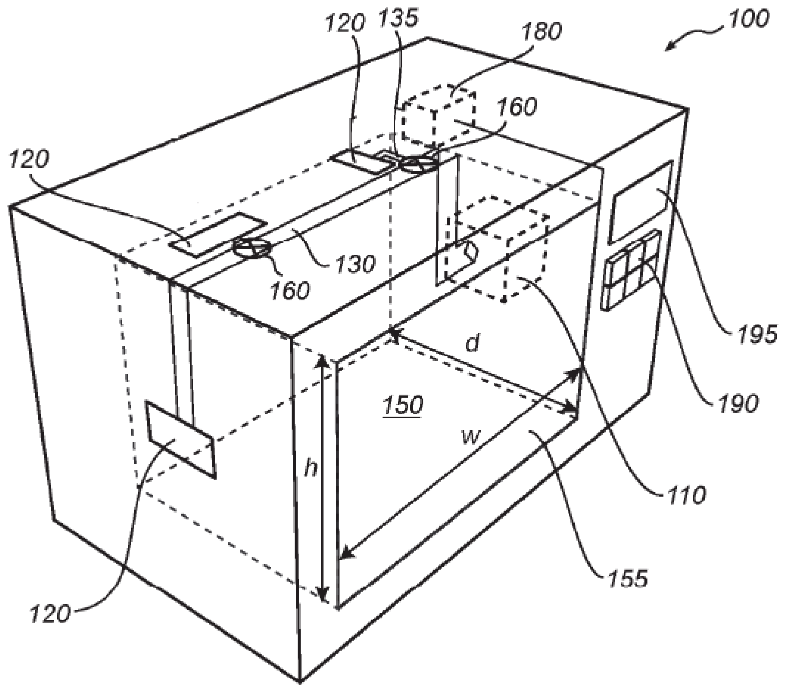
# ADVANTAGE OF SOLID STATE TECHNOLOGY - TEAM EXPERIENCES

## Load Sensing

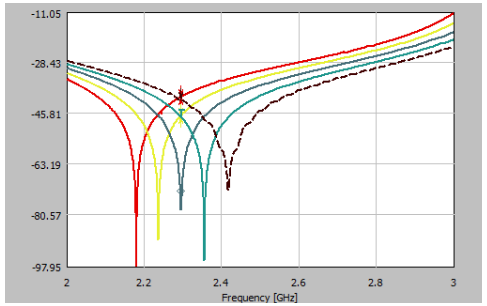
***RF load recognition***

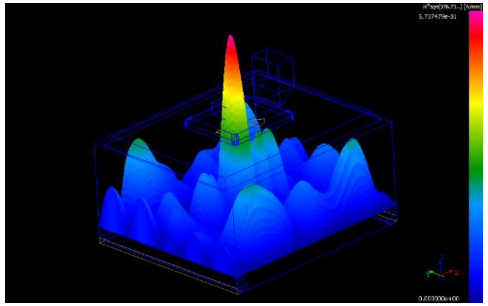
- Using a low power (mW level), we do not need to stay within the ISM band (2.4 – 2.5 GHz) as measurement frequency
- A sweep across a frequency band will give a kind of “fingerprint” of the load
- With higher frequencies, the antenna structure can be smaller. They can be placed within the same feeding waveguide as the heating power.
- Penetration depth into food (millimeters) will limit what can be concluded about food load



# EXAMPLES OF COMPETENCE - SIMULATION

- **Simulations within the RF and Microwave domain**
  - ✓ *Antenna performance*
  - ✓ *Matching optimizing*
  - ✓ *Filter and choke design*
  - ✓ *Heating patterns*
  - ✓ *Heating Efficiency*

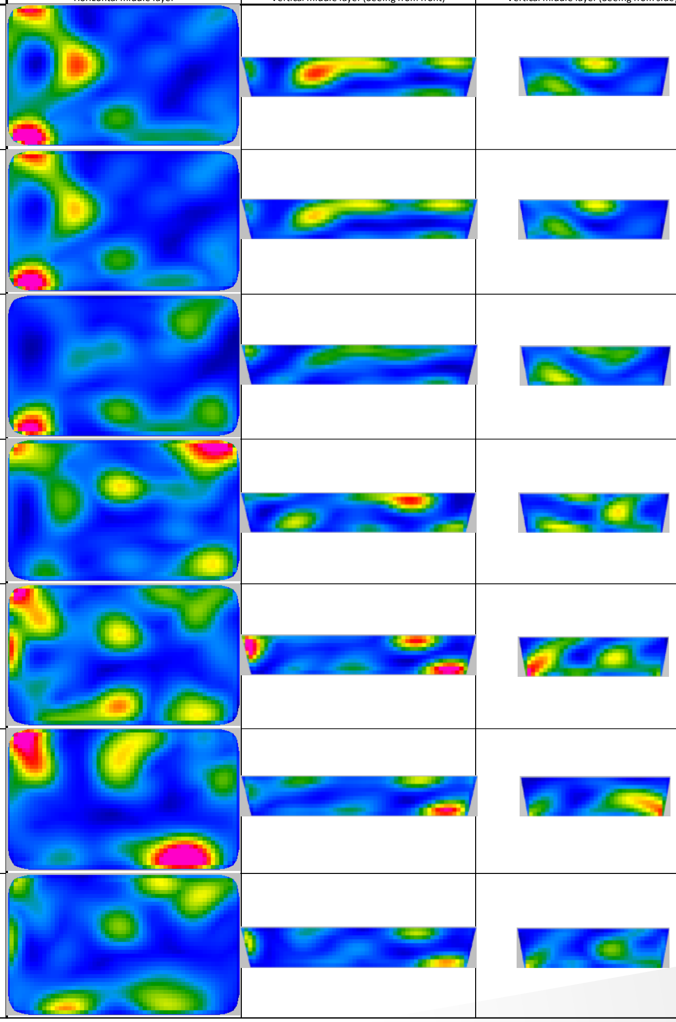



- **High efficiency ≠ Heating Uniformity**

*The selected cavity and feeding concept to reach the best efficiency has been evaluated via simulations with respect to heating uniformity. It is concluded that the uniformity is not sufficient, especially due to lack of center heating for a single load in a house hold MWO. See dissipated power for each frequency on the simulation pictures*

| Freq. | Phase setting | Dissipated Power in Load (Locked scale) | | |
|---|---|---|---|---|
| | | Horizontal middle layer | Vertical middle layer (Seeing from front) | Vertical middle layer (Seeing from side) |
| 2431 | Setting1 | | | |
| 2435 | Setting2 | | | |
| 2440 | Setting3 | | | |
| 2445 | Setting4 | | | |
| 2450 | Setting5 | | | |
| 2455 | Setting6 | | | |
| 2460 | Setting7 | | | |



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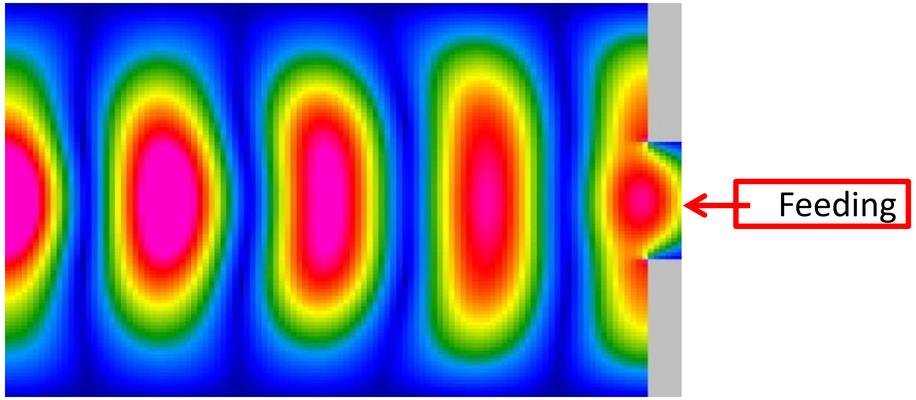
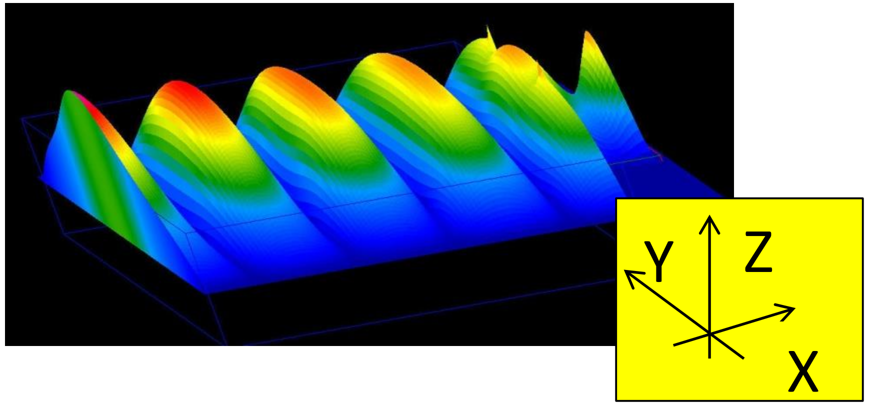
# EXAMPLES OF COMPETENCE – DESIGN OF APPLICATOR

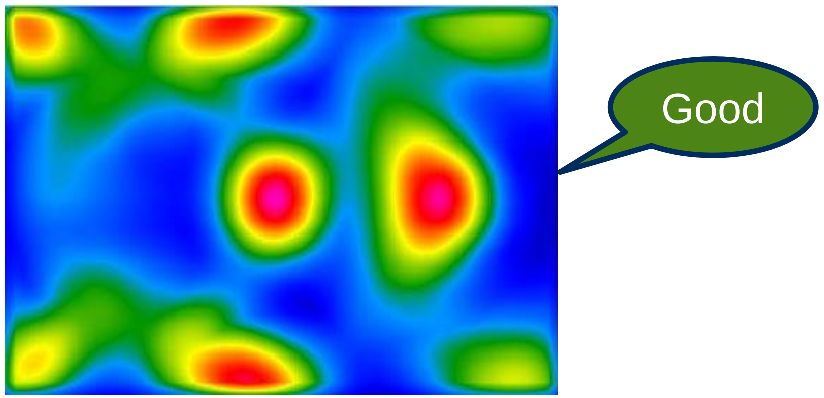
- In a electrical closed volyme, a cavity, there will be resonance.

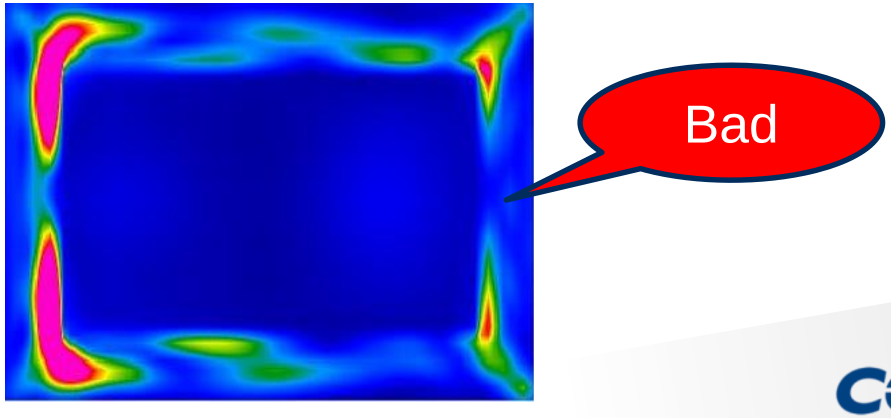



Perspective view




- In a good design you get the energy far in to the material you want to heat

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# SOLID STATE TECHNOLOGY - DEMONSTRATION

# OUR SERVICES – INDUSTRIAL PROCESS DEVELOPMENT

- **Project Idea**
  *We often start our process by a Think Tank activity which generates different project ideas. A potential customer is approach. It could also be a customer who approach us with an project idea.*

- **Technical Feasibility Study**
  *The first step is to determine if the use of microwave heating is feasible. The advantages are typically raised from the ability of electromagnetic energy to interact selectively and /or volumetrically with materials. Research and literature study, material characterization, heating trials are done to show that the broad process objectives are achievable as well as an economic evaluation.*

- **Small Scale Design and Testing**
  *The second step often involves building a small scale demonstrator. A robust characterization of the fundamental microscale interactions between microwave energy and the material are done. The result are used to re-evaluate the techno-economic feasibilities of the application.*

- **Pilot Scale Process Development**
  *System concepts are optimized not only to the properties of the material  but also to commercial design basic requirements such as material handling, scale and throughput, microwave power and energy requirements, health and safety etc. All to allow robust techno-economic feasibility re-evaluation.*


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# RESEARCH PROJECTS – ZERO CARBON DIOXID TECHNOLOGY FOR ASPHALT

## **SMMART** – **S**wedish **M**agnetite **M**icrowave **A**sphalt **R**oad **T**echnology

**A VINNOVA funding by Challenge driven innovation in 3 steps.**

**If the pavement contains ferromagnetic material like magnetite, the asphalt can be heated by microwave technology without emissions. The technique will be tested on cast asphalt with different amounts and particle sizes of magnetite. The heating is faster as the entire volume is heated and not just surface.**

**The work is conducted in defined work packages.**

**A Demonstrator will be designed and built based upon a…**

Research Partners Step 1

LKAB ecoloop Binab TÄTSKIKT

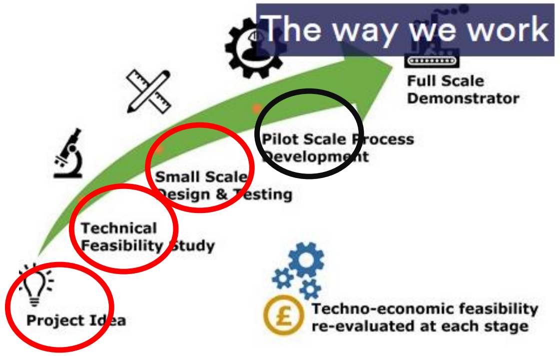
TRAFIKVERKET NCC LULEÅ TEKNISKA UNIVERSITET

Additional Partners Step 2

SKANSKA vti NYNAS

### Funding Granted step 1


### Application step 2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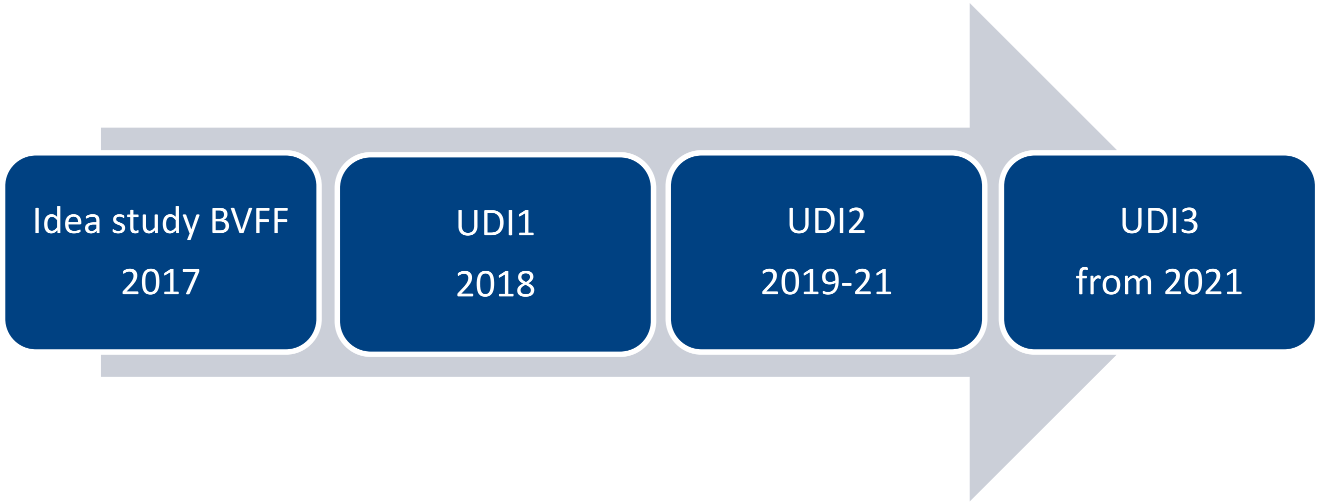
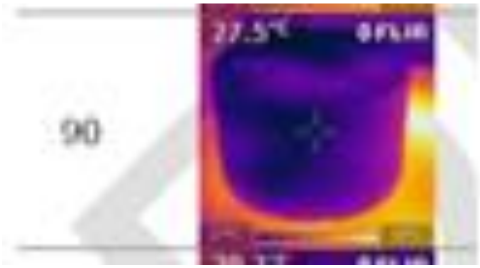
# SWEDISH MAGNETITE MICROWAVE ASPHALT ROAD TECHNOLOGY

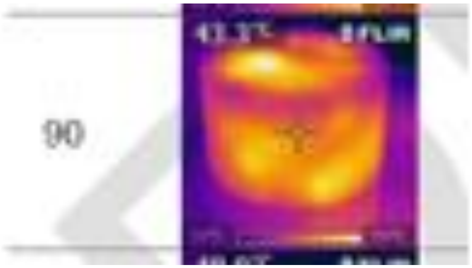
**UDI 1 – 2018**
The idea is based upon that magnetite is ferri-magnetic and absorbes microwaves efficient
Tests were conducted in a lab oven which proves it

**UDI 2 – 2019-2021**
- Develop reciep and microwave demonstrator and methods
- Identify challanges and form strategies to improve working environment and gender equality
- Identify market- and environment potential, impact on policy instruments as well as future possibilities

**UDI 3 – 2021—**
To commercialize the technology…





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# SMMART – DEMONSTRATOR FROM UDI 1

**A Magnetron based demonstrator**

- Microwave Power: 4 kW
- Capacity: 90 liter
- Power: 3x32 A, 230 V

# SMMART – DEMONSTRATOR FROM UDI 2

- 12 kW Microwave Power
- 200 liter capacity
- Power: 3x32 A, 230 V

For reference, not actual demonstrator

# QUESTIONS?

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## INNOVATIVE PRODUCT DEVELOPMENT IN MICROWAVE HEATING

**COMBITECH** has a team of former Whirlpool Microwave product development engineers with long experience, 30+ years, of developing microwave ovens with market leading performance.

You probably have a microwave oven in your kitchen and you probably appreciate its fastness in heating portion sized food items. But did you ever reflect over what makes microwaves an efficient heat source and if it can be used for heating other stuff than food?

Most heat sources actually only act on the surface of the object for heating. The bulk of the object then gradually gets warm by heat conduction. Depending on the material, that can be a slow process.

Microwaves have the ability to penetrate into most materials (exception is electrically conductive material, such as metal). This means that the volume which gets heated is much bigger than just the surface. It does not heat from the inside out (that's a myth you may have heard), but depending on the material properties of the object, the heating can take place several centimetres into it. In many cases, that is a significant efficiency gain compared to surface acting heat technologies.

For an efficient microwave application, the system needs to be carefully designed - Taking into consideration aspects such as material properties, desired capacity, requirements of heating evenness and geometric aspects. **Competences you see listed to the right.**

**Our team at COMBITECH are involved in several initiatives in research, development, engineering and training of Microwave systems for Domestic and Industrial applications.**

**Applications based upon Microwave generators as the Magnetron or Solid State Technology (Transistor)**

**Our competences:**

- **Microwave technology**
- **Electronics hardware design**
- **High Power Amplifier design, usage and specification**
- **Power supply usage and specification**
- **Frequency and phase control**
- **Transmission lines, wave guides**
- **Cavity design and feeding with multiple sources**
- **Sensing and closed-loop control (e.g. Humidity, S-parameters, IR)**
- **Measurement technology**
- **Shielding, EMC – Electromagnetic compatibility and Microwave containment**
- **Thermal management / Air flow system**
- **Cooking with RF, IR radiation and convection**
- **Control algorithms**
- **Sensor technology & Control**
- **Product development (Process, concept development, design)**
- **Simulations**
- **Quality Systems – Six Sigma**
- **Product safety**
- **Education**
- **Problem solving**
- **Project management**
- **IP Rights – Patent applicants**
- **EMC – labb**
- **Microwave – labb**
- **Electronic – labb**

**Our services:**

- **For Customers develop a full function Microwave based application**
  To be owned by Customers to increase its product range and/or end customer base.
- **To be a development partner**
  Customer to use Combitech in improving its product.
- **The COMBITECH support can be organized as ad hoc support (by the hour), active project team participation or as complete ownership of technical system or sub-system.**

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# AREA OF MWO COMPETENCE & RESOURCES

- Microwave technology for heating
- Electronics hardware design
- High Power Amplifier design, usage and specification
- Power supply usage and specification
- Frequency and phase control
- Transmission line, wave guides
- Cavity design and feeding with multiple sources
- Sensing and closed-loop control (e.g Humidity, S-parameters, IR, etc)
- Measurement technology
- Shielding, EMC – Electromagnetic compatibility, Microwave containment
- Thermal management / Air flow system
- Cooking with RF, IR radiation and convection
- Control algorithms
- Product development (Process, concept development, design)
- Simulations
- Quality Systems – Six Sigma
- Product Safety
- Education
- Problem solving
- Project management
- IP Rights – patent applicants
- EMC-, Microwave- & Electronic lab


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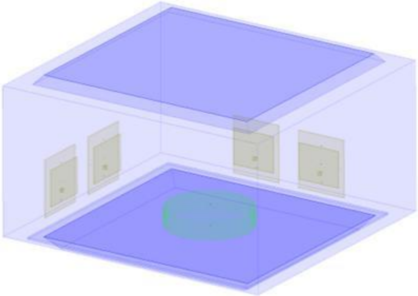
# EXAMPLES OF COMPETENCE – CAVITY DESIGN & FEEDING

- **Several cavity types have been studied,**
  - ✓ *Resonator boxes (small and big)*
  - ✓ *Circular resonators*
  - ✓ *Applicators*

*Based on this analysis, it was concluded that any cavity geometry could be selected, no preference from technical perspective. The triplets, F/P/A, plus time can provide sufficient control parameters.*

- **Several feeding has been studied,**
  - ✓ *Waveguide apertures*
  - ✓ *Patch antennas*
  - ✓ *Slot antennas*
  - ✓ *Helix antennas*
  - ✓ *Monopole antenna*
  - ✓ *E-probes*
  - ✓ *Dipole antennas*
  - ✓ *Loop antennas*



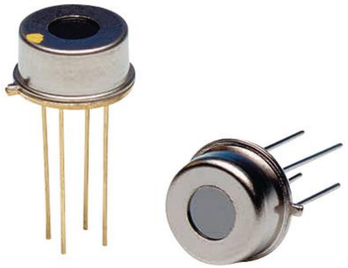
*Most experience with waveguide apertures since these have a relatively good efficiency.*

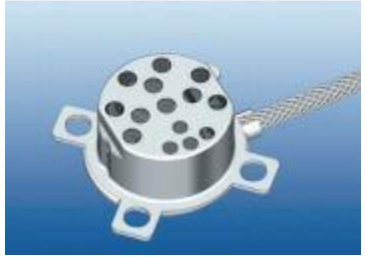
# EXAMPLES OF COMPETENCE – SENSING

- **Load monitoring technologies that have the potential to give useful information and in different ways to achieve <u>optimized efficiency</u> are:**
  - ✓ *Dynamic impedance measurement in the feeding line between each generator and cavity*
  - ✓ *IR sensors / Arrays, measuring inside cavity*

- **Load monitoring technologies that have the potential to give useful information and in different ways helps to achieve improved <u>heating evenness</u> are:**
  - ✓ *IR sensors / Arrays, measuring inside cavity*
  - ✓ *Image recognition, measuring inside cavity*

- **Other sensor options**
  - ✓ *Humidity, sensing evaporation*
  - ✓ *RFID, identification of food items prior to heating*
  - ✓ *Weight sensors*
  - ✓ *E-field sensors*
  - ✓ *THz*





- **Consumer input of important load parameters**

- **Several of such parameters shall be used to determine "Process Ready", i.e. Cooking time**

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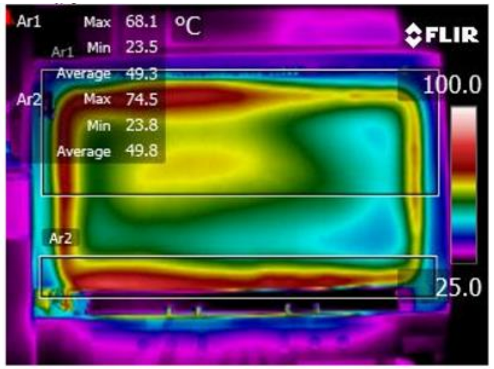
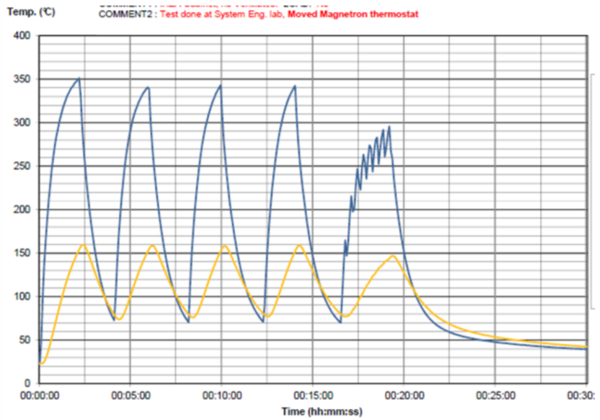
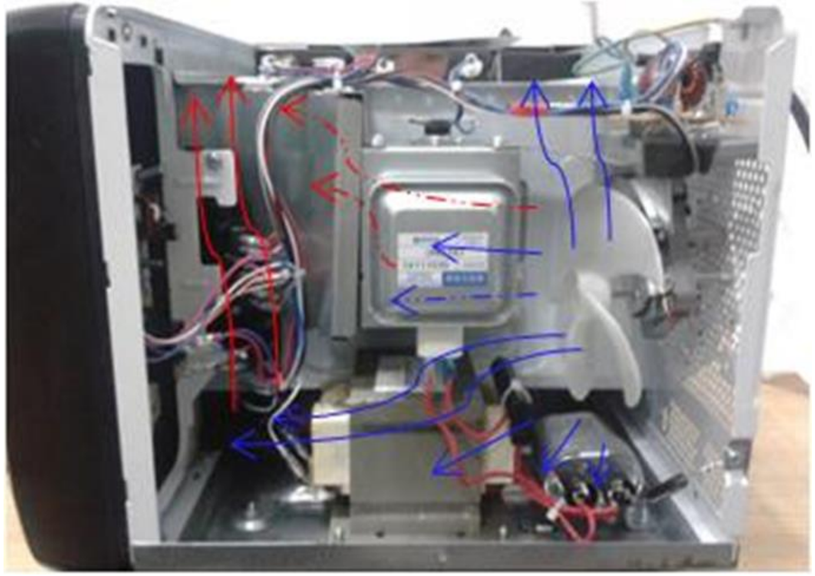
# EXAMPLES OF COMPETENCE – THERMAL MANAGEMENT

- **Cooling of critical components in microwave systems**
  - ✓ *Magnetron*
  - ✓ *HVT and inverter power supplies*
  - ✓ *Solid state HPA's*
- **New cooling system design**
- **Analysis and improvement actions on existing systems**



## Parameters

- **Temperature**
- **Air flow and velocity**
- **Pressure**

# EXAMPLES OF COMPETENCE - TRAINING

| Subject | Content |
|---|---|
| 1. **General theories** | Substances exposed to MW (electromagnetic) energy; Food properties; Electromagnetic field theories; Cooking with MW-energy |
| 2. **MW system design** | Mode analysis; SBD; Drawbacks; Prototyping; Examples of MW systems; Cooking tests |
| 3. **Antenna and stirrer design** | Antenna theories; Antennas in resonant cavities; Secondary antennas; Rotating beacon antenna; Mode stirrer; Strongly coupled stirrer |
| 4. **Magnetron, oscillator function** | Tube structure; Properties; Power supply; Critical parameters; Failure modes; Anode current/voltage curves |
| 5. **Magnetron, thermal** | General; Measuring temperature (Anode, Antenna, Magnets); Blower |
| 6. **MW impedance** | Measurements; The magnetron Rieke diagram, Oven impedance; Tuning elements |
| 7. **Thermal management** | Cooling/Ventilation system; Critical components; Humidity; Noise; Measurement and simulation |
| 8. **Door seal design** | Concept; Critical parameters; Simulations and prototyping |

| Subject | Content |
|---|---|
| 9. **MW Leakage** | Measurements; Trouble shooting; Human safety |
| 10. **EMC** | Standards; Trouble shooting; Magnetron filters |
| 11. **MW-Combi technologies** | General; Grill characteristics (Quartz, Metal tube, Halogen); Interaction with MW; Forced convection characteristics; Cooking tests |
| 12. **Cooking accessories** | Crisp, Popcorn and susceptor |
| 13. **Fuzzy logic closed loop regulation** | A code efficient and intuitive process control methodology used for automated cooking |
| 14. **Auto cooking** | General 6th sense; Cavity ventilation; Window of success; Cooking functions |
| 15. **Potential errors and defects** | Cooking performance/impedance versus mechanical flaws in the appliance |
| 16. **Recommended materials** | Material properties in MW environment; Dielectric materials; Metal |

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# EXAMPLES OF TRAININGS

| Customer | Area | Nr People |
|---|---|---|
| Whirlpool Cassinetta, Italy | Microwave Heating (all areas) | 55 |
| | Cooling and Ventilation | 20 |
| Whirlpool Cleveland, USA | Microwave Heating (all areas) | 24 |
| Whirlpool Joinville, Brazil | Microwave Heating (all areas) | 14 |
| Whirlpool Hefei, China | Microwave Heating (all areas) | 45 |
| | Cooling and Ventilation | 15 |
| V-Zug, Schweiz | Microwave Heating (all areas) | 40 |

# OUR SERVICES – SINGLE OR TEAM CONSULTANCY

- **Project Management**
  - ✓ *A Project Manager with experience and knowhow about process/product development*
- **RF/Microwave Engineer**
  - ✓ *An Engineer with experience and knowhow about designing a heating system optimized for heating evenness, MW seals and efficiency.*
- **Electromagnetic Simulation**
  - ✓ *An Engineer with experience and knowhow of microwave simulation as a design tool to minimize the number of physical prototypes and optimize heating evenness through resonance modelling.*
- **Mechanical Engineering**
  - ✓ *An Engineer with experience and knowhow of microwave system´s mechanical conditions for optimal heat distribution and minimization of microwave leakage.*
- **Electronic Engineer**
  - ✓ *An engineer with experience and knowhow in developing hardware for a microwave heating application*
- **Thermal Management**
  - ✓ *An Engineer with experience and knowhow in development, simulation and optimization of heat, cooling and ventilation flows in a microwave system.*
- **Sensing and Control**
  - ✓ *An Engineer with experience and knowhow in sensing and control technology for monitoring and feedback control systems.*
- **Software Developer**
  - ✓ *An Engineer with experience and knowhow in development of algorithms and control systems for microwave heating applications.*
- **Product Safety**
  - ✓ *A Product/Process Safety Engineer with experience and knowhow in risk analyzes to avoid, for example, electricity, fire and gas explosions in a microwave heating and other applications.*
- **Measurement Technician**
  - ✓ *An Engineer with experience and knowhow in measuring dielectric /magnetic properties of a material for optimized heating evenness and impedance measurement for optimized power in the microwave generator and in its life span.*
- **EMC Manager/Engineer/Technician**
  - ✓ *An Engineer with experience and knowhow about standards and regulations for electromagnetic compatibility and measurement techniques for minimizing radiated and radiated field disturbance.*
- **Quality Engineer**
  - ✓ *An Engineer with experience and knowhow in Six-Sigma methodology to assure high quality in product design and production methodologies of microwave related products/components as door choke and other critical MWO components*
- **Patent services**
  - ✓ *An Engineer with experience and knowhow in investigating patent opportunities, risk of patent infringement and opportunities to avoid it.*

- **CONSULTANCY Services** can be provided by the hour as active project team participation or as complete ownership of a technical sub-system or a complete system.

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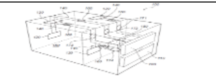
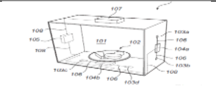
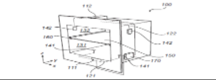
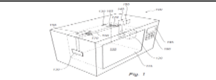
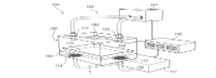
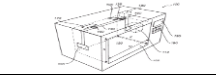
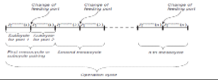
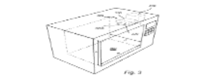
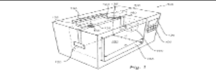
# EXAMPLES OF COMPETENCE – PATENT SERVICES

- **Several Solid State Technology related Intellectual Propoerty Documents have been generated with the team involved, total nr of 39 patents.**

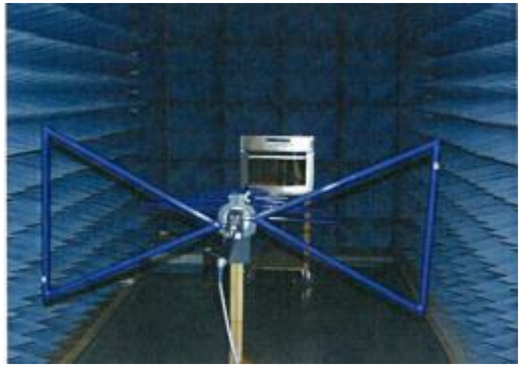
- **Knowledge and experience in investigating in a patent possibility.**

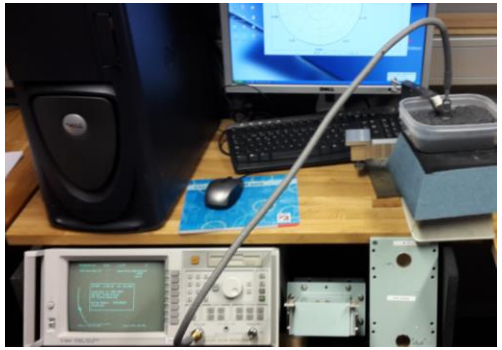
- **Risk of patent infringement and ways to avoid it.**

| Number | Priority | Titel | Short abstract | |
|---|---|---|---|---|
| EP12.172.392.2 | June18, 2014 | Multi feeding points from single source | The microwave heating apparatus (100) comprises a cavity (150) arranged to receive a load, a microwave source (110) for generating microwaves and a plurality of transmission lines (140) for guiding the generated microwaves to the cavity. An electronic device (160) adapted to adjust the impedances of each of the plurality of transmission lines individually |  |
| EP12.152039.9 | Jan 23, 2012 | Picture analysis and zone cooking | The microwave heating apparatus comprises a plurality of feeding ports for feeding microwaves from a plurality generators to the cavity, and a control unit. The control unit shall obtain a desired temperature pattern based on information about a plurality of regions of the load, determine a heating pattern comprising zones of different intensities corresponding to the desired temperature pattern, and control at least some of the generators for providing the heating pattern within the cavity. |  |
| EP11.194095.3 | Dec 16, 2011 | Dual level heating of food, Divider shelf | The microwave heating apparatus comprises a cavity dividable into at least two compartments, a first microwave generator and a first feeding port for feeding, a second microwave generator and a second feeding port for feeding a first and second mode field in a each compartment of the cavity. The first and the second mode field provide complementary heating patterns in the cavity when the cavity is undivided. |  |
| EP10188461.7 | Oct 22, 2010 | Selection of antenna for optimal efficiency | The microwave oven comprises a cavity, at least one microwave source, a plurality of feeding ports. The feeding ports are connected to the source and the cavity. A measuring unit is adapted to measure the reflected power for each one of the plurality of feeding ports. A control unit is adapted to select at least one of the feeding ports based on reflected power to feed microwaves to the cavity via the one selected feeding port |  |
| EP10164960,6 | June 4, 2010 | Crisp with SSMG | The microwave heating device comprises a first microwave generating means configured to supply microwaves at the cavity bottom such that a browning function is provided, a second microwave generating means to supply microwaves into the cavity for exciting cavity modes and a control unit to control the first and second microwave generating means based on a food category and/or a cooking program |  |
| EP 2326141 | Nov 18, 2009 | Microwave oven and related method, Load recognition | The microwave oven comprises a magnetron for providing microwave power to heat a load placed in the microwave oven, and a solid-state microwave generator for providing microwave power to sense presence and/or determine nature of the load in the microwave oven. |  |
| EP09157516,7 | April 7, 2009 | Regulation of a microwave heating device with field sensors | The microwave heating device comprises a cavity with at least two microwave sources, feeding microwaves through at least two feeding ports and at least two field sensors adapted to measure field strengths of the microwave energy in the cavity. The microwave heating device comprises a control unit connected to the sources and the field sensors for regulating the microwaves based on the measured field strengths. |  |
| EP09155733,07 | March 20, 2009 | MICROWAVE HEATING DEVICE, Small aperturs | The feeding structure comprises a transmission line for transmitting microwave energy and a resonator at the junction between the transmission line and the cavity for operating as a feeding port of the cavity. The dielectric constant of the material in the interior of the resonator and the dimensions are selected such that a resonance condition is established in the resonator and impedance matching is established |  |
| EP 2200402 | Dec 19, 2008 | MICROWAVE OVEN Switching betw predefined modes | The method comprises the steps of selecting, for the predefined modes, at least two of the identified resonance frequencies and switching the operating frequency of the microwave source using the selected frequencies |  |
| EP 1329136 | Oct 25, 2000 | MW feeding by multi port feeding in series | A serial microwave feeding to a cavity microwave radiation that is reflected from a first feeding port is directed, preferably via a microwave circulator, to a second feeding port. | |
| EP 1317873 | Sept 15, 2000 | MW feeding by selected modes | A predetermined mode in the cavity of a microwave oven is fed by means of an associated feeding port which is arranged to feed essentially the intended mode only | |

# OUR SERVICES – LAB FACILITIES

- **Electronics and Microwave Lab**
  - ✓ Electronic design
  - ✓ Microwave field simulation
  - ✓ Measurements with Infrared Camera
  - ✓ Dielectric Measurements
  - ✓ Impedance Measurements
- **RF and EMC Facilities**
  - ✓ EMC Emission Pre-Compliance Chamber
  - ✓ EMC Emission test antennas
  - ✓ EMI Immunity Test
  - ✓ GigaHertz Transvers Electro Magnetic Cell





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# CUSTOMERS AND BUSINESS PARTNERS

MAFA
ÖHLINS ADVANCED SUSPENSION TECHNOLOGY
Infineon
syncore technologies
NASA
ircon DRYING SYSTEMS
Biotage
dimac Since 1979
WELBILT Bringing innovation to the table
HOLMEN
CNS Systems
SCANFIL
NXP
RATIONAL
VÄDERSTAD
CTT SYSTEMS
VESTEL
Humidity in balance
AMPLEON
CEMENTA HEIDELBERGCEMENT Group
LKAB
Koenigsegg
DANISH TECHNOLOGICAL INSTITUTE
DOMETIC Mobile living made easy.
V-ZUG
Whirlpool CORPORATION
VOLVO
Skåne-möllan AB Med mjöl som möjlighet
SAAB
ICE SOLUTION
SIG
Tetra Pak
MACOM Partners from RF to Light
IKEA
Midea
DANISH TECHNOLOGICAL INSTITUTE
DIPOLAR
Electrolux
Miele
Haier
SCANIA
BOSCH SIEMENS
BILLERUDKORSNÄS
FREUDENBERG INNOVATING TOGETHER
Tupperware
ECONOVA
GreenWaves Srl Engineering Services for Wireless Applications
Plextek
Prodma
RAGN-SELLS
Fiskeby 1637
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# KUND CASE - KOENIGSEGG


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# RESEARCH PROJECTS - SPECTRA

**An European Commission research & Innovation Horizon 2020 – Funding Application**

***Integrated Hyperspectral sensing for Smart Solid State Cooking System***

**The main scope of SPECTRA is the research and prototype of a quasi-real time computational electromagnetic engine to be fed by Radio Frequency (e.g. RF) and vision systems to i) enable advanced sensing and control applications such as zone & automatic cooking and ii) improve reliability and repeatability of the cooking process, while reducing the number of required inputs from the user.**

NOT GRANTED

Research Partners

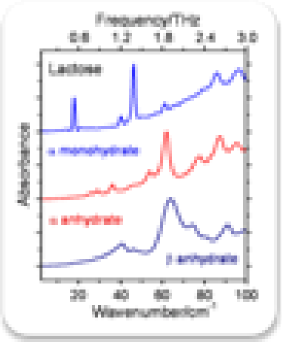
# RESEARCH PROJECTS – THZ R&D ALLIANCE INITIATIVE

**A Swedish Foundation for Strategic Research – Funding for an Industrial PhD student together with LiU**

One interesting area is sensor systems for domestic appliances, where this technology can give additional information as complement to existing sensor signals and add value to the customer in terms of enhanced functionality and energy saving. Some potential applications include:

- *Detection of differences in water content could be used to monitor browning level of food or dryness level of fabrics*
- *High resolution images could be used to get information on food geometries/numbers, also through packages*
- *Spectral fingerprints could give information to distinguish different food categories or maturity level. It could also be used to measure soil content in the drain water for better control of washing processes*

NOT GRANTED




## Research Partners

LiU LINKÖPINGS UNIVERSITET
KTH VETENSKAP OCH KONST
CHALMERS
SWEDISH ICT ACREO

## Industrial Partners

infineon
silex MICROSYSTEMS

## Application Partners

Whirlpool
Electrolux
Haier
BOSCH Invented for life
Miele
V-ZUG
SIEMENS

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# RESEARCH PROJECTS - PARADIGSYS

**An European Commission research & Innovation Horizon 2020 – Funding Application International Training Network**

**Paradigm Shift towards Future Energy Efficient Microwave Systems – the Six-Port Concept for Enhanced Power Added Efficiency**

**The uniqueness of the six-port radio technology can be summarized as follows. Firstly, it utilizes the microwave design principle and offers much larger data capacity than the traditional radio technology. Secondly, it is low cost since it is based on the printed circuit technologies utilizing either organic or ceramic multi-layer substrates. At frequencies higher than 20 GHz, the six-port circuits can also be integrated on silicon or III-V semiconductors, e.g., GaAs.**

GRANT TO BE COMMUNICATED
JUNE 2018

## Research Partners

Brandenburgische Technische Universität Cottbus - Senftenberg

LINKÖPINGS UNIVERSITET

Université de Lille

FRIEDRICH-ALEXANDER UNIVERSITÄT ERLANGEN-NÜRNBERG

AGH AKADEMIA GÓRNICZO-HUTNICZA IM. STANISŁAWA STASZICA W KRAKOWIE

innovations for high performance microelectronics
Leibniz-Institut für innovative Mikroelektronik

POLYTECHNIQUE MONTRÉAL
LE GÉNIE EN PREMIÈRE CLASSE

UNIVERSIDAD DE MÁLAGA

## Industrial Partners

SILICON radar

novotechnik
Siedle Gruppe

InnoSenT
Innovative Sensor Technology

SEGULA TECHNOLOGIES

ABB

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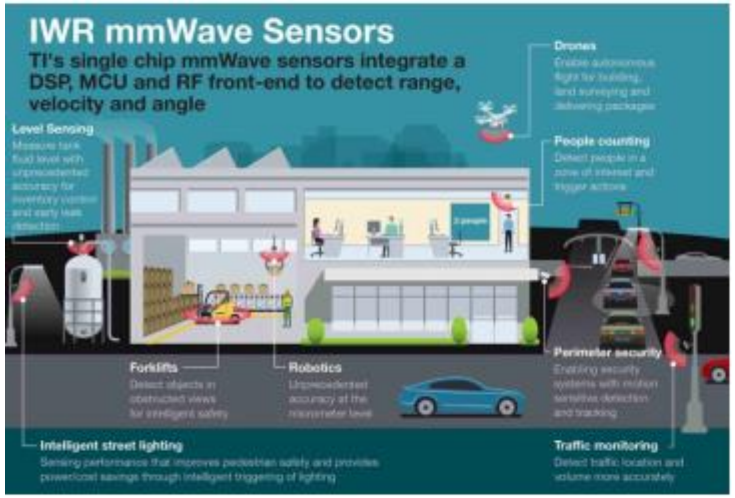
# RESEARCH PROJECTS – MM WAVES COTS SYSTEMS

**Norrköping municipality fund for research and development - Funding Application**

- **Cost-effective millimeter wave system for radar sensors and 5G in the smart city**




**One possible industrial application is to characterize dielectric properties of different material (eg to determine whether cheap mm wave sensors could be used to determine the water content in food and better optimize industrial heating processes.)**

Research Partners

LINKÖPINGS UNIVERSITET

RI. SE

GRANT TO BE COMMUNICATED MAY 2018

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# Reference Case – Development Industrial Application

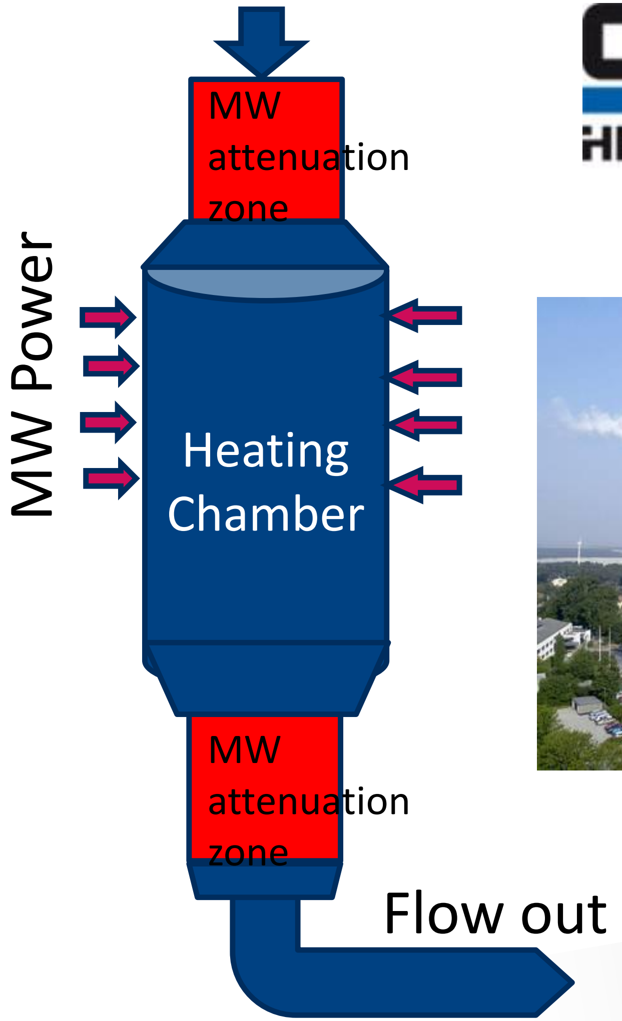
- Skånemöllan; a company a mill in Tågarp Skåne delivers flour and cereal products to bakeries, food industries and consumers.
- They have an industrial microwave oven (picture) to hyginienze oats cores to kill the enzyme Lipas which make the oats unsaturated fat to get bad.
- This requires to heat the oat to 125˚C during 1 hour.
- The microwave oven is:
  - 5 m height and 3m in diameter
  - Power: 144 kW
  - Capacity: 1000 kg/hour
- Our assignment: To analyze the problem with efficiency, reliability and thermal management and solve the issues. Result: A well function oven.

# REFERENCE CASE – DEVELOPMENT INDUSTRIAL APPLICATION

- **Cementa and Vattenfall conduct a project to electrify the manufacturing process of Cement. This in order to reduce the climate impact by eliminating the CO2 emission from 1,7 million tons to Zero by 2030 – the CemZero project.**

- **Our assignment: To conduct a technical feasibility study in the possibility to use microwave heating in the manufacturing process.**
  - **Temperatur up to 1450 degrees Celsius**
  - **1 million ton per year in capacity**

- **POSSIBILITY: To conduct the next step, small scale design and testing in a demonstrator.**




CEMENTA
HEIDELBERGCEMENT Group

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# RESEARCH PROJECTS – SANITATION OF SLUDGE BY MICROWAVE HEATING

**Norrköping municipality fund for research and development**
**- 2016/2017 – Concept study: A literature study of the sludge treatment process were microwave technology have been applied. Several laboratory test was performed.**

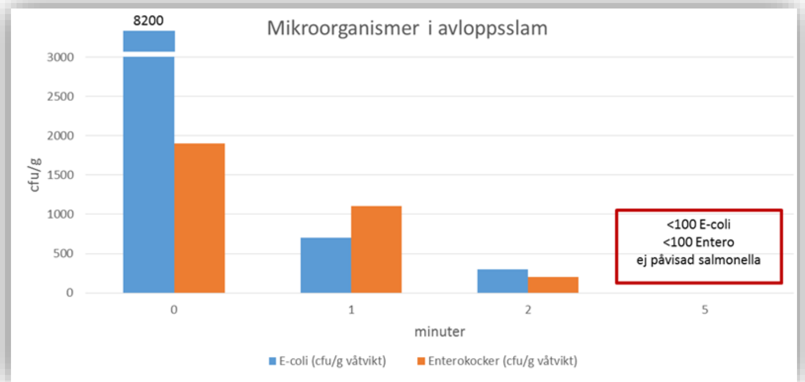
- **2017/2018 – Demonstrator: To build a small scale demonstrator to develop an industrial microwave processing for sanitation of sludge.**

## Funding Granted for both projects

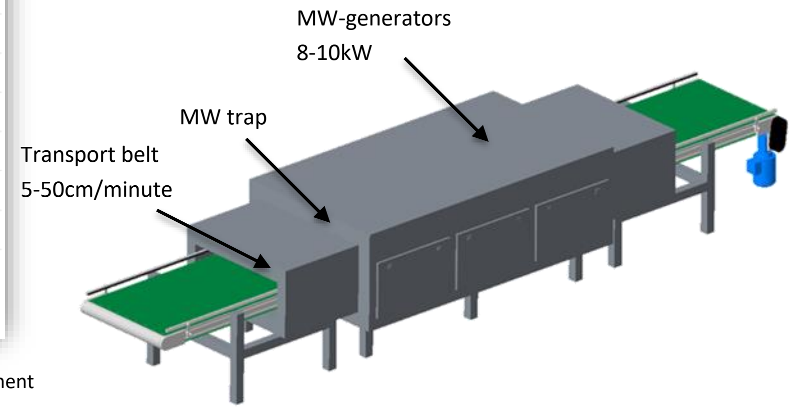
Research Partners

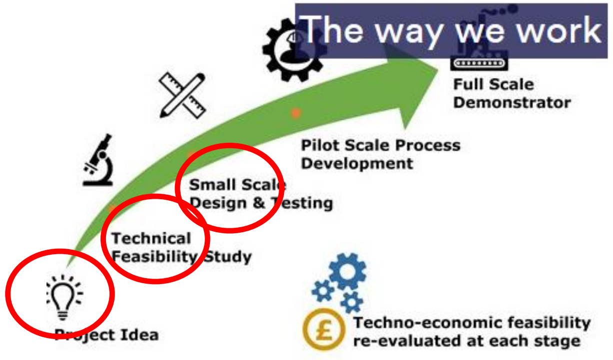
LINKÖPINGS UNIVERSITET

NORRKÖPING VATTEN OCH AVFALL




Number of E-coli and Enterococcus bacteria in sludge before and after microwave treatment




SUSTAINABLE SOCIETY
PLANET
PROFIT
PEOPLE

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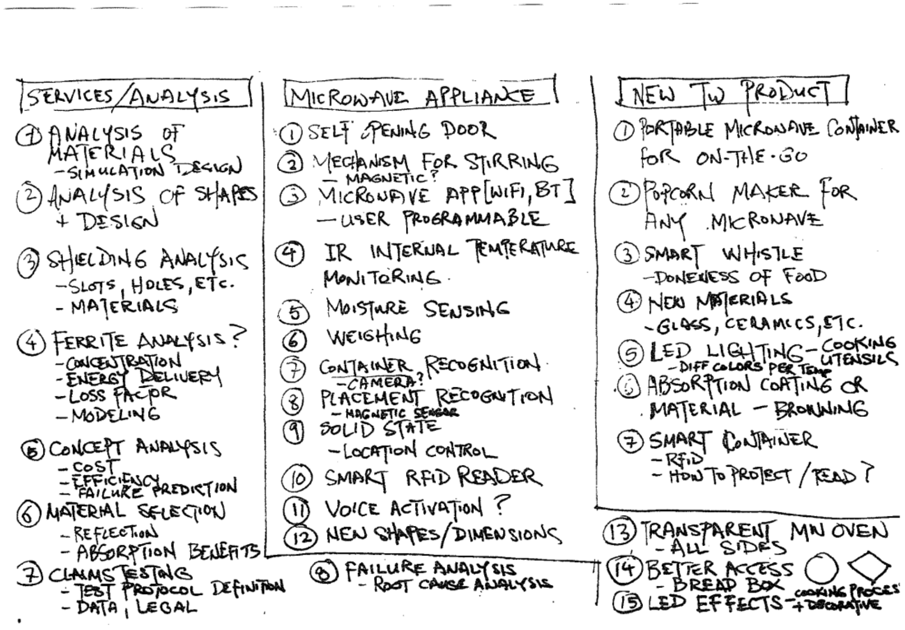
# REFERENCE CASE – DEVELOPMENT DOMESTIC APPLICATION

- **Tupperware has several microwave oven related product on the global market.**

- **Our assignments:**
  - ✓ **Conducted a training and innovative brain storming workshop.**
  - ✓ **Roote Cause Analysis of Micro-Grill product, present solution and recomendation for improvment.**
  - ✓ **Risk Analysis of Micro-Bake product in order to prevent the same problem as in the Micro-Grill.**

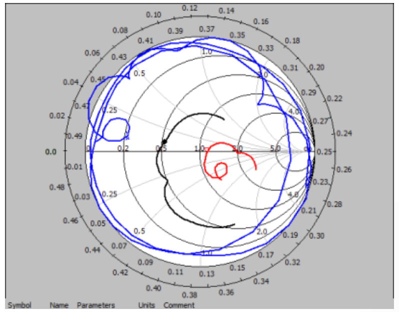
- **POSSIBILITIES:**
  - ✓ **To develop a lab oven**
  - ✓ **To develop a microwave oven dedicated to TW products.**

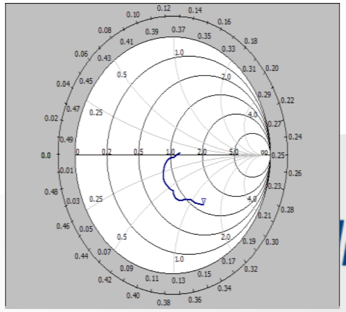

SERVICES/ANALYSIS
① ANALYSIS OF MATERIALS
- SIMULATION DESIGN
② ANALYSIS OF SHAPES + DESIGN
③ SHIELDING ANALYSIS
- SLOTS, HOLES, ETC.
- MATERIALS
④ FERRITE ANALYSIS?
- CONCENTRATION
- ENERGY DELIVERY
- LOSS FACTOR
- MODELING
⑤ CONCEPT ANALYSIS
- COST
- EFFICIENCY
- FAILURE PREDICTION
⑥ MATERIAL SELECTION
- REFLECTION
- ABSORPTION BENEFITS
⑦ CLAIMS TESTING
- TEST PROTOCOL DEFINITION
- DATA, LEGAL
⑧ FAILURE ANALYSIS
- ROOT CAUSE ANALYSIS

MICROWAVE APPLIANCE
① SELF OPENING DOOR
② MECHANISM FOR STIRRING
- MAGNETIC?
③ MICROWAVE APP [WIFI, BT]
- USER PROGRAMMABLE
④ IR INTERNAL TEMPERATURE MONITORING
⑤ MOISTURE SENSING
⑥ WEIGHING
⑦ CONTAINER RECOGNITION
- CAMERA?
⑧ PLACEMENT RECOGNITION
- MAGNETIC SENSOR
⑨ SOLID STATE
- LOCATION CONTROL
⑩ SMART RFID READER
⑪ VOICE ACTIVATION ?
⑫ NEW SHAPES/DIMENSIONS

NEW TW PRODUCT
① PORTABLE MICROWAVE CONTAINER FOR ON-THE-GO
② POPCORN MAKER FOR ANY MICROWAVE
③ SMART WHISTLE
- DONENESS OF FOOD
④ NEW MATERIALS
- GLASS, CERAMICS, ETC.
⑤ LED LIGHTING - COOKING UTENSILS
- DIFF COLORS PER TEMP
⑥ ABSORPTION COATING OR MATERIAL - BROWNING
⑦ SMART CONTAINER
- RFID
- HOW TO PROTECT / READ ?
⑬ TRANSPARENT MW OVEN
- ALL SIDES
⑭ BETTER ACCESS
- BREAD BOX
⑮ LED EFFECTS - COOKING PROCESS + DECORATIVE

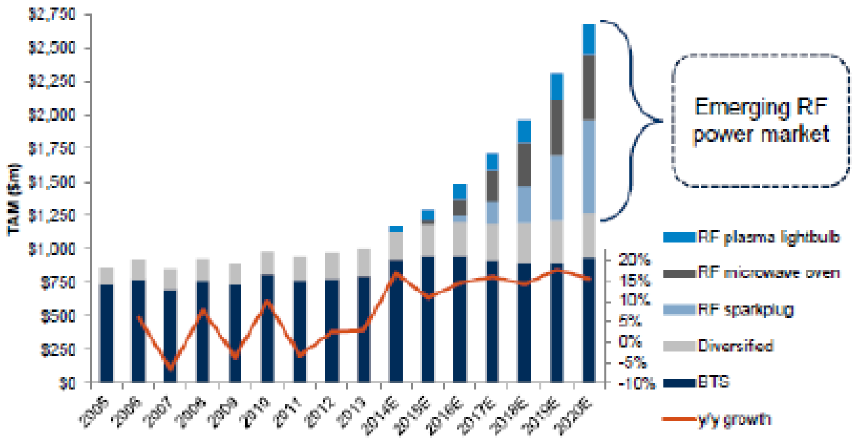
Impedance simulation, MWO with bottom feed.





# POSSIBILITIES IN SOLID STATE TECHNOLOGY

- **Elimination of the Circulator and dummy load**
  - ✓ **Reduced Size**
  - ✓ **Reduced Cost**
  - ✓ **Advantages in control capability**
- **Patent application**




Source: SunTrust Robinson Humphrey

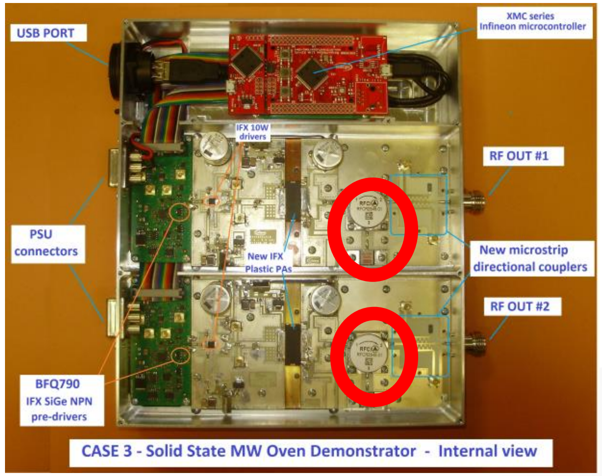
- **Transistor Manufactures**

MACOM Partners from RF to Light

NXP

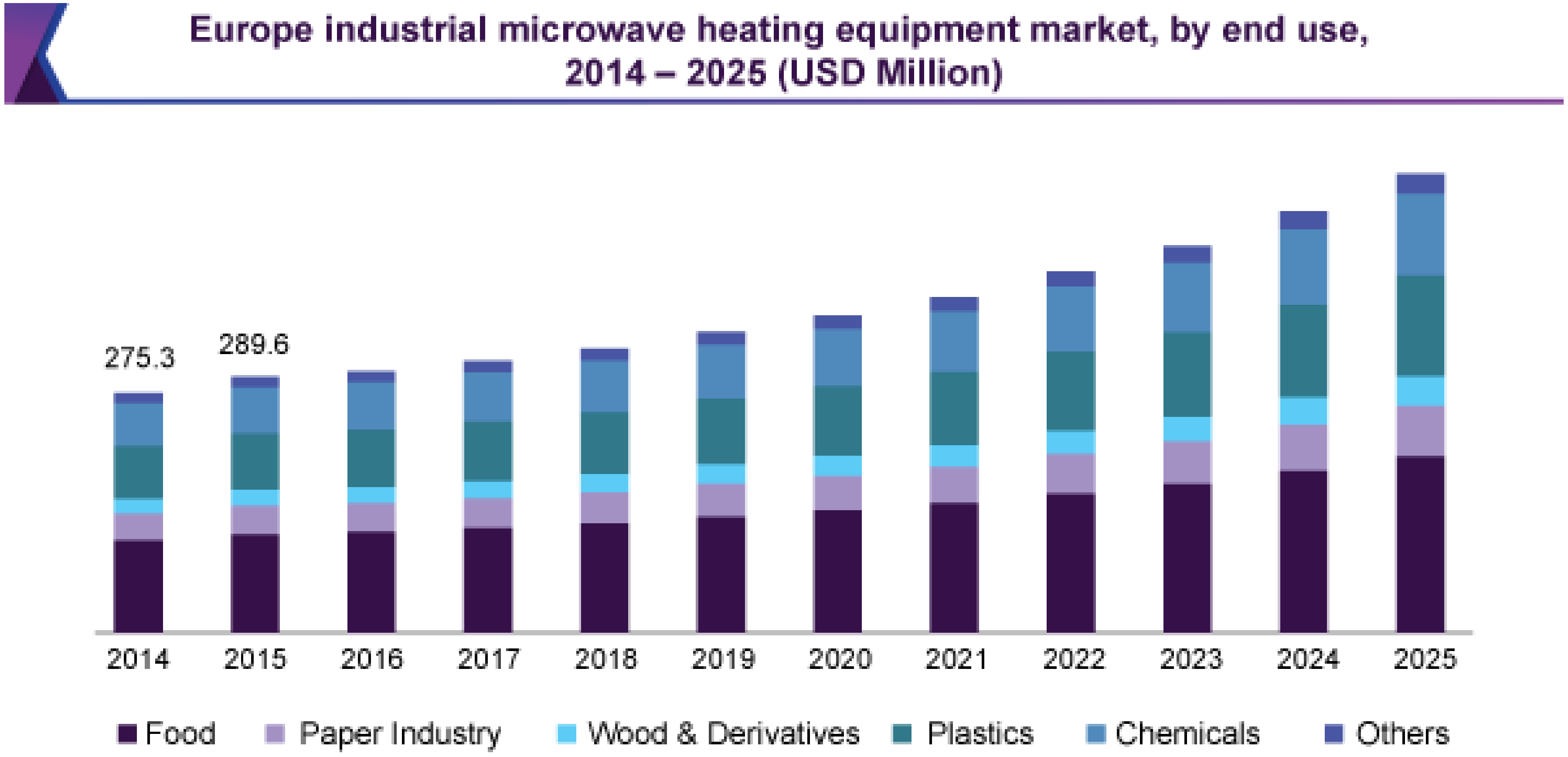
AMPLEON

infineon




COMBITECH

# LJUS FRAMTID FÖR INDUSTRIELL MIKROVÅGSVÄRMNING

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