Quantum
Mechanical &
Electromagnetic
Systems
Modelling Lab

# Accurate Characterization of Radiation from Interconnects on Interposer at mmWave Frequencies

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# Outline

Introduction

Design test vehicles

Design measurement set-up

Measurement results

Conclusions & future work

# Introduction

# Towards mmWave communication

Driverless cars

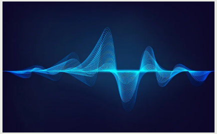
Smart cities

HD streaming

Bandwidth ↑

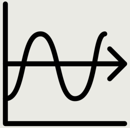
Latency ↓

Next-generation communication standard



mmWave frequencies

# Interposer to achieve heterogeneous systems

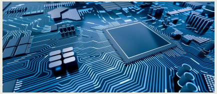


Frequency ↑

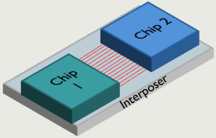
Solution:

%

Efficiency ↓
of active and
passive components



Heterogeneous systems
with complex interconnects




Interposer supports
passive components
& high-speed interconnects

# Radiated emission

- Proximity of different components & mmWave operation
  - → Stringent electromagnetic compatibility (EMC) requirements to guarantee proper performance
- Signal integrity high-speed lines need to be preserved through entire, complex routing
- Rising frequencies → electric length ↑ → lines become effective radiators
- Composite nature interposer makes identification noise sources almost impossible

# Goal

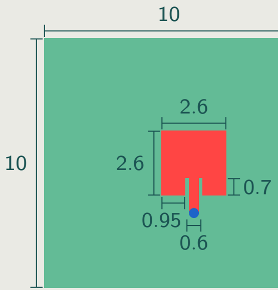
Study into radiation mechanism of interposers at mmWave frequencies

- Accurate measurements through well-designed set-up
  - → Particular care in shielding influence measurement equipment
- Designated interposer structures with corresponding simulation model
- Simulation study into mechanism responsible for discrepancy between measurement ↔ model

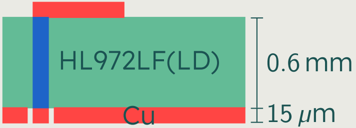
# Design test vehicles

# Interposer

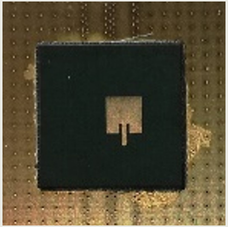
## Patch antenna




All dimensions in mm



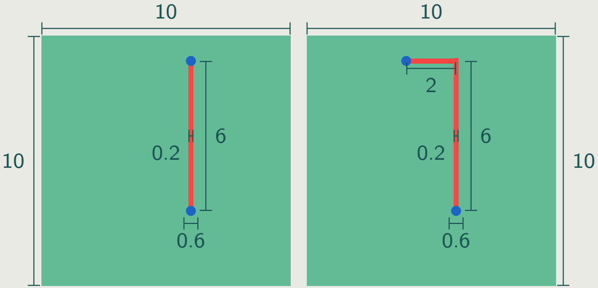

HL972LF(LD):
$\epsilon_r = 3.4$, $\tan\delta = 0.004$



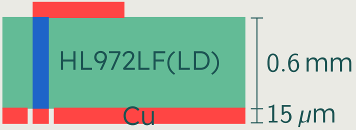
- Strong radiator → calibration structure
- Easy detection fabrication deviation

# Interposer

## Interconnects




All dimensions in mm

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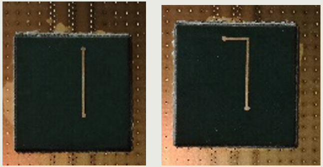
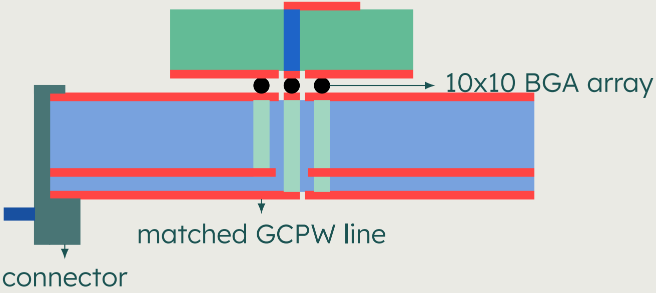


- Archetypal microstrip interconnects
- Two variants: top via shorted or matched to 50 Ω

# Measurement PCB

Design & rationale

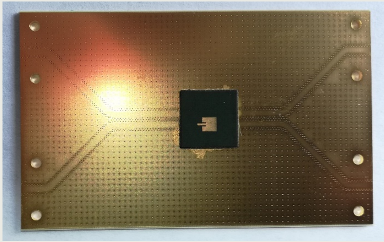




Megtron 6:
$\epsilon_r = 3.6$, $\tan\delta = 0.004$

PCB measures 6.5 cm by 4 cm

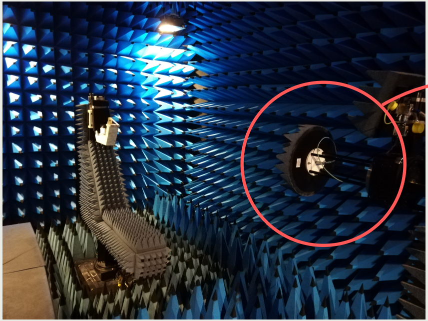
- Accommodates connector and fixes interposer to measurement system
- Feed line at the back to minimize forward radiation



# Design measurement set-up

# Anechoic chamber

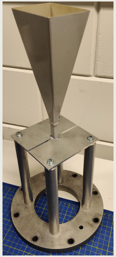
Specifications



Spherical measurement system in full anechoic mode

Calibration

WR-34 Probe

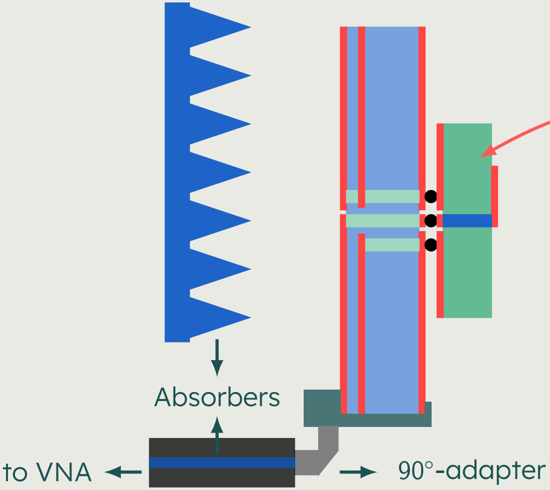


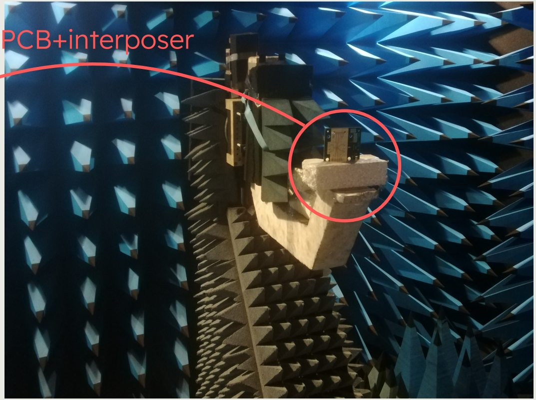
standard gain horn

Losses GCPW line PCB calibrated via dedicated TRL set

# Anechoic chamber

Shielding

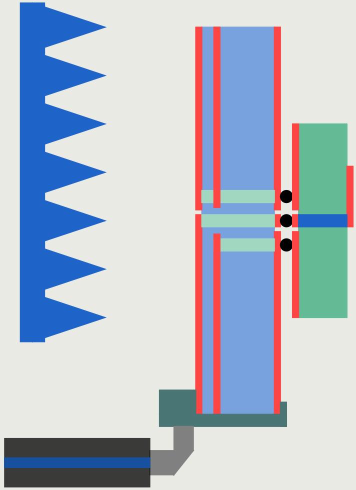



Set-up at DUT side

# Anechoic chamber

## Shielding

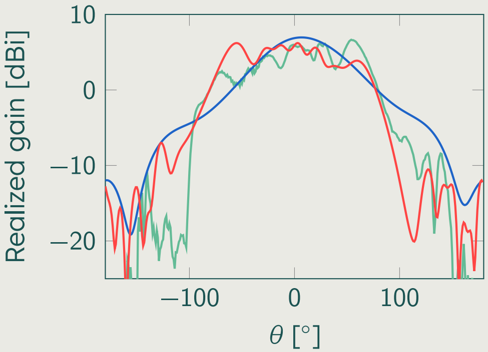


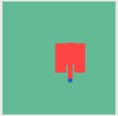
- Right-angled adapter right at the connector to avoid long cable in the plane of the interposer
- Cable wrapped in RF absorbent foam for additional shielding
- Pyramidal absorbers at the back of the PCB to avoid unwanted reflections

# Measurement results

# Patch antenna

Measurement vs. simulation model



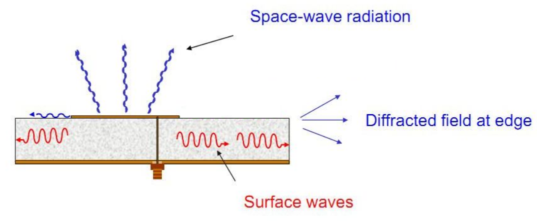
- Realized gain in the $\phi = 90°$ cut at 28 GHz
- Interposer only model exhibits typical radiation pattern patch antenna
- Measured pattern has broadened beam and suppressed back radiation due to PCB and ...
- together with the full model (interposer + PCB) exhibits a prominent, superimposed ripple

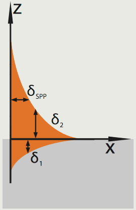
→ Origin turns out to be *surface waves* originating on the interposer, interacting with the PCB's ground plane

# Surface waves

## Main characteristics

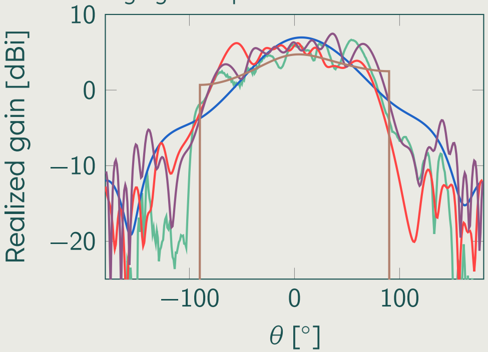
- Surface waves or (Sommerfeld-)Zenneck waves are cylindrical waves supported by interfaces of media with different $\epsilon$
- Decay slower ($\propto 1/\sqrt{r}$) than space-waves ($\propto 1/r$) in the propagation direction but decay exponentially along their normal axis
- Classified in typical waveguide modes: transverse electric (TE) and magnetic (TM) modes
  - Interposer only supports TM0 mode at 30 GHz



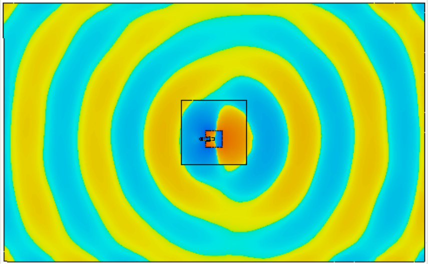



# Surface waves

Influence large ground plane




simplified model: interposer backed by PEC ground plane with PCB's dimensions

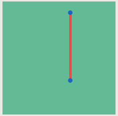


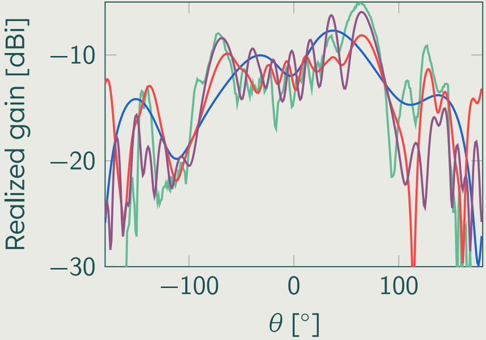
- Neither the interposer model nor one backed by an infinite ground plane, show any ripple
- However, a simplified model does give rise to the observed phenomenon

→ Surface waves originate on interposer and interact with electrically large ground plane PCB

# Surface waves

## Interconnect structures



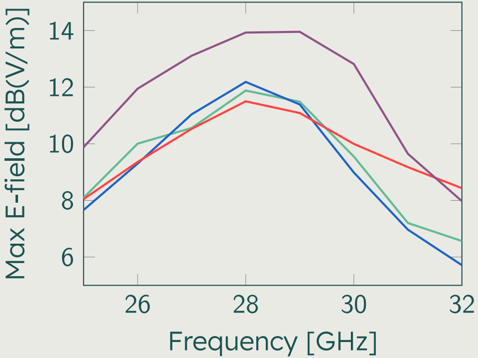



- Realized gain in the $\phi = 90°$ cut at 28 GHz for a shorted straight line
- Ripple does occur for weak radiators in measurement, full and simplified model but not in the interposer model, further demonstrating its origin

# Maximum electric field strength

Patch antenna

In an EMC context, a more relevant quantity than the gain is the maximum electric field strength at a fixed input power and distance. Does the ripple have an effect on such measure?



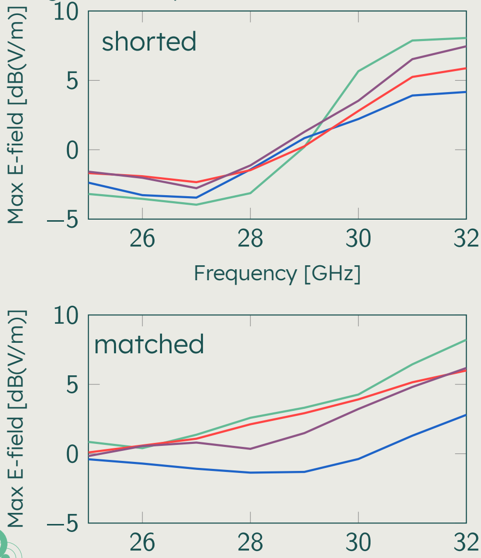

Seemingly not for the patch antenna:

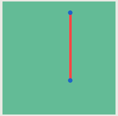
- Measurement, full & interposer model agree very well
- Simplified model lacks losses

→ Ripple compensates for gain reduction due to ground plane

# Maximum electric field strength

Straight microstrip

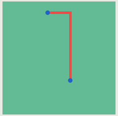


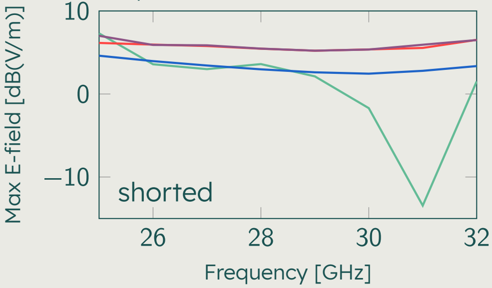
- Interposer model underestimates max. measured field by up to 6 dB
- Full and simplified predict very similar levels

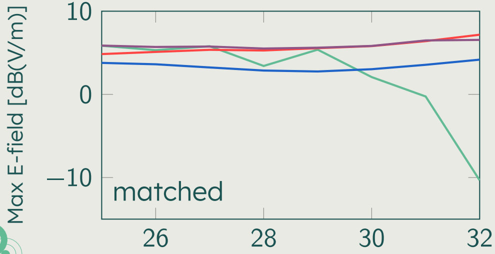
→ Ripple has larger impact on microstrip line than on the patch antenna

# Maximum electric field strength



Bent microstrip




- Measurements exhibit unidentified dip in radiation
  - No decisive cause found
  - Presumably an unidentified mismatch issue
- Full and simplified predict very similar levels
- Difference with interposer model is a consistent 2–3 dB

→ Ripple has larger impact on microstrip line than on the patch antenna

# Conclusions & future work

# Conclusions

Five mmWave test vehicles to identify dominant radiation sources

Dedicated measurement set-up to prevent perturbation by external factors

Combined simulation and measurement strategy is able to predict maximum field levels accurately …

… and reveals issue of interposer's surface waves interfering with PCB to (negatively) impact emission performance

# Future work

Investigate (cost-effective) strategies to eliminate excitation surface waves

Explore design of vertical via topologies and other interconnect approaches to assess radiated emission

Realize, model and measure differential interconnects to assess common mode vs. differential mode performance quest.

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