2.5D Technology-based Integrated Antenna Array mm-Wave System For Non-Invasive Food Safety Scanner (TIAS)

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Outline

1. Background & Motivation Food Safety and Risk Assessment to Animals and Humans
   - ➢ Existing Methods for Melamine Detection
2. The Proposed System
   - ➢ Mm-Wave & Antenna Array
   - ➢ 2.5D Packaging Technology
   - ➢ The proposed three-tier TIAS
3. Conclusions

Motivation

- Food safety/public health concerns [1]:
  - Including **animal feed up** to sale or supply of food to the **consumer**

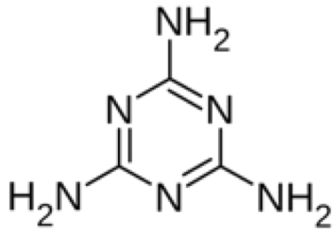
- Food safety is not only essential for human health but also plays an important role in the development of national economies, trade, and tourism

- Unsafe food poses a global threat, particularly to vulnerable groups such as pregnant women, young children, infants, and the elderly

https://www.cdc.gov/foodsafety/people-at-risk-food-poisoning.html

ASEAN Food Safety Policy, www.asean.org [accessed Oct. 2020]

Melamine

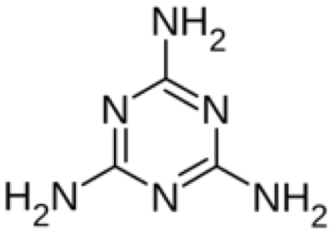


- Harmful substances such as **cyromazine** or **melamine** in daily foods, milk and animal feeds causes actual environmental and human health problems

- **Illegally** added to inflate the apparent protein content of food and animal feeds:
  - 50% of dietary supplements are contaminated with melamine
  - Found in baby formula milk in China, 2008, which was responsible for severe **renal** problems and **kidney** stones in infants.

Food safety should be widely monitored and improved

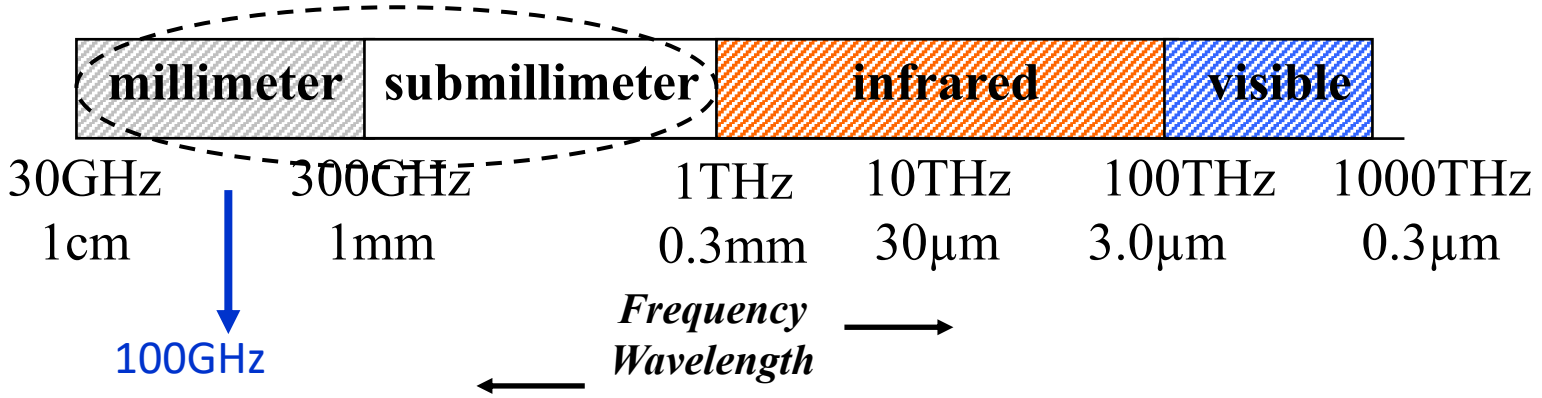
Existing Methods for Melamine Detection



- Melamine analysis mainly by chemical or gas methods:
  - chromatographic analysis: gas chromatography–mass spectrometry (GC-MS); High performance liquid chromatography(HPLC);
  - liquid chromatography-tandem mass spectrometry (LC-MS/MS) ; ultra-performance liquid chromatography (UPLC)
- However,
  - cost of equipment, complex operation for inspection
  - takes a long time
  - limit the application of these methods for foods/milks consumers

-> Research and develop a **non-invasive** method for **rapid detection** of melamine.

Mm-Wave Applications

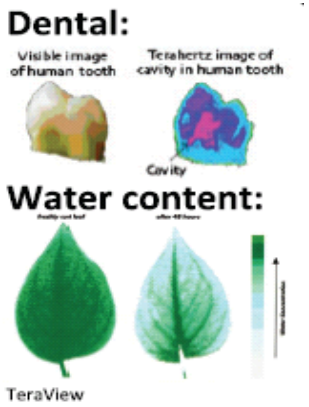


Mm-Wave radiation:

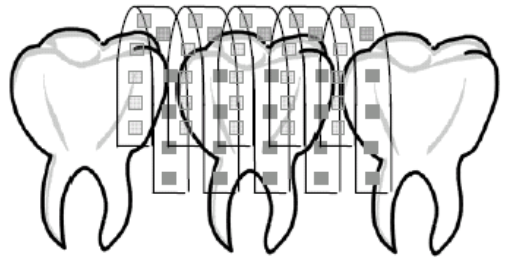
- **non-ionizing**
- no damage to DNA and possibly cause cancer

Mm-Wave Applications:

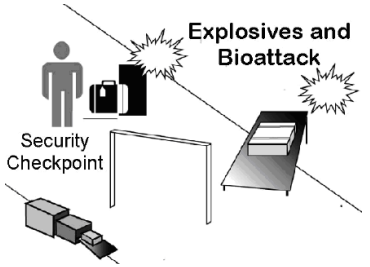
- Communication
- Material detection: based on dielectric properties



Mm wave imaging tranceiver



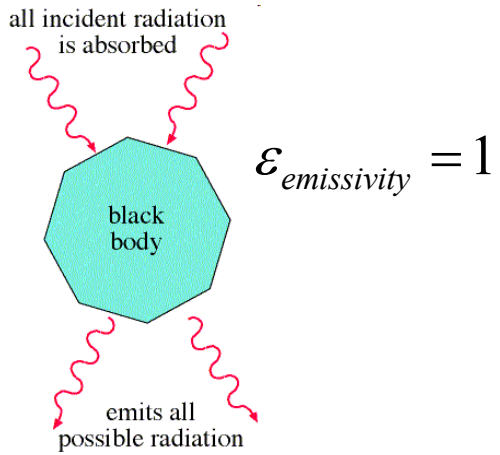
(E. Laskin, Univ. of Toronto, Canada)



Mm-Wave Imaging Principle

- Spectral radiance of Planck's Law (for black body):

$$L_f(f) = \frac{2hf^3}{c^2} \cdot \frac{1}{e^{\frac{hf}{kT}} - 1} \qquad [W / m^2 / Hz / sr] \qquad (1)$$



- Real object ($\varepsilon_{emissivity}$)<1), replace T in (1) by

  $T_S = \varepsilon_{emissivity}.T$

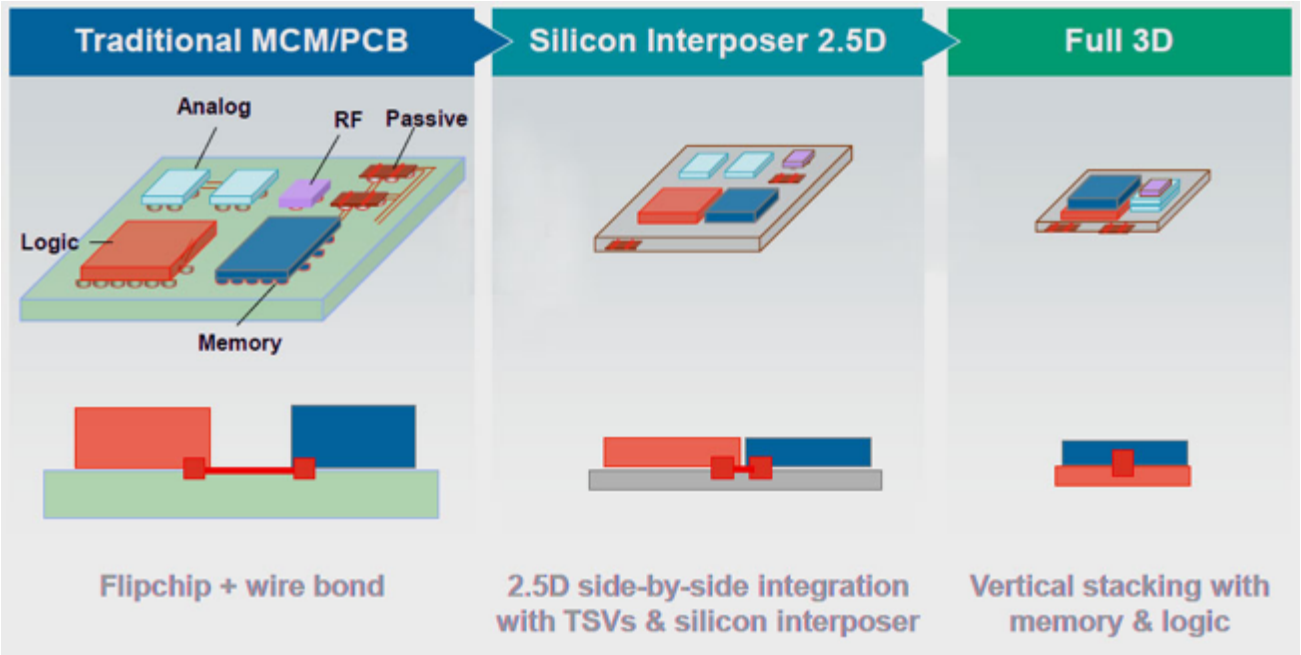
- *For example:* water in 100 GHz, $\varepsilon_{emissivity}$)=0.59, @27°C
  Spectral Radiance L_f = 0.537 [mW/m²/sr/THz]

$L_f(f)$ is the black body spectral energy density,
c: light's speed, f: frequency, h : Planck's constant, k: Boltzman's constant, T: absolute temperature.
$\varepsilon_{emissivity}$: emissivity of a material, T_S : radiometric temperature,

Why Antenna Array for The Proposal

- Gaining more sensitivity
- Beamforming controllability for the sensing purpose
- More accurate and faster than non-phased antenna arrays
- other EM benefits

System-in-Package (SiP) Technologies

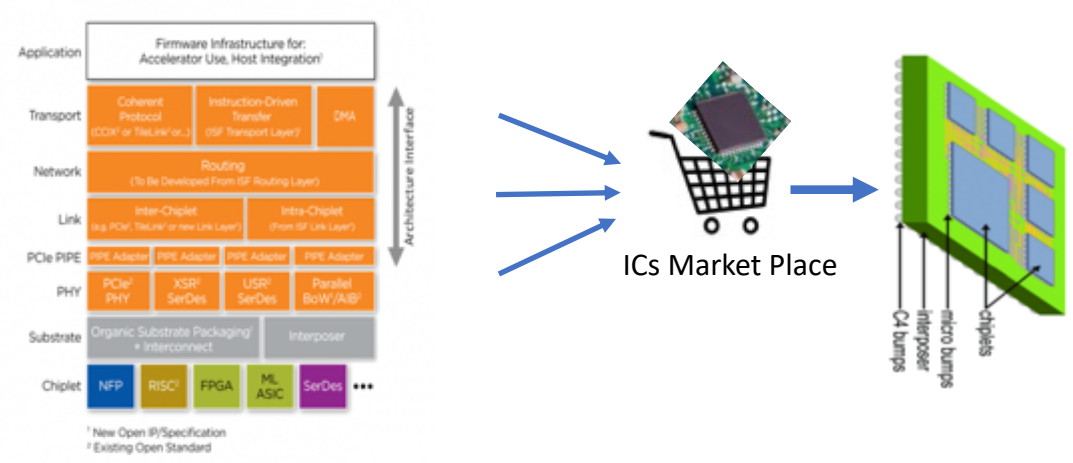


einfochip.com

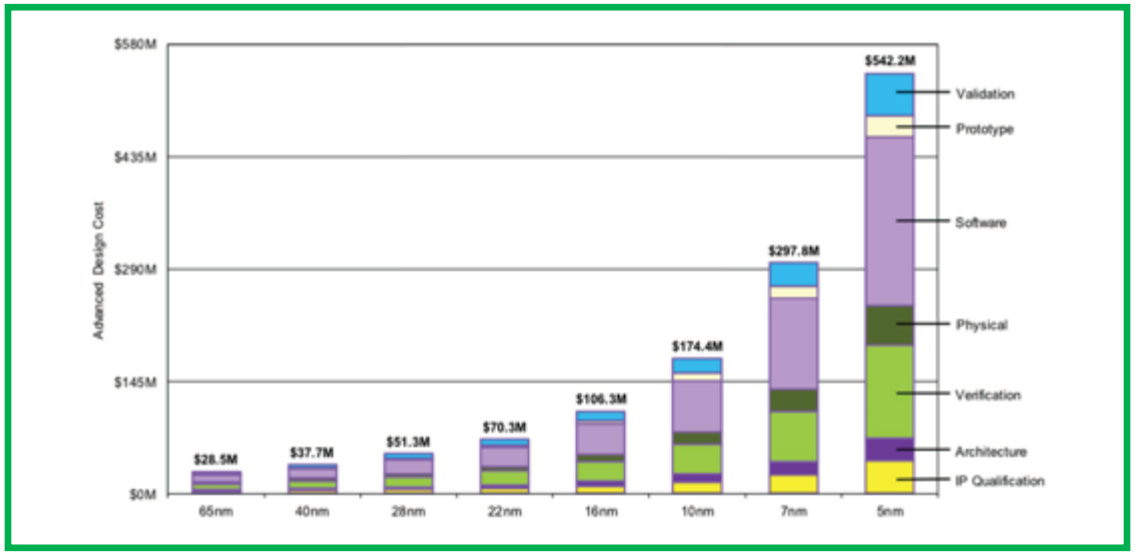
- System on Chip (SoC) : functions on multiple chips are integrated onto the same die.
- * SiP, is a way of bundling two or more ICs inside a single package.

System-in-Package (SiP) Technologies: Key Trend Drivers

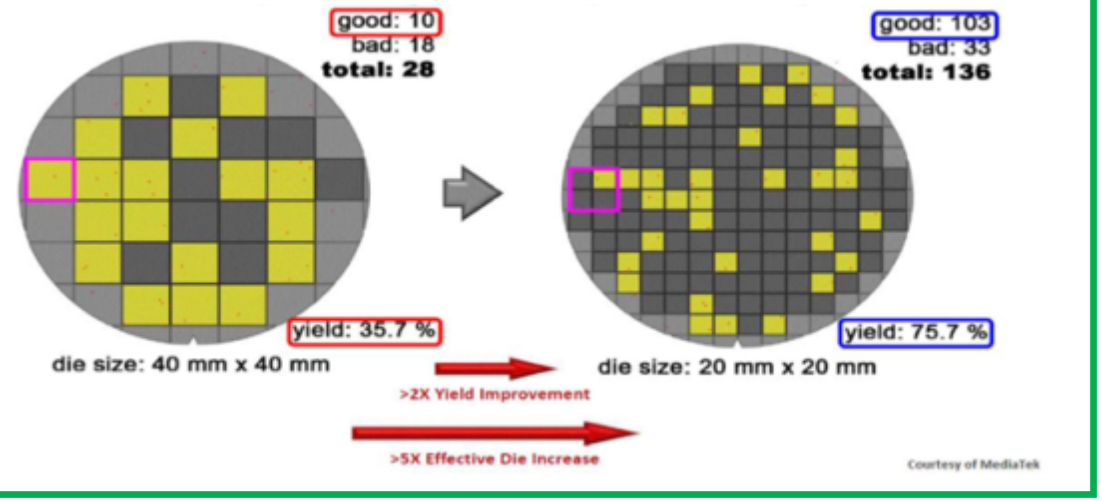
Driver 1- Chiplets



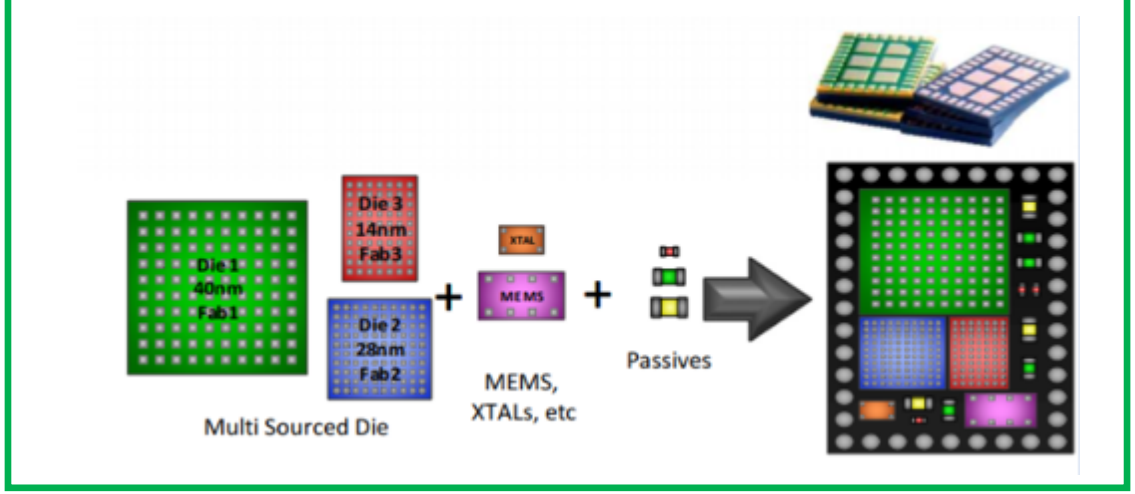
Driver 2- Si Node Dev Cost



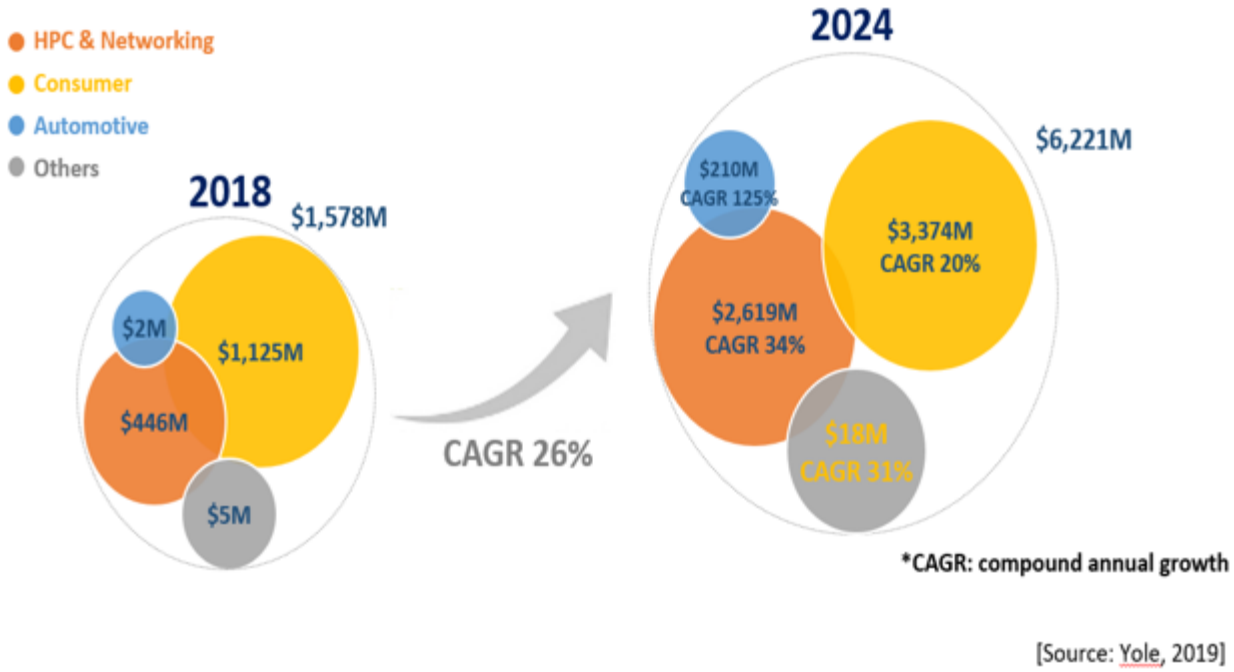
Driver 3- (Homogenous) Yield Improvement



Driver 4- Si Node Optimization



System-in-Package (SiP) Technologies : Market Analysis



[Source: Yole, 2019]

Accelerating Adoption

Segment	2018	2019	2020	2019-2020 Growth
Utilities	0.98	1.17	1.37	17.09%
Government	0.4	0.53	0.7	32.08%
Building Automation	0.23	0.31	0.44	41.94%
Physical Security	0.83	0.95	1.09	14.74%
Manufacturing & Natural Resources	0.33	0.4	0.49	22.50%
Automotive	0.27	0.36	0.47	30.56%
Healthcare Providers	0.21	0.28	0.36	28.57%
Retail & Wholesale Trade	0.29	0.36	0.44	22.22%
Information	0.37	0.37	0.37	0.00%
Transportation	0.06	0.07	0.08	14.29%
Total	**3.96**	**4.81**	**5.81**	**20.79%**

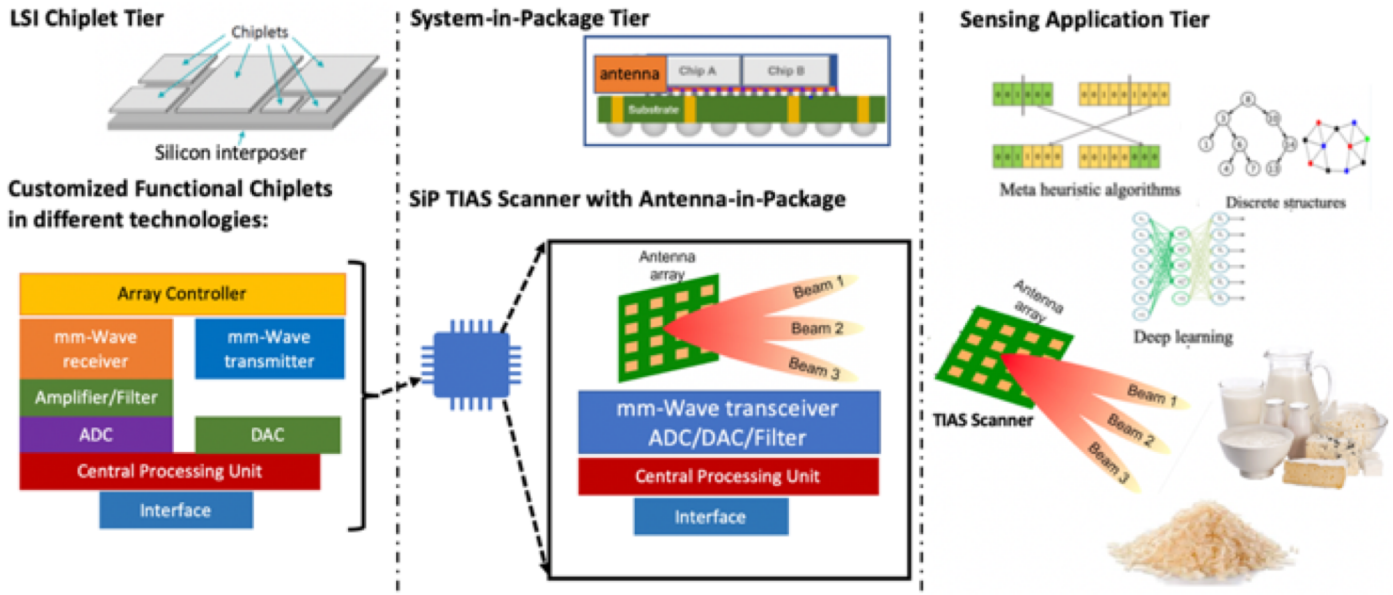
IoT Endpoint Market by Segment, 2018-2020, Worldwide (Installed Base, Billions of Units)
Source: Gartner (August 2019)

The Proposed TIAS

- "**2**.5D Technology-based **I**ntegrated **A**ntenna Array mm-Wave **S**ystem For Non-Invasive Food Safety Scanner **(TIAS)**"

- **Target**:
  - detect plastic/melamine materials or harmful substances in foods by employing this mm-Wave property
- Heterogeneous integrated sensing system:
  - 2.5D packaging technology:
    - Design architecture: **Flexible** adoption of suitable IP and chiplet
    - Easier upgrade by **reusing** and plugging in new accelerators
    - **Yield**: Since each chiplet is tested before integrating into the system, this approach has a better yield as compared to a giant monolithic SoC design.
  - Integrated anntena array

The Proposed TIAS (*cont*)



Conclusions

TIAS

- Portable system to detect melamine in feeds and food mm-Wave frequency properties
- 2.5D packaging fabrication technology and antenna-array technology
- Low-power; low-loss for mm-Wave signals; and small form factor
- Look ahead:
  - Artificial Intelligence and Internet-of-Things (AIoT) library for mm-Wave-based sensing data
  - Database for consumer users with a traceability to e-society