RF Packaging and Design for Development of High Performance 5G mmWave Modules

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Outline

- Introduction
- Need for Scalability of 5G mmWave Modules
- RF Design and Packaging of Scalable 5G mmWave Modules
- Role of Packaging Materials for 5G mmWave Modules

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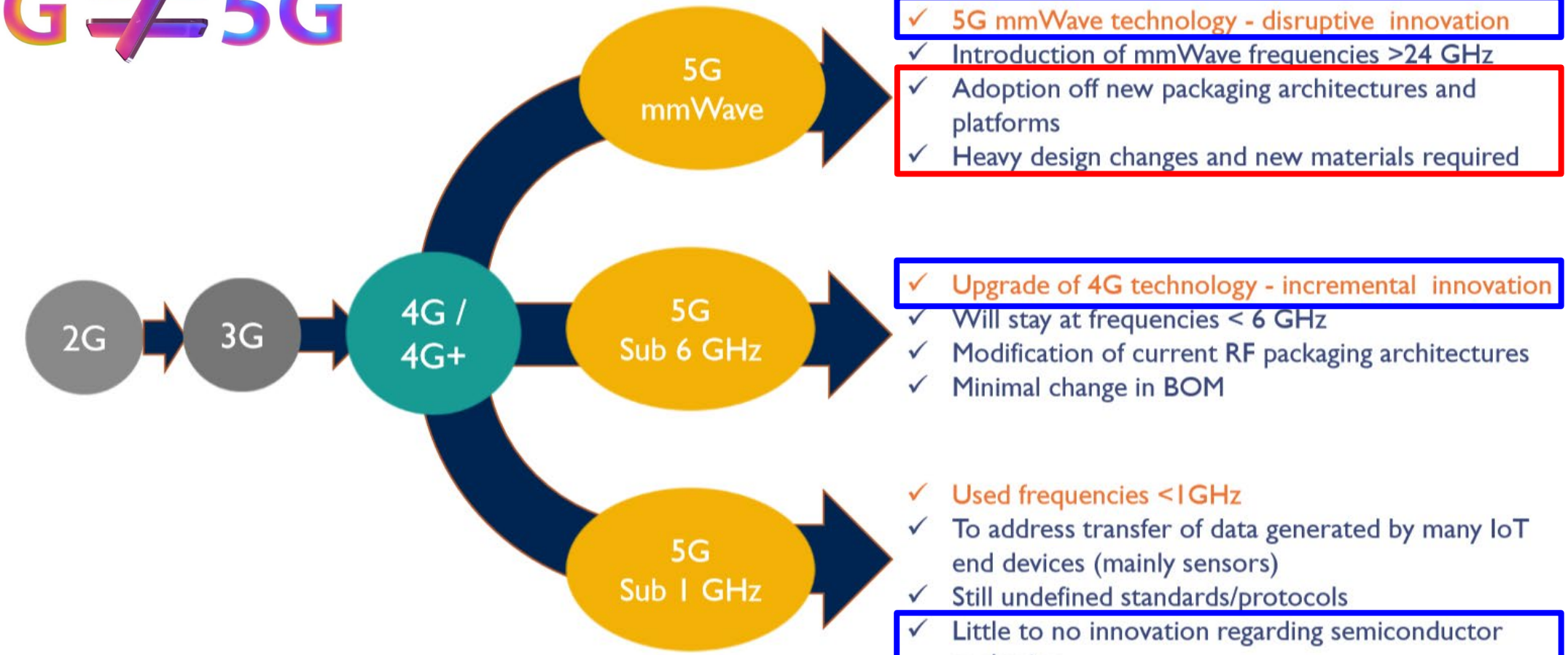
Introduction



YOLE Développement https://www.macrumors.com/guide/mmwave-vs-sub-6ghz-5g/

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Applications of 5G mmWave

- Lower Latency
- Larger Bandwidth
  - **More devices per unit area**
    - Improved industrial automation, smart factories/manufacturing, e.g., connection of robots
    - High traffic areas
      - Stadiums
      - Airports
      - Train terminals
  - **High-speed data transmission with less delay**
    - Enhanced real-time video transmission
      - Public security
      - Medical application
    - Indoor short range data transfer, Entertaintment/Augmented reality, etc.

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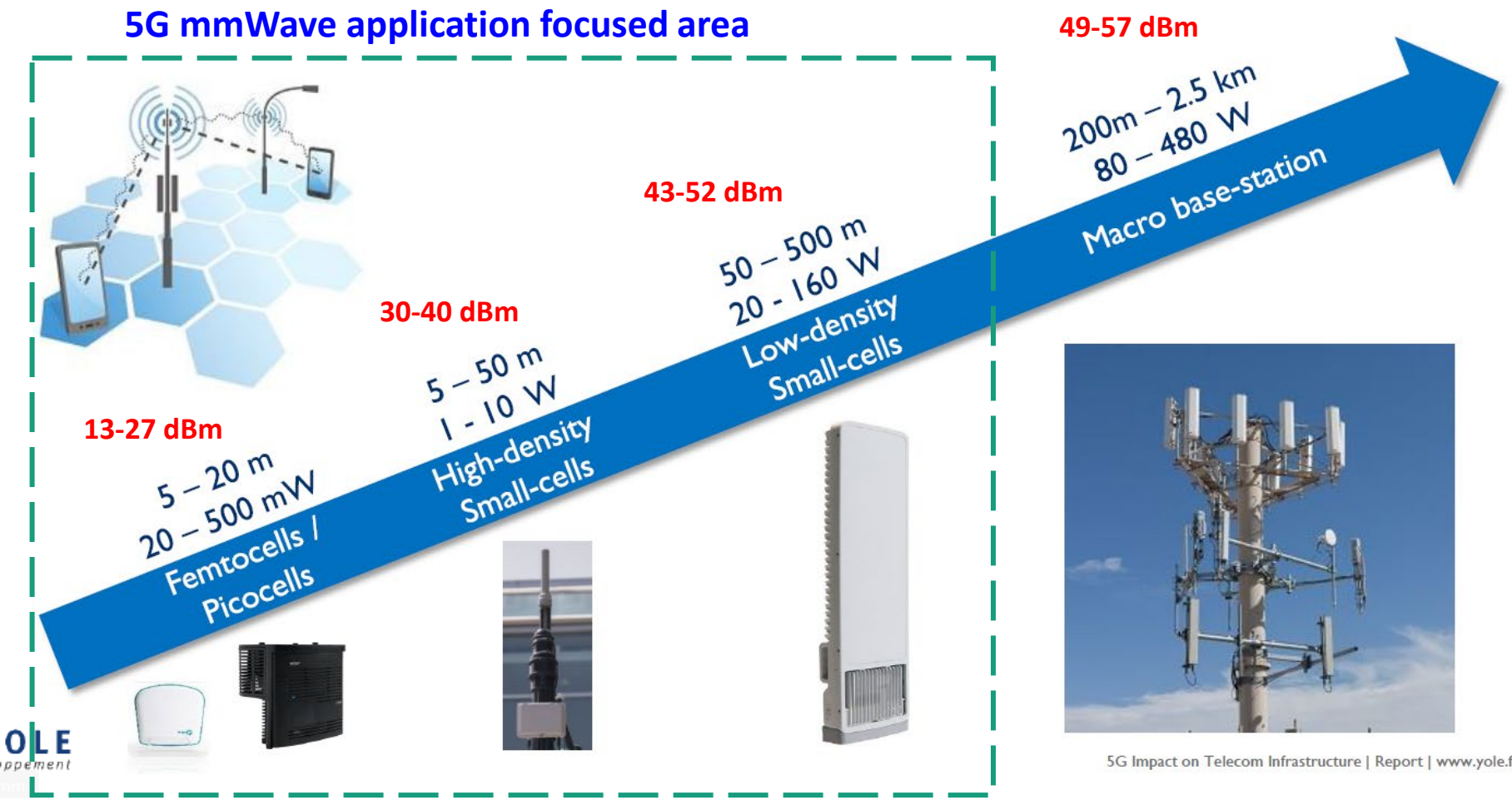
Need for Scalable 5G System Architecture – 1/2

- Scalability enables EIRP adaptation to meet application, high yield & cost reduction



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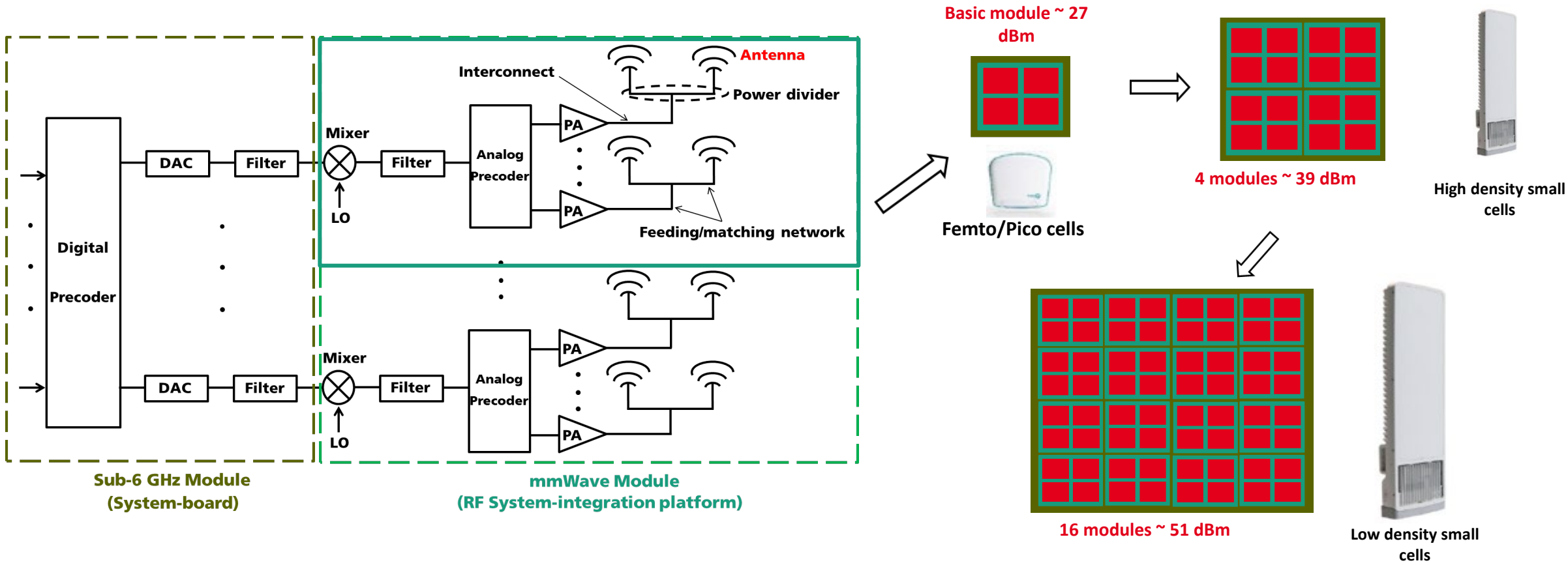
Need for Scalable 5G System Architecture – 2/2

- Scalability enables EIRP adaptation to meet application, high yield & cost reduction



Ivan Ndip, Klaus-Dieter Lang, "Roles and Requirements of Electronic Packaging in 5G", *7th IEEE Electronics System-Integration Technology Conference 2018*, Dresden, Germany.

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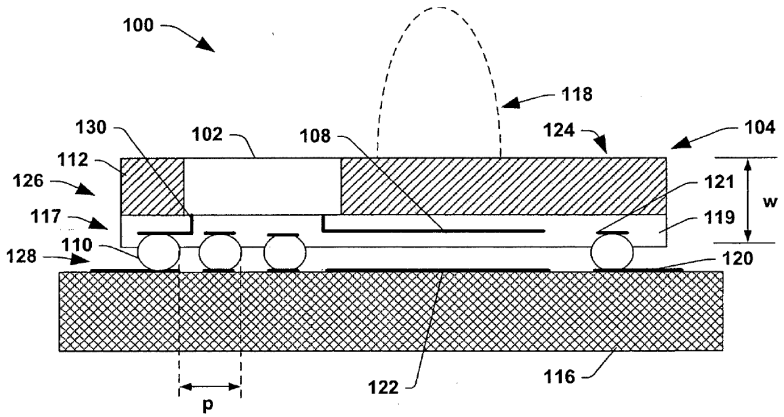
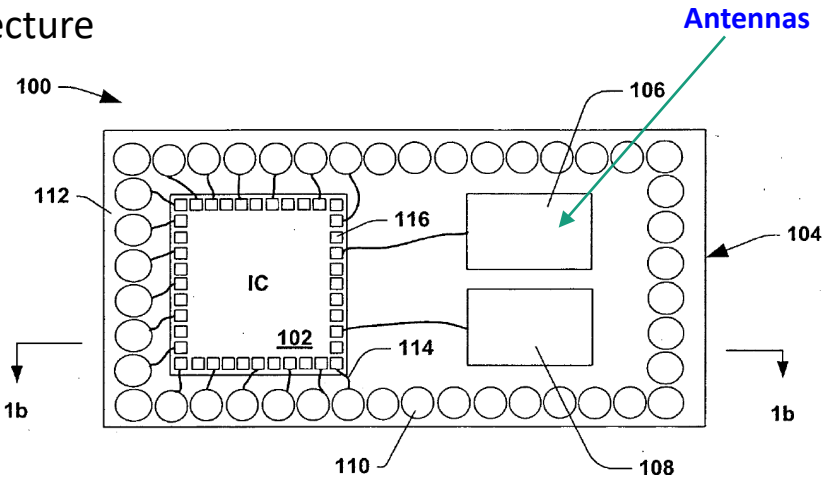
Fundamental Building Blocks of Scalable 5G mmWave Modules

- RF front-end ICs
- Integrated antennas
- Passive components
- Scalable RF packages (AiPs)for scalable system-integration of IC+ passives + antennas
  - Packaging architecture
  - Pckaging materials & interconnects

Example of non-scalable packaging architecture



Infineon (Germany)
DE102010001407A1



Ivan Ndip, Klaus-Dieter Lang, "Roles and Requirements of Electronic Packaging in 5G", *7th IEEE Electronics System-Integration Technology Conference 2018*, Dresden, Germany.

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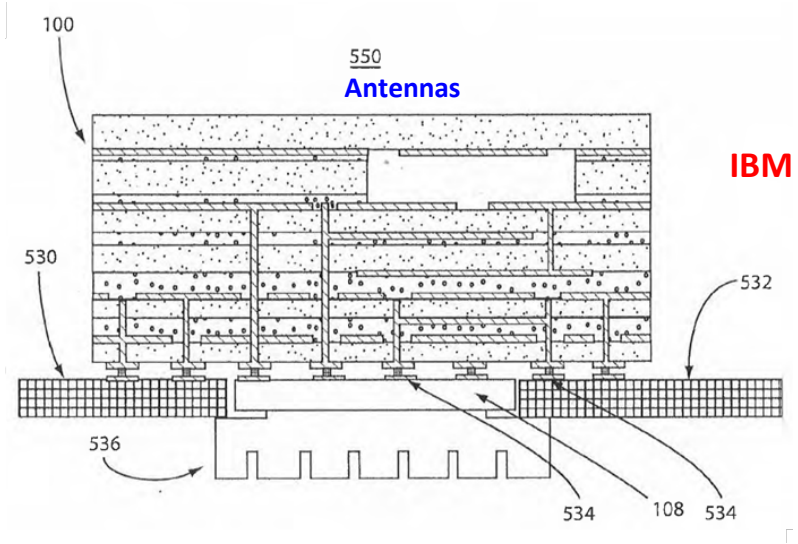
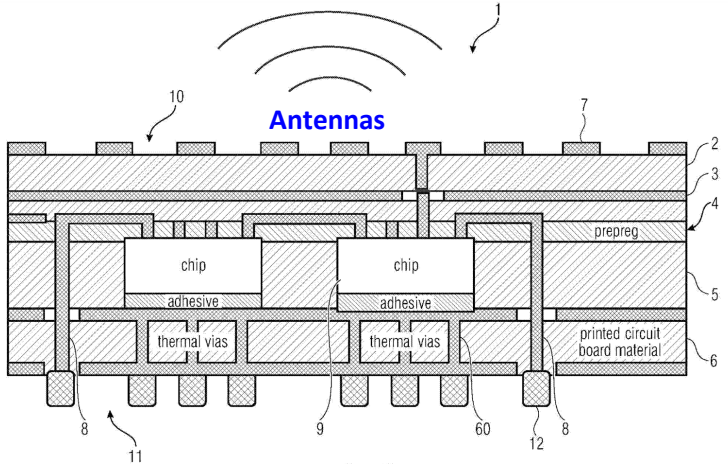
Examples of Scalable Packaging Architectures (AiPs) for 5G mmWave



IBM



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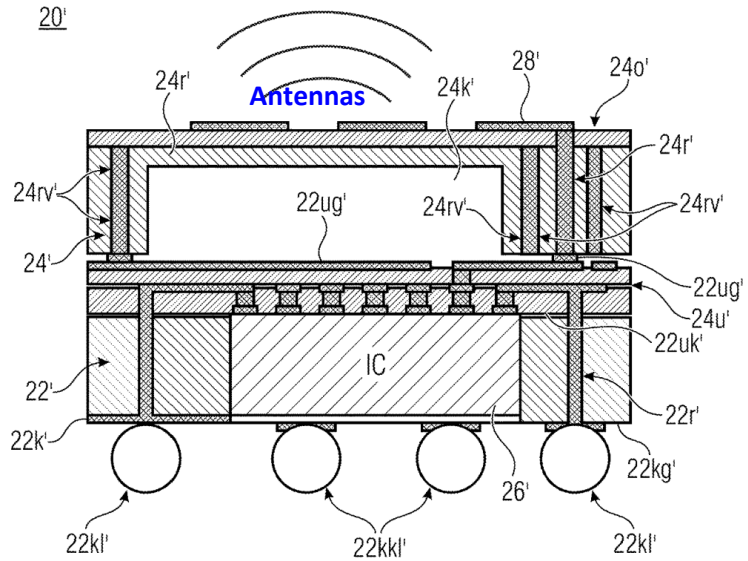

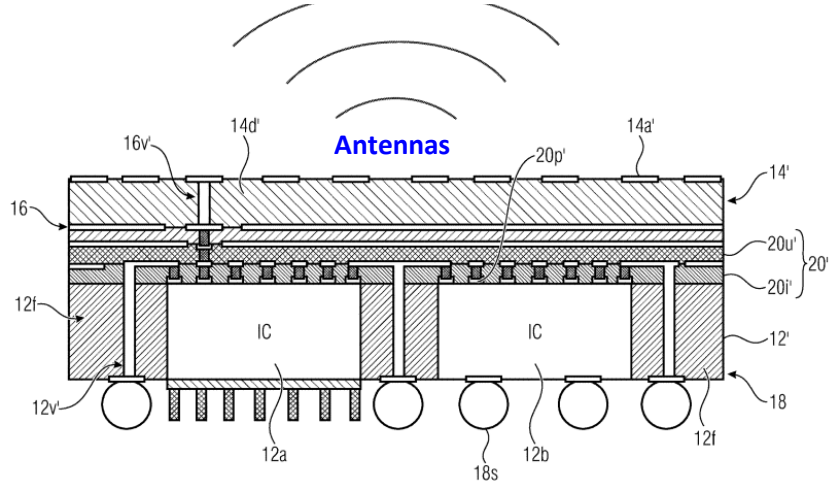

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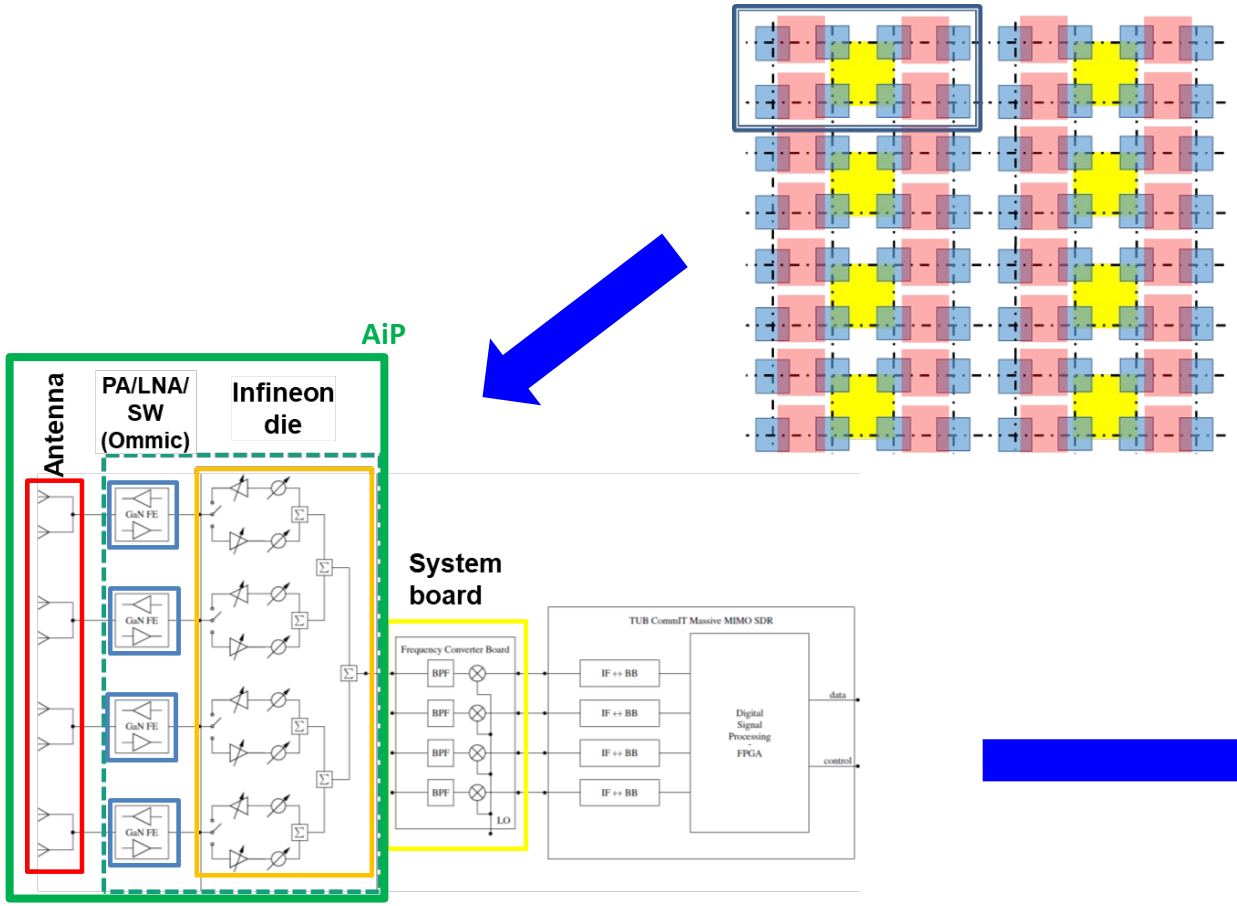
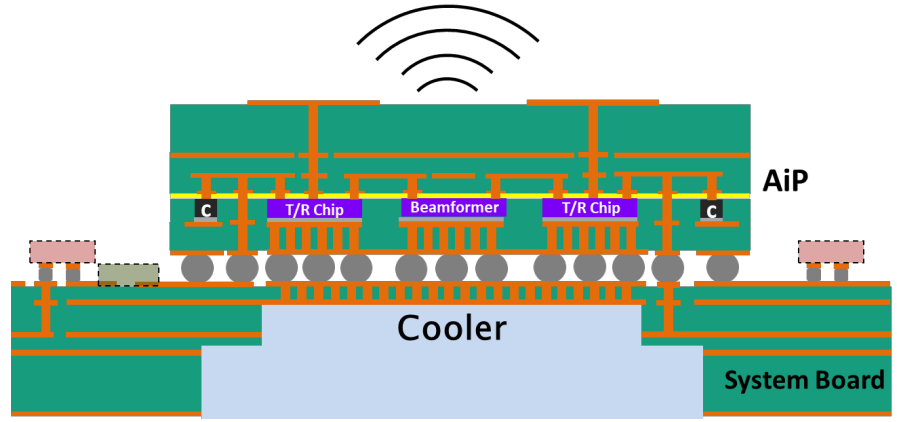
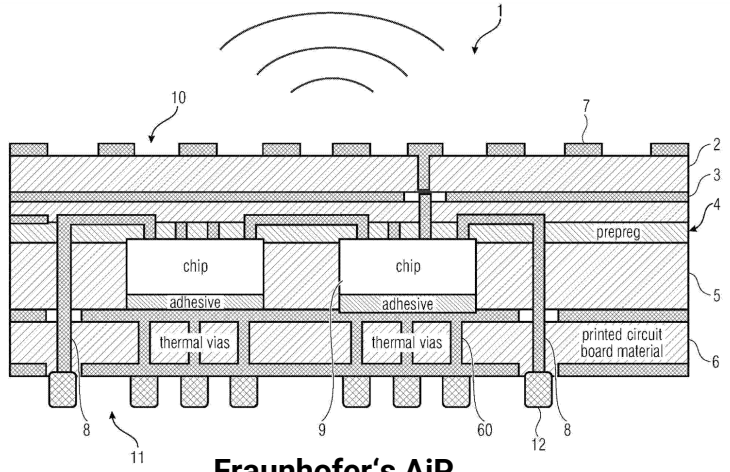
Ex.: Scalable 5G mmWave Base Station using Fraunhofer‘s AiP Platform – 1/5







Fraunhofer‘s AiP

ERICSSON
OMMIC
Innovating with III-V's
CHALMERS
UNIVERSITY OF TECHNOLOGY
SEREN
European Commission

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Infineon technologies
FOI
EPIGAN
TECHNIKON

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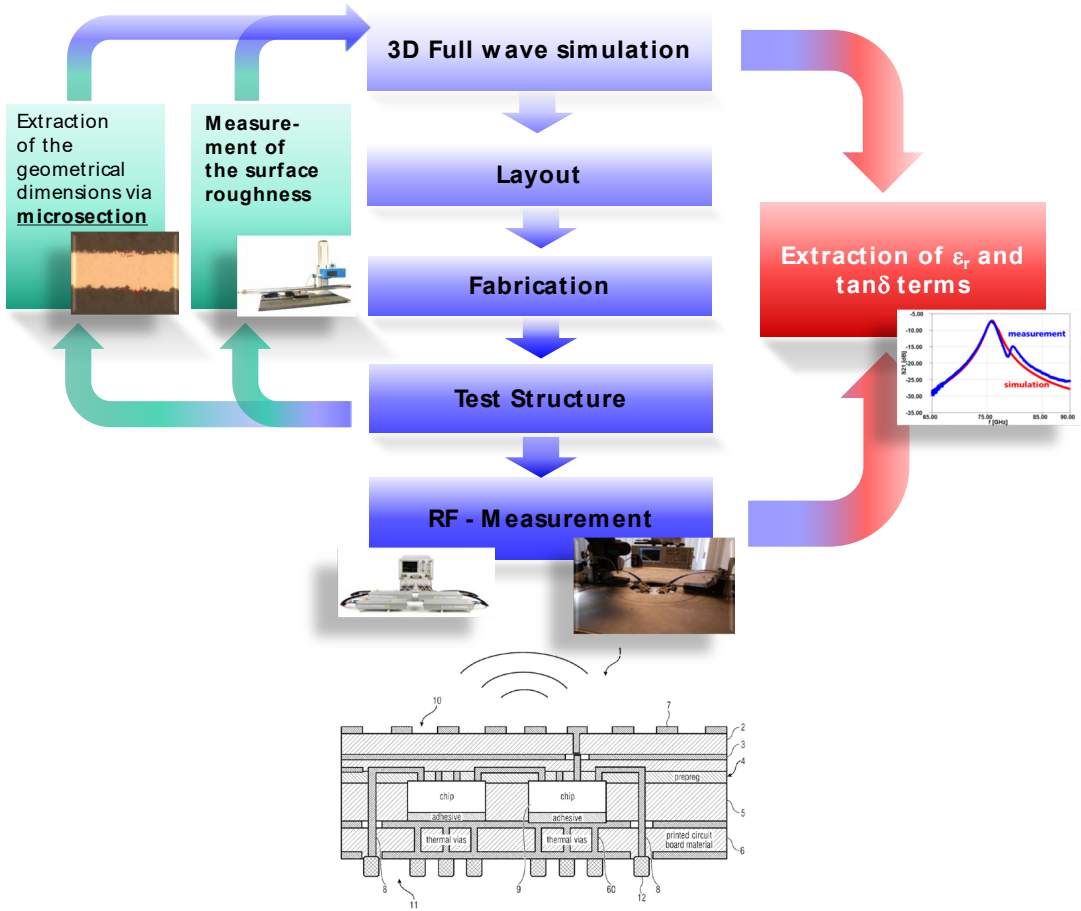
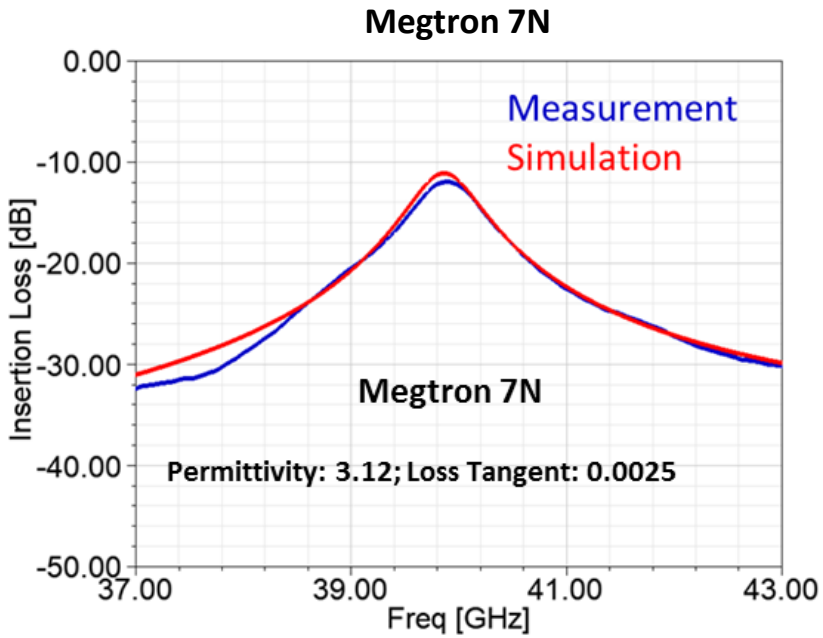
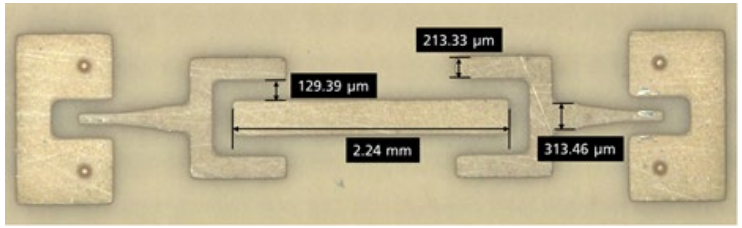
Ex.: Scalable 5G mmWave Base Station using Fraunhofer's AiP Platform – 2/5

- Measurement & characterization of packaging material







Fabricated planar resonator for measuring relative dielectric constant and loss tangent of Megtron 7N substrate

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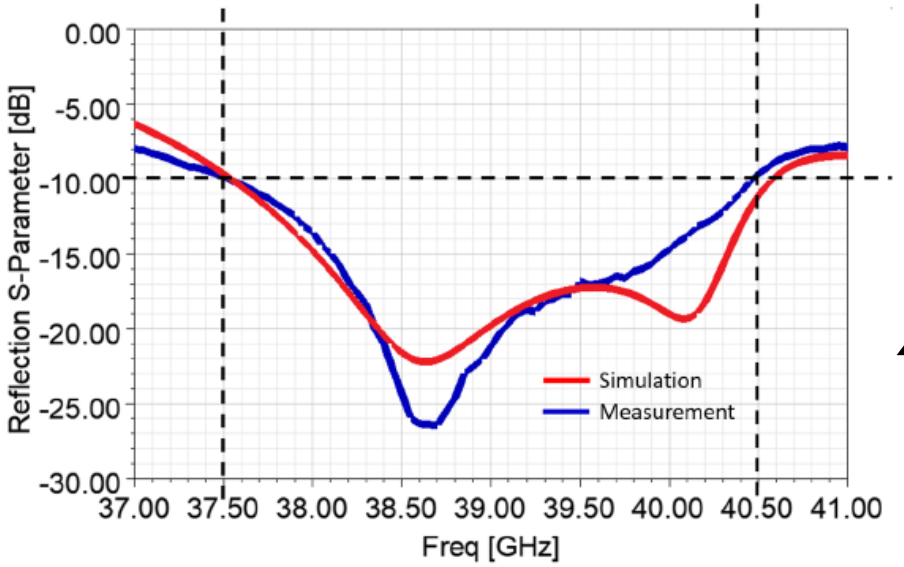
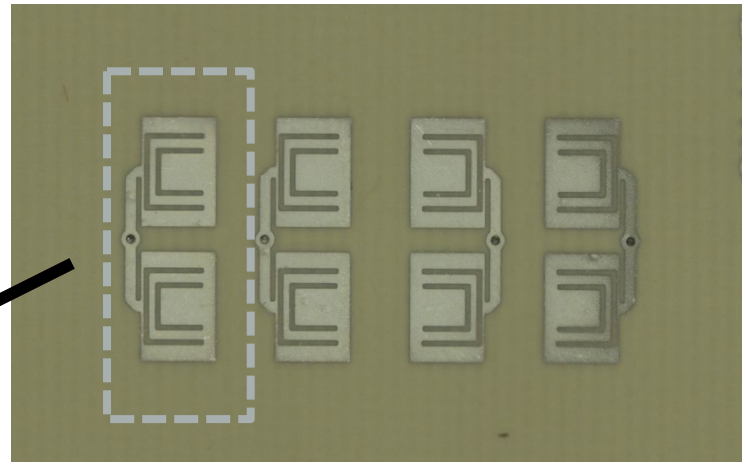
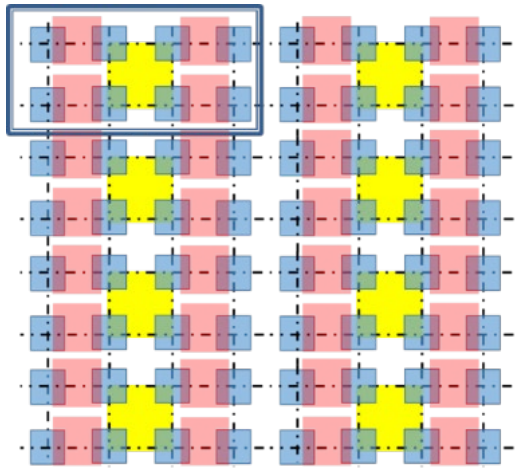
Ex.: Scalable 5G mmWave Base Station using Fraunhofer's AiP Platform – 3/5

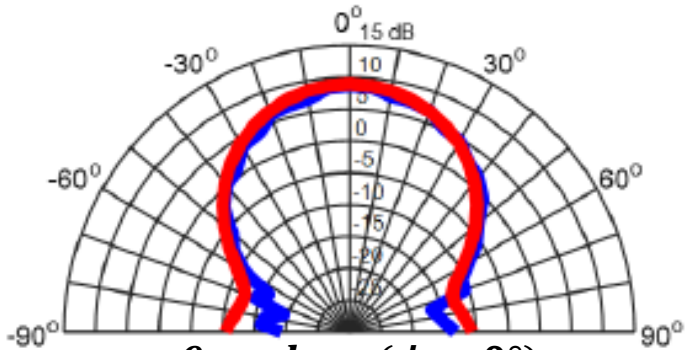




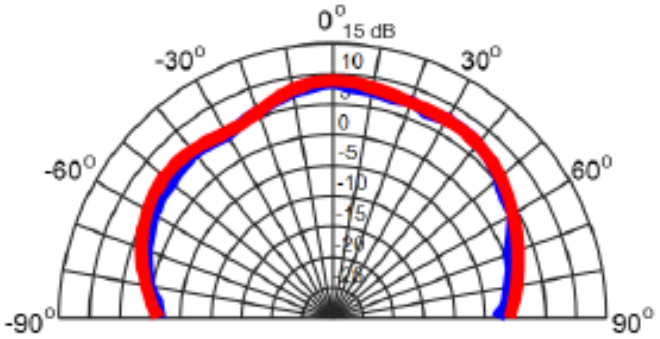
Fabricated antenna array



Parameter	Simulation	Measurement
Bandwidth	3 GHz (37.5 GHz – 40.5 GHz)	3.1 GHz (37 GHz – 40.6 GHz)
Peak Gain	9 dBi	8.8 dBi



$\theta - plane(\phi = 0°)$



$\theta - plane(\phi = 90°)$

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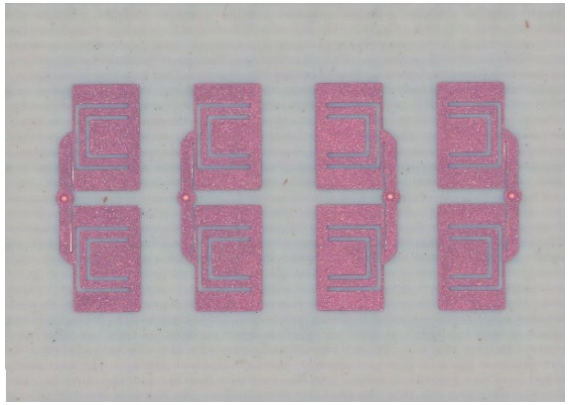
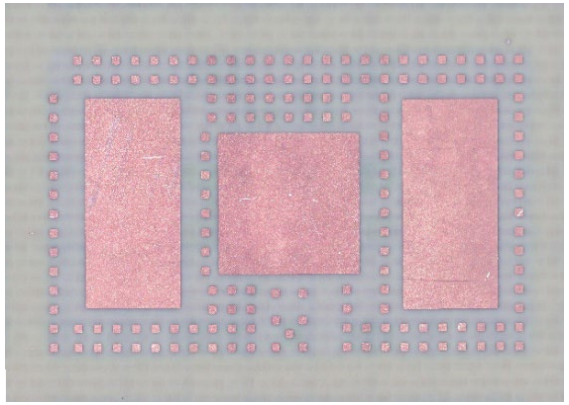
Ex.: Scalable 5G mmWave Base Station using Fraunhofer‘s AiP Platform – 5/5

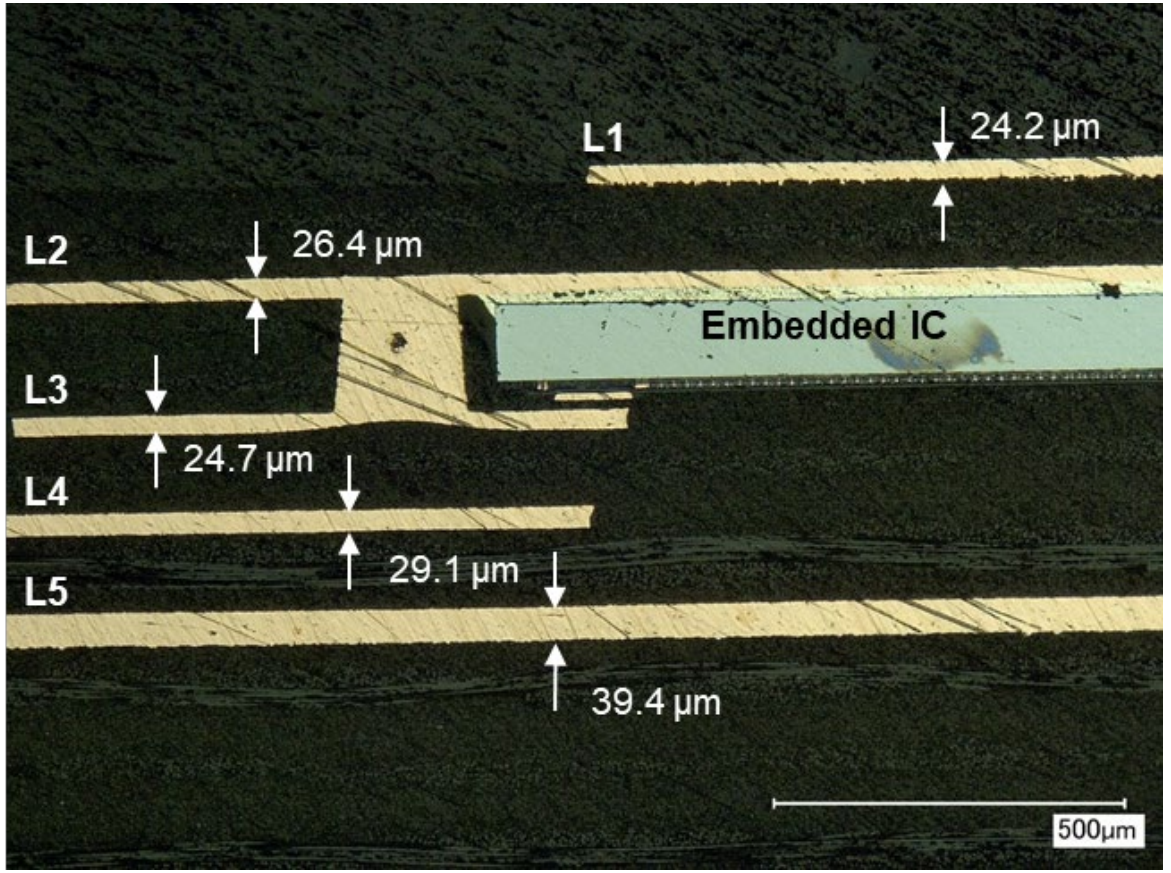
Fabricated complete 5G mmWave module



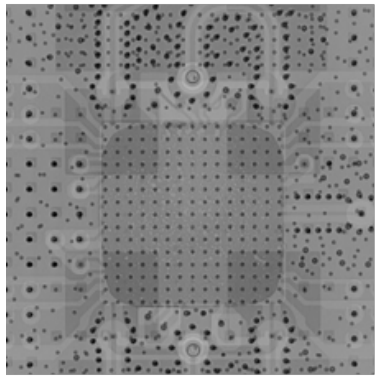
Top: Antenna layer

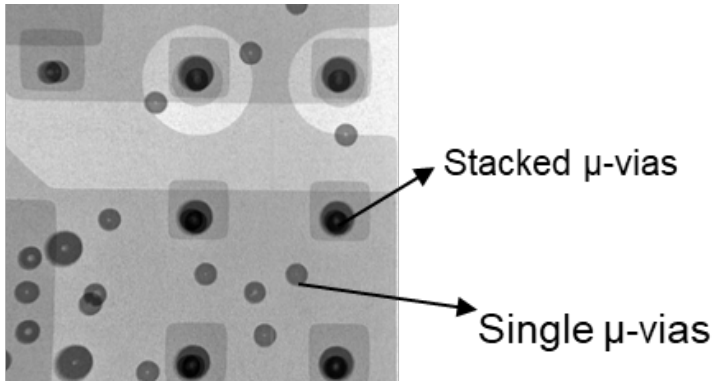


Bottom: LGA layer



Cross sectional view of fabricated module





Fabricated module X-ray image: Top View

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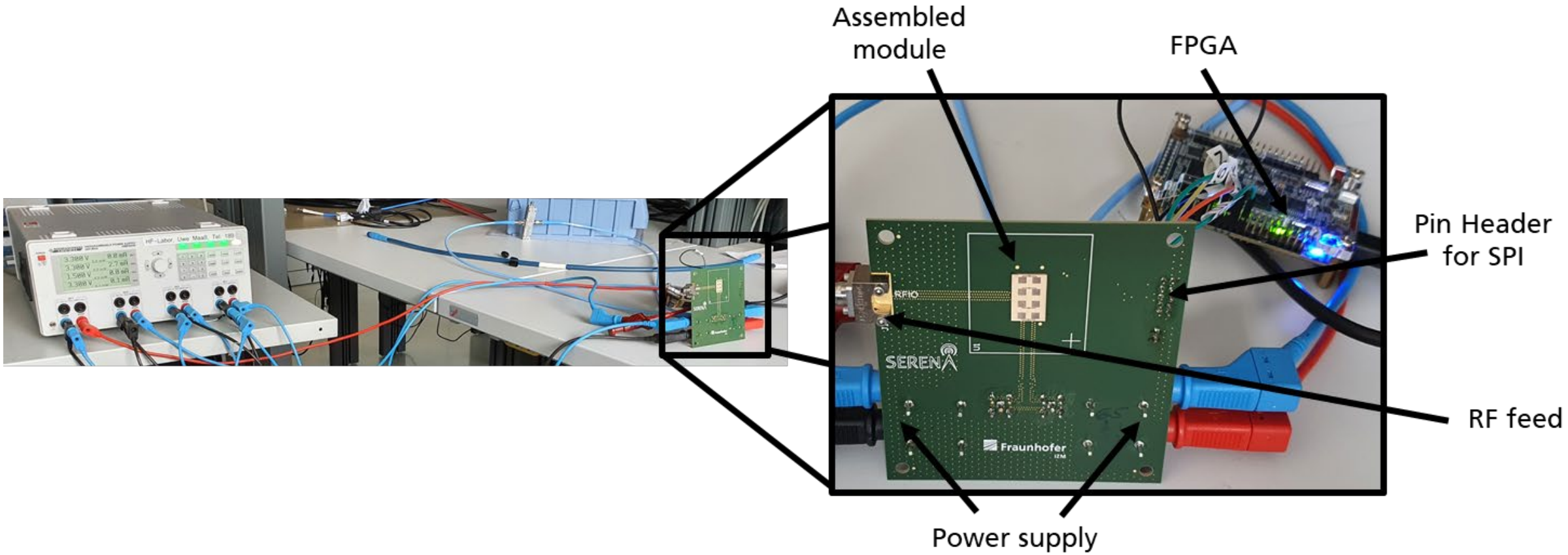
Ex.: Scalable 5G mmWave Base Station using Fraunhofer‘s AiP Platform – 5/5



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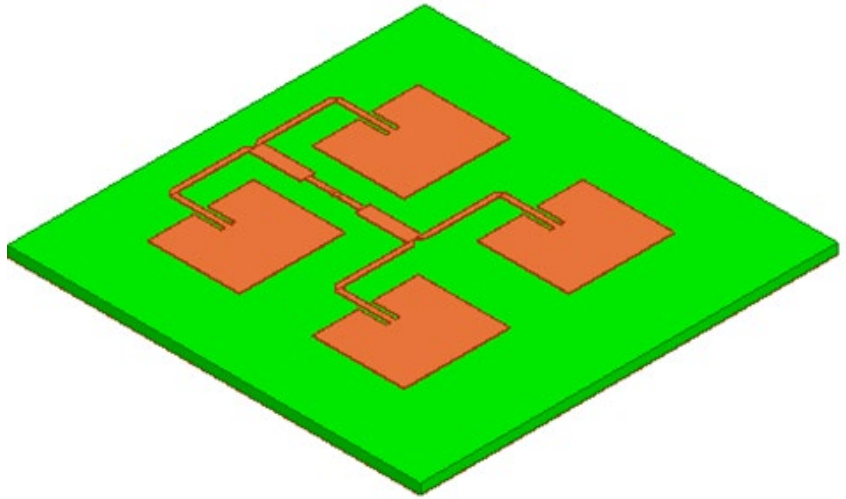
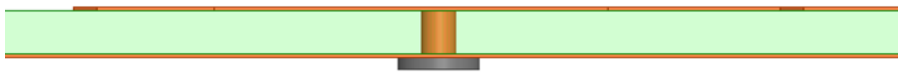
Role of Packaging Materials on 5G mmWave Modules – 1/5

- Packaging materials have significant impact on 5G mmWave modules
  - Antenna efficiency and antenna gain of modules
  - Communication distance
  - Energy efficiency
  - Cost
  - …

$$G(\vartheta,\varphi) = D(\vartheta,\varphi) * e_{diel.} * e_{cond.} * e_{mat.}$$



Top view of basic antenna array



Side view

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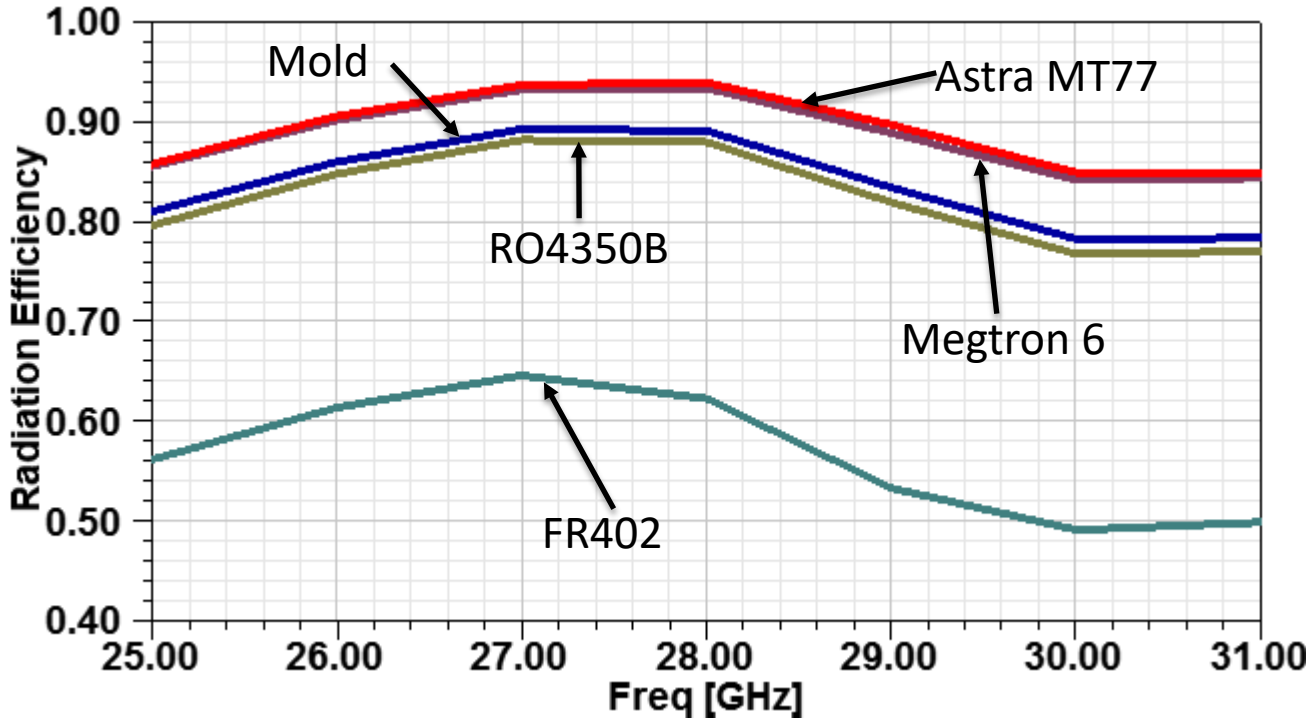
Role of Packaging Materials on 5G mmWave Modules – 2/5

- Packaging materials have significant impact on 5G mmWave modules
  - Antenna efficiency and antenna gain of modules



$$G(\vartheta,\varphi) = D(\vartheta,\varphi) * e_{diel.} * e_{cond.} * e_{mat.}$$

	DK	DF
RO4350B	3.66	0.004
Astra MT77	3	0.0017
Megtron 6	3.35	0.002
Mold	3.65	0.0035
FR402	4.3	0.015

Low Dk and low Df materials highly recommended for high performance 5G mmWave modules

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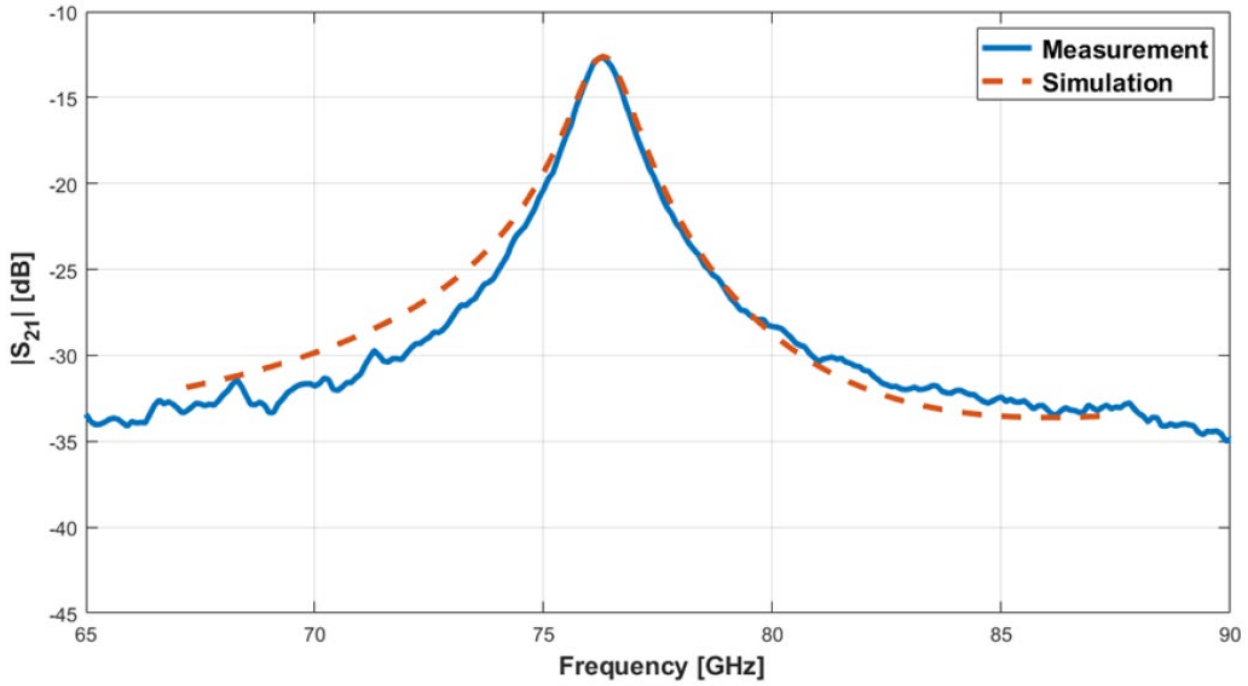
Role of Packaging Materials on 5G mmWave Modules – 3/5

- Packaging materials have significant impact on 5G mmWave modules
  - Antenna efficiency and antenna gain of modules
    - **Example of measured low Dk and Df material from Chemours**



Extracted material parameters	
ε_r	2.257 ± 0.009
tanδ	0.001 ± 0.0002

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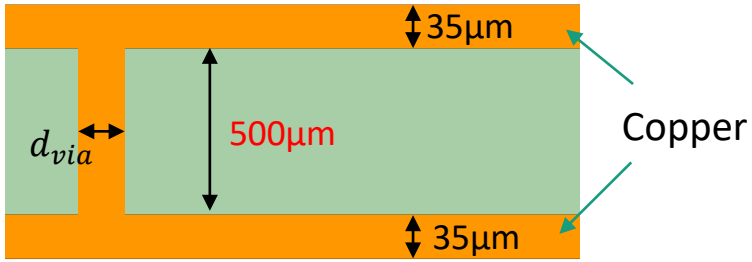
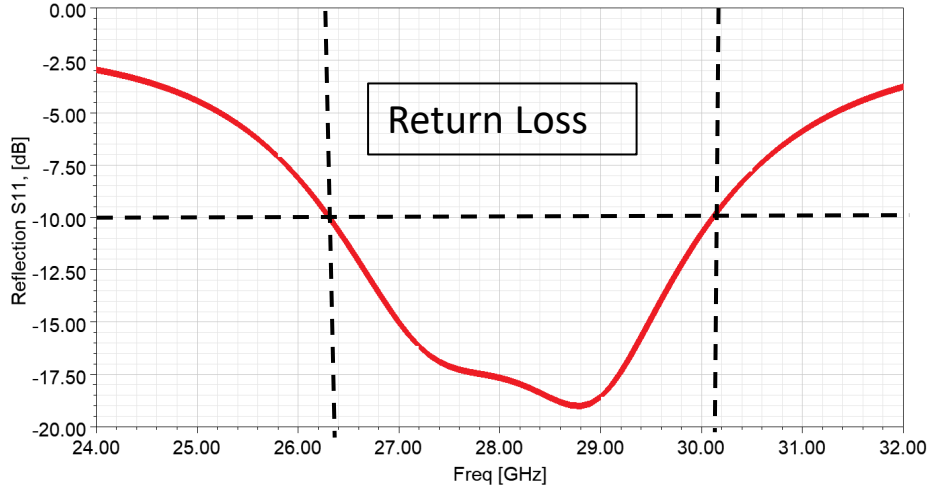
Role of Packaging Materials on 5G mmWave Modules – 4/5

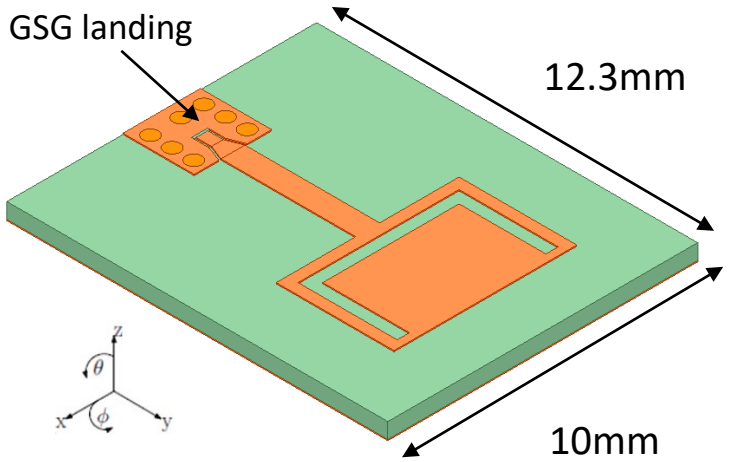
- **Very high antenna efficiency and gain due to Low Dk and Df; > 3GHz bandwidth**



$$\varepsilon_r = 2.25; tan\delta = 0.002$$

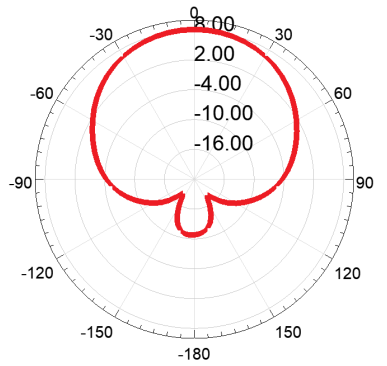


3D Model

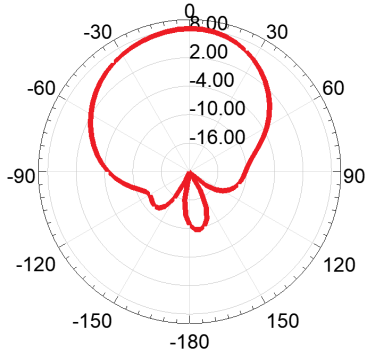


Parameter	Values
-10 dB Bandwidth	3.8 GHz
Gain	8.1 dBi
Radiation Efficiency	97.7%

$\theta - Plane\ (\phi = 0°)$



$\theta - Plane\ (\phi = 90°)$



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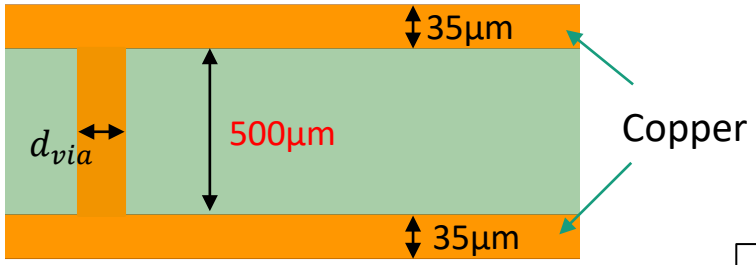
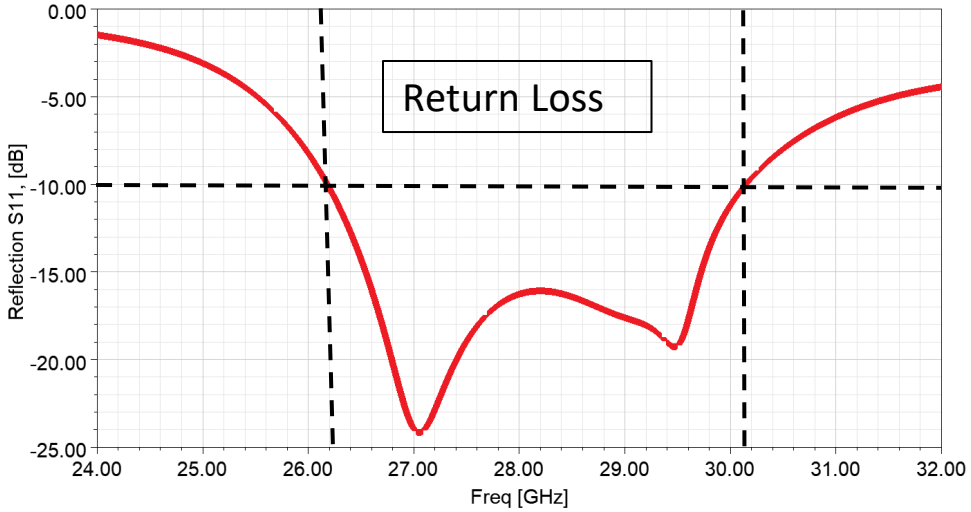
Role of Packaging Materials on 5G mmWave Modules – 5/5

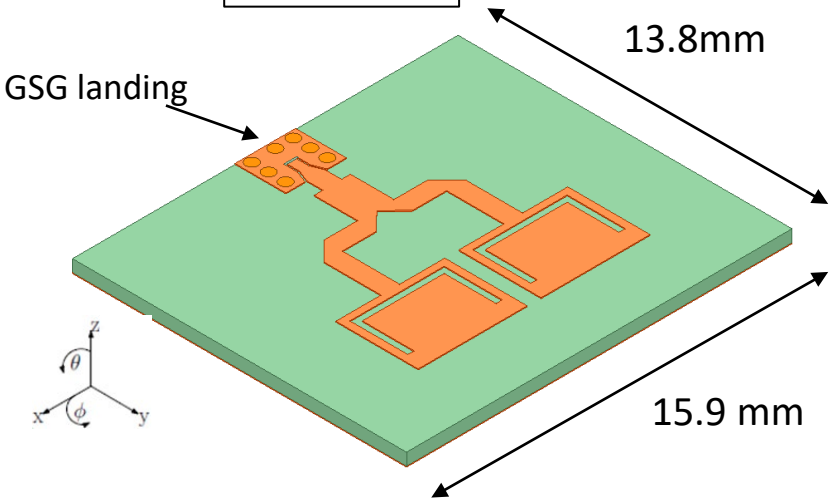
- **Very high antenna efficiency and gain due to Low Dk and Df; > 3GHz bandwidth**



$$\varepsilon_r = 2.25; tan\delta = 0.002$$

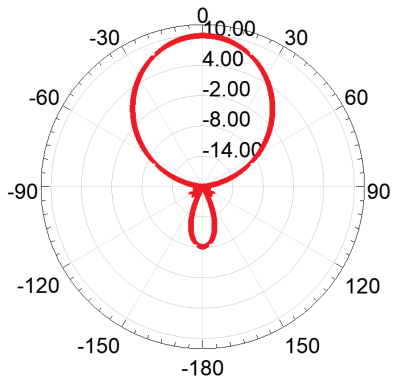


3D Model

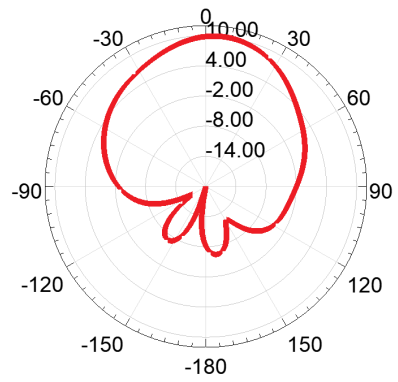


Parameter	Values
-10 dB Bandwidth	3.97 GHz
Gain	9.9 dBi
Radiation Efficiency	97%

$\theta - Plane\ (\phi = 0°)$



$\theta - Plane\ (\phi = 90°)$



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Thank you very much for your attention

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