On-Board and On-Chip Millimeter-Wave Antennas

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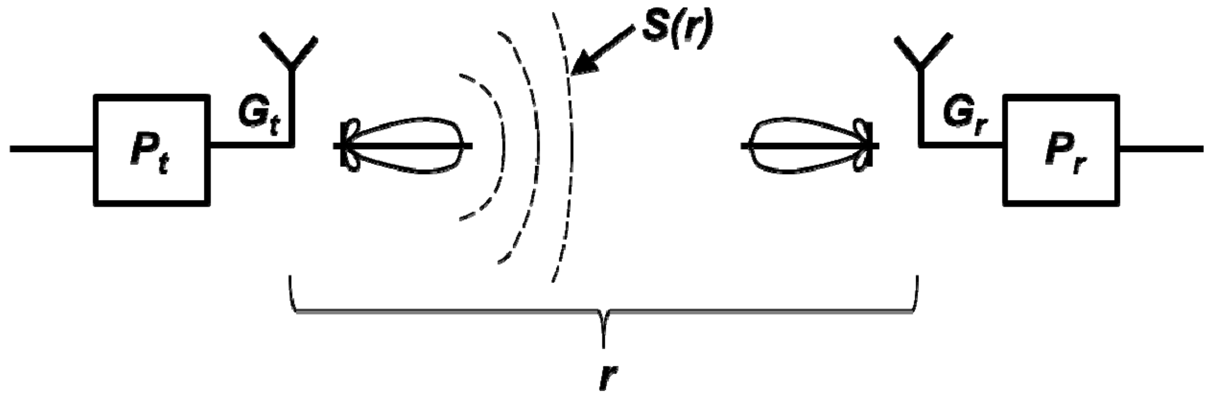
~ 27´000 students (BSc, MSc, PhD); mostly in engineering & natural sciences


[University of Stuttgart Campus Vaihingen]

[Stuttgart – headquarter of Mercedes & Porsche]

Motivation

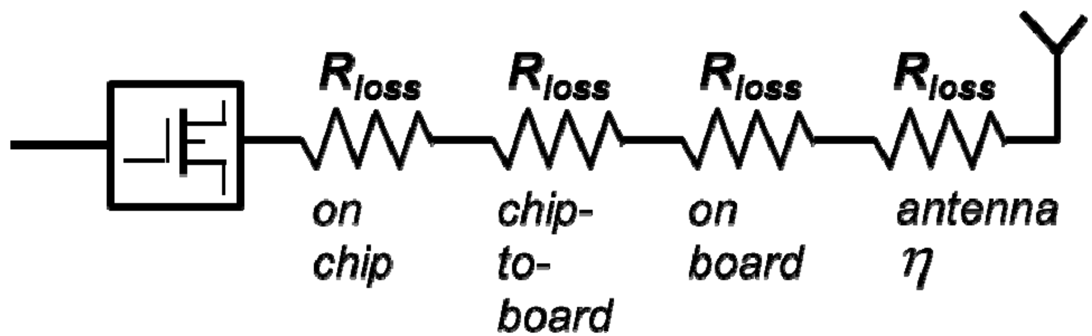
Basics



Wireless short-range links described by Friis' equation:

$$P_{rec} = P_{trans}\,\eta_{trans}\,D_{trans}\,\eta_{rec}\,D_{rec}\left(\frac{\lambda}{4\pi r}\right)^2$$

Requirement of high antenna radiation efficiency & low loss between antenna and amplifier

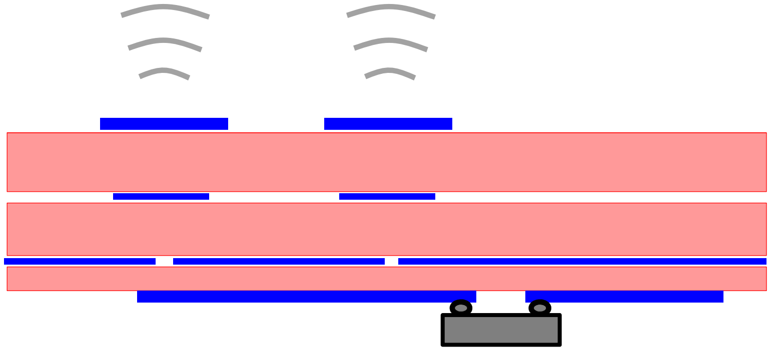


Additional requirements: bandwidth (~15% for 60 GHz WiGig) and cost

Examples of typical 60 GHz WiGig antennas

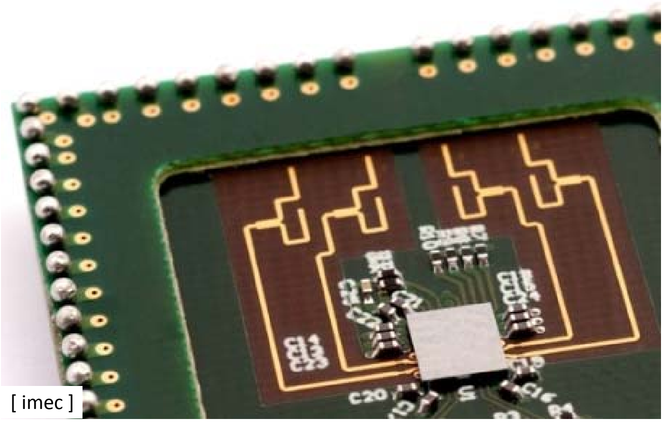
Stacked patch antenna on polymer multilayer board:

→ ~ 55% antenna efficiency



Microstrip or stripline feedline + flip chip mount + on-chip line:

→ 1/3 … 2/3 of power lost from antenna to transistor



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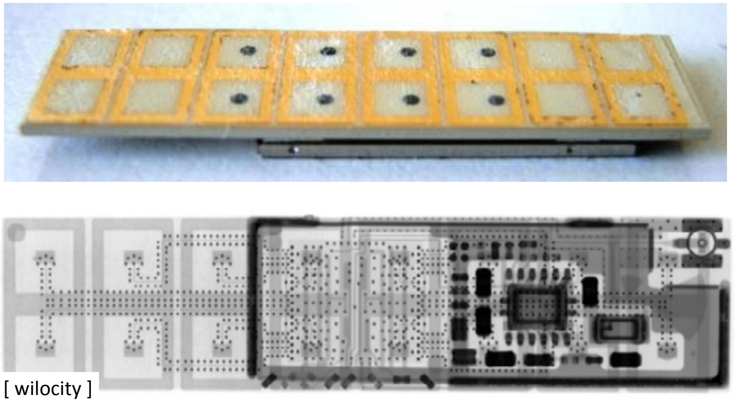

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Outline

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Surface-mount on-board antennas:

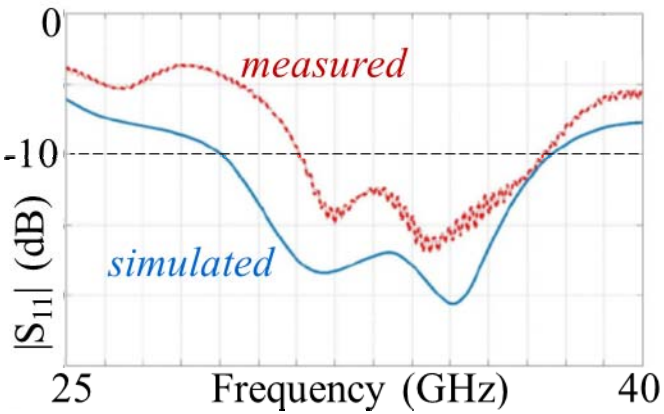
- A patch antenna based on a stamped metal sheet
- A metalized molded plastic radiator
- A dual-polarized edge-mount radiator

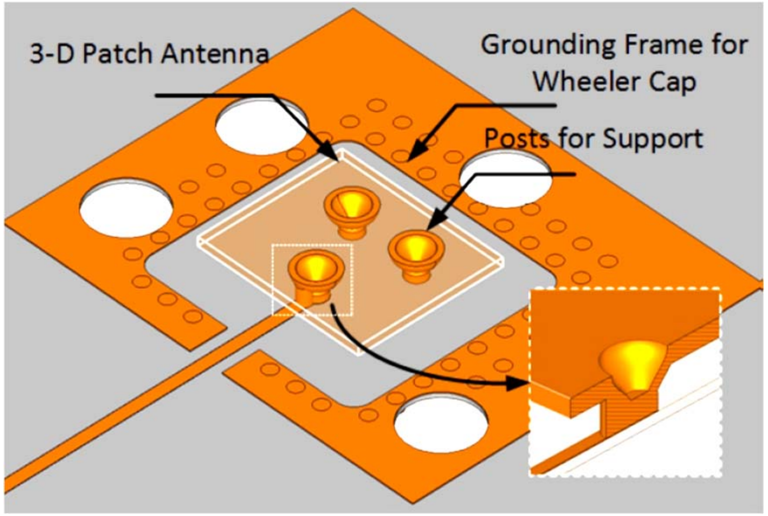
High-efficiency on-chip antenna:

- The spherical dielectric resonator on-chip antenna

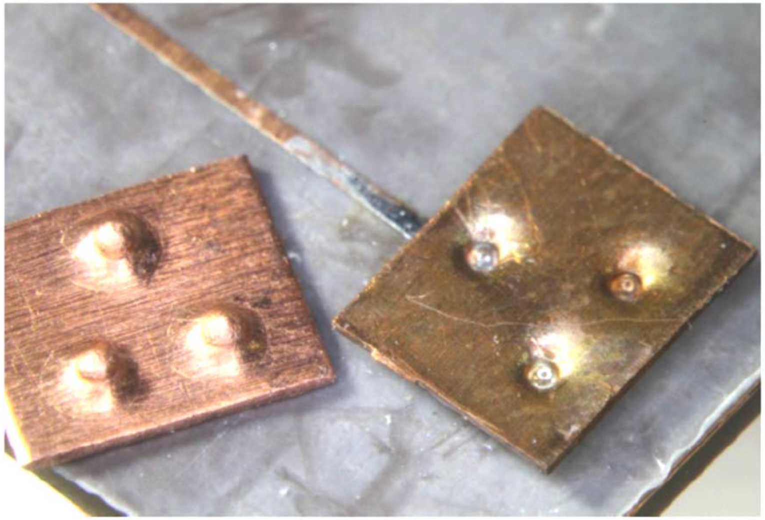
A patch antenna based on a stamped metal sheet

- Microstrip feedline on thin single-layer substrate without metal via-holes (→ weak surface-wave excitation, low cost)
- Stamped metal sheet structure, surface-mount assembly (→ low cost)
- Bandwidth >15%
- High efficiency ~90% @ 30 GHz

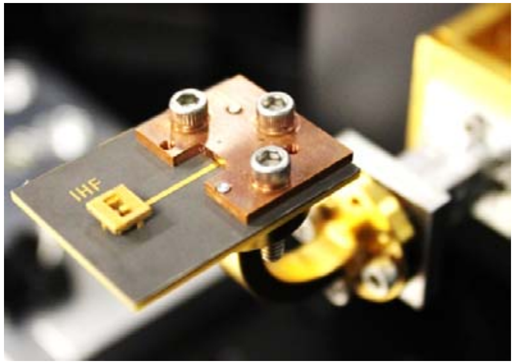




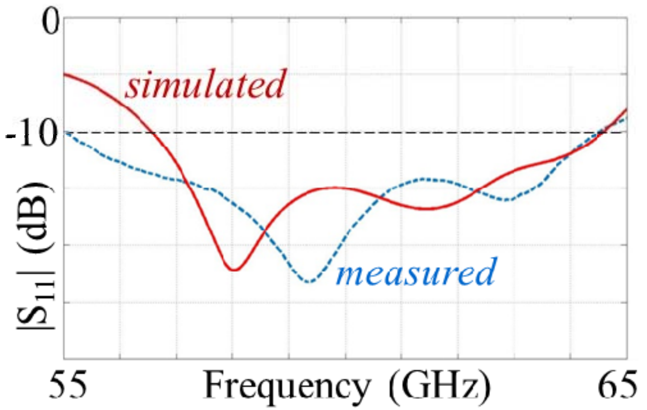
patch size 4.25 x 5 mm²

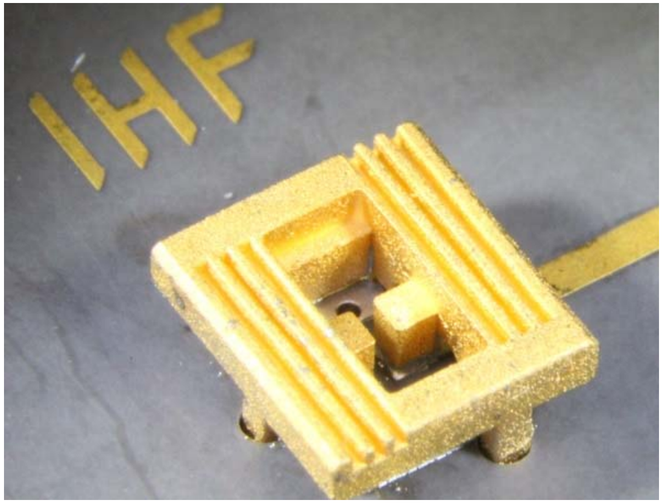


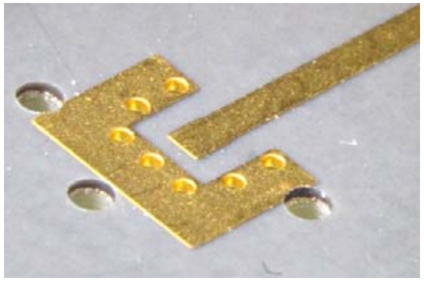
A metalized molded plastic radiator

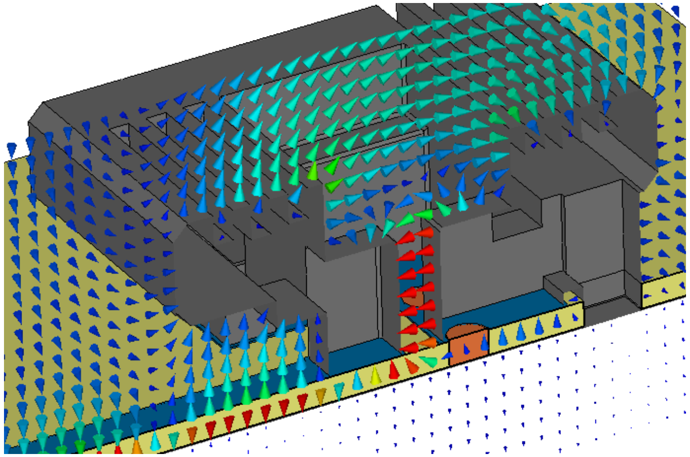


- Microstrip feedline on thin single-layer substrate (→ weak surface-wave excitation, low cost)
- Fully metalized injection molded plastic structure, indentation free, SMT assembly (→ low cost)
- Bandwidth ~15%
- Efficiency ~90% @ 60 GHz (measured)









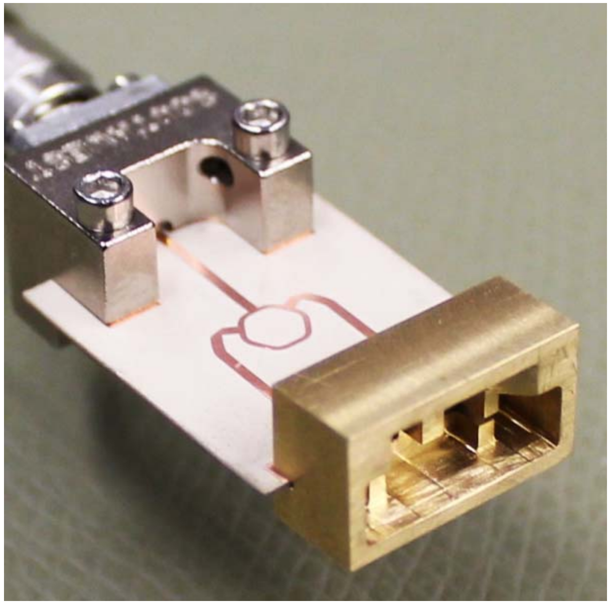
A dual-polarized edge-mount radiator

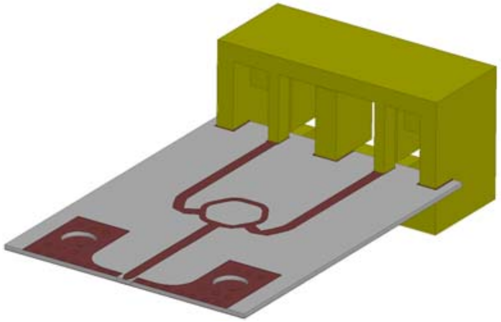
Radiation in board edge direction

Two feeds: in-phase for vertical polarization or out-of-phase for horizontal polarization

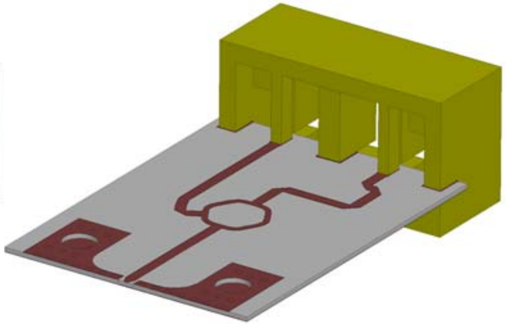
Single layer microstrip feed, indentation-free 3D part, bandwidth > 10%, high efficiency

… ongoing project for size reduction towards 0.6 λ x 0.6 λ

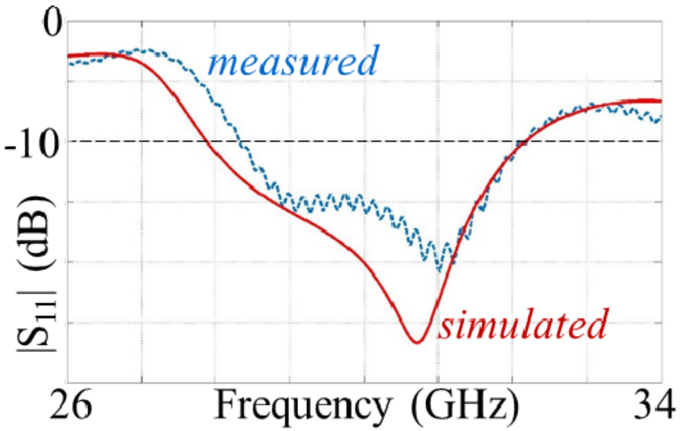




feed 0°/ 0°



feed 0°/ 180°



-12 dB bandwidth 28.5 GHz – 31.8 GHz

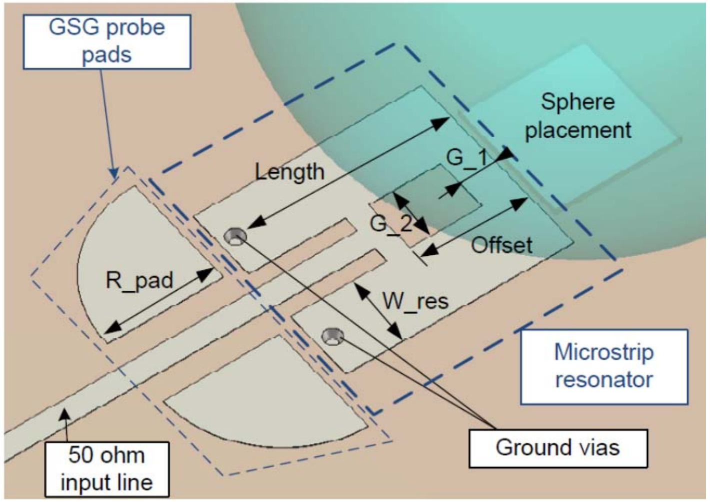
The spherical dielectric resonator on-chip antenna (1/2)

Dielectric sphere fed by thin-layer microstrip resonator
(→ lowest loss between transistor and „air“,
small on-chip footprint,
can be tested @ 50Ω GSG before mounting the sphere,
cheap accuracy & alignment,
dual-polarization possible)

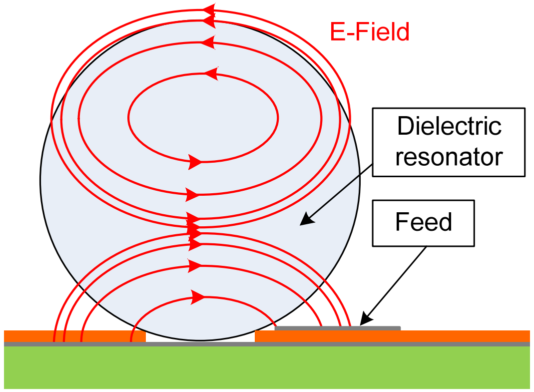
Bandwidth > 5%

High efficiency ~70% @ 68 GHz including microstrip feed resonator

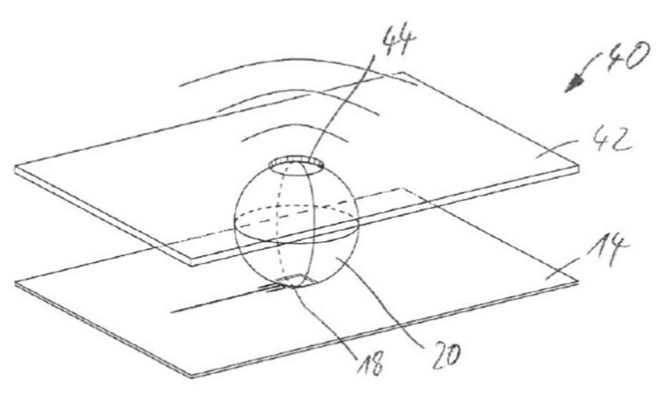
1.59 mm alumina sphere for operation at ~68 GHz



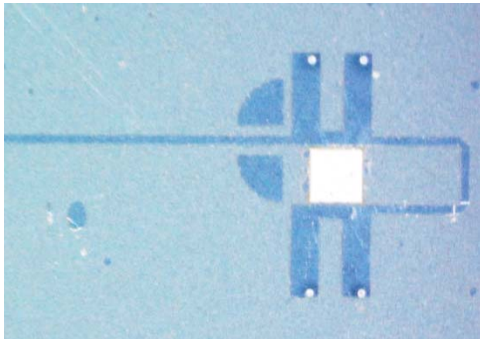
The spherical dielectric resonator on-chip antenna (2/2)



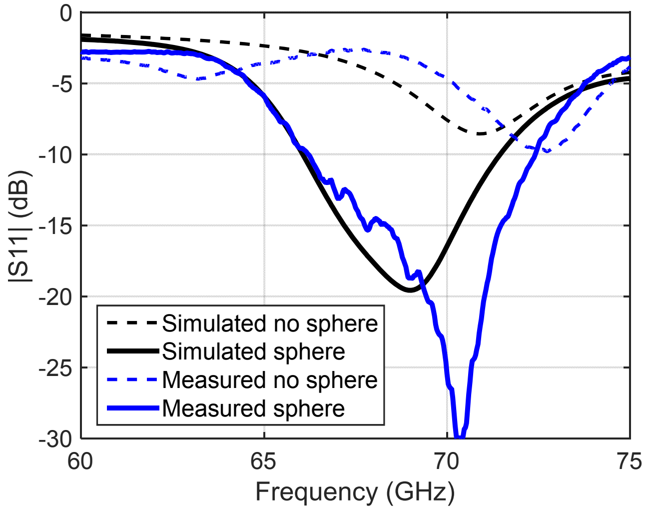
the resonance mode



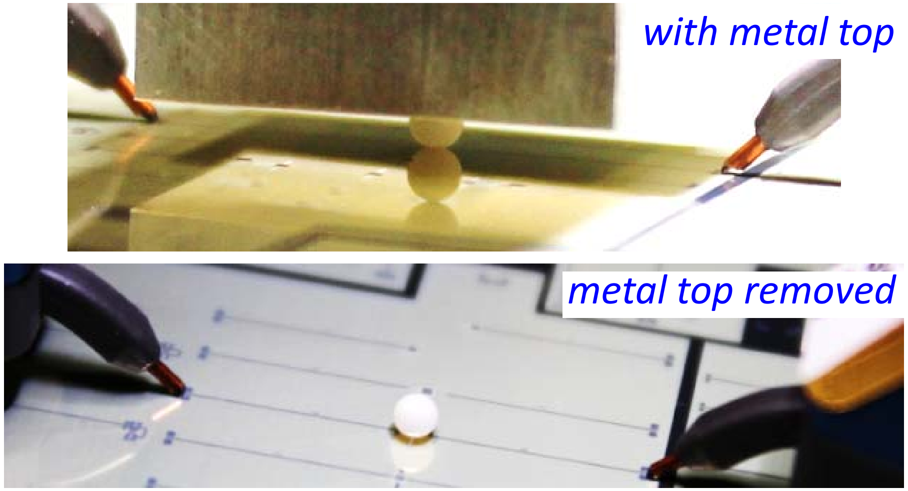
clamping with dielectric sheet



test structure (Si, 24µm BCB, AlSiCu)



measured impedance match



non-radiative resonator test (Q_u=1580 @ 65 GHz)

Conclusion

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Efficiency (antenna + feed loss) is important for mm-wave systems

Surface-mount on-board antennas are

- of high efficiency (1dB…2dB better than multi-layer patch),
- low cost (cheap structure, cheap assembly, low-cost board),
- broad bandwidth easy to achieve (10%...15%).

On-chip dielectric sphere antenna is

- of high efficiency (3dB…5dB better than chip-board-patch),
- low cost (cheap accuracy and alignment),
- approx 5% bandwidth (larger with added external resonators).

Acknowledgment

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Thank You

Questions?

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