Antenna innovations in CWT/e projects

Electromagnetics (EM) group

Prof. Dr. Ir. Bart Smolders

October 18 2011

Electrical Engineering

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Where innovation starts

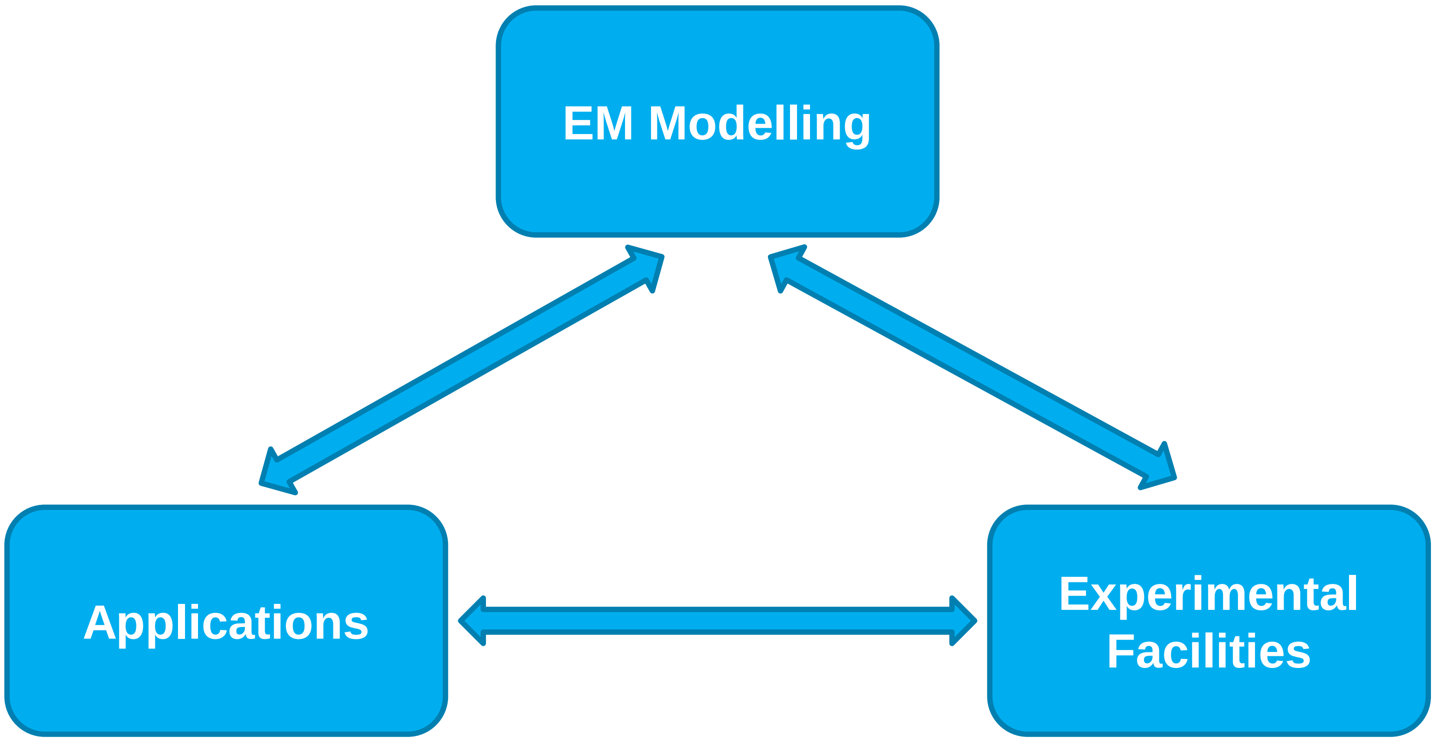
Content

- Antenna team with CWT/e
- mm-wave antenna activities @CWT/e
  - Printed and dielectric antennas
  - Circular polarisation
  - Antenna-on-Chip (AoC)
  - THz antennas
  - mm-wave antenna test facility
- Netherlands Antenna Framework (NAF)
- Conclusions

Antenna team within CWT/e
Within ElectroMagnetics group

- **Scientific staff:**
  - Prof. Dr.ir. Bart Smolders
  - Prof. dr. Giampiero Gerini (pt)
  - Prof. Dr. Anton Tijhuis
  - Dr.ir. Matti Herben
  - Dr.ir. Huib Visser (pt)
  - Dr.ir. Martijn van Beurden
  - Dr.ir. Peter Smulders
- **Technical staff**
  - Ad Reniers and Ing. Rainier van Dommele
- **3 Postdoc positions, 10 PhD/PDEng positions**
- **Embedded in CWT/e.**

Balanced expertise of EM Team



Mm-wave antenna activities @ CWT/e

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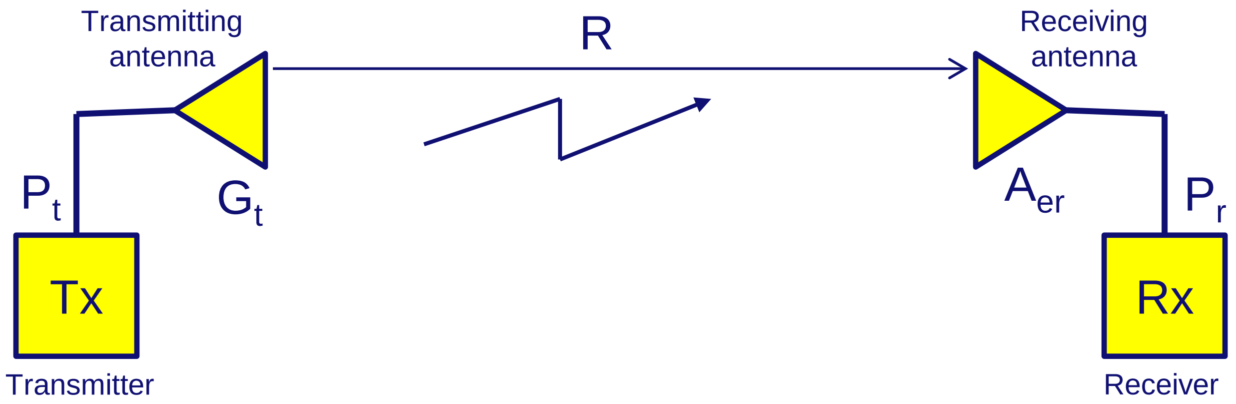
Path loss "confusion" at 60 GHz

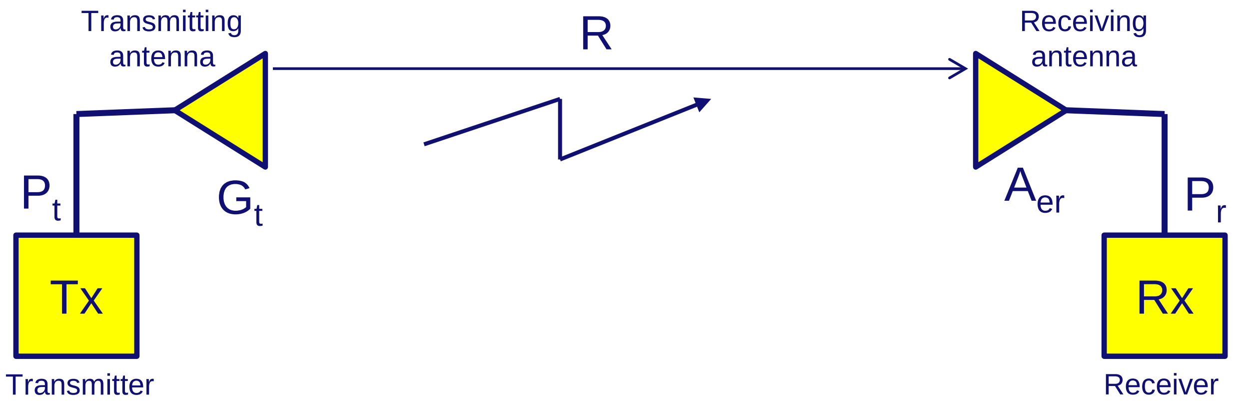


$$P_r = \frac{P_t \, G_t \, A_{er}}{4 \pi R^2}$$

- **Received Power P_r is <u>independent of freque</u>ncy.**
- **Path loss is not a function of frequency!**
- **A_{er} (Effective Antenna Area) [m^2] is the key parameter**

- **N.B: We neglected the O_2 absorption ~10 dB/km**

Design challenge at mm-waves



- A_{er} (Effective Antenna Area) [m^2] is the key parameter
- Need to develop antennas with large "relative" A_{er}
  - Phased-arrays
  - Lenses and reflectors
  - Focal-plane arrays

Printed and dielectric antennas at 60 GHz

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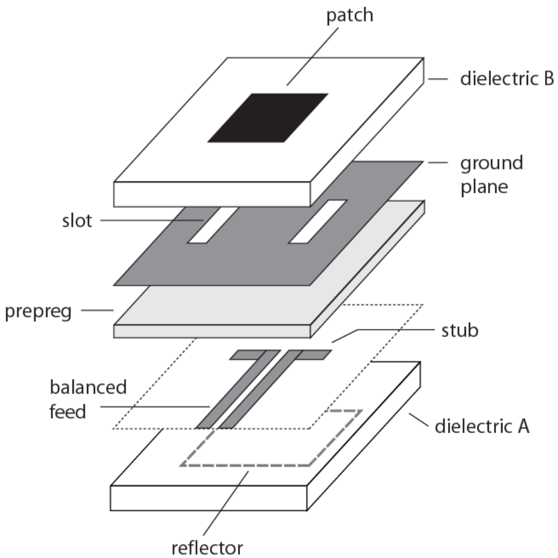
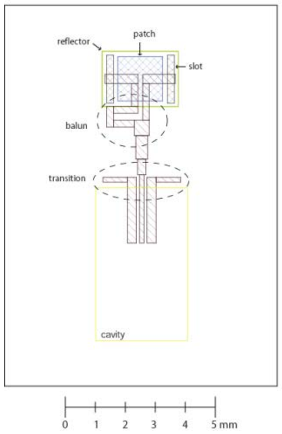
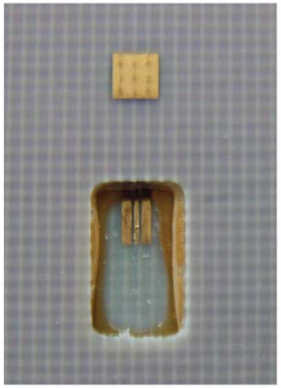
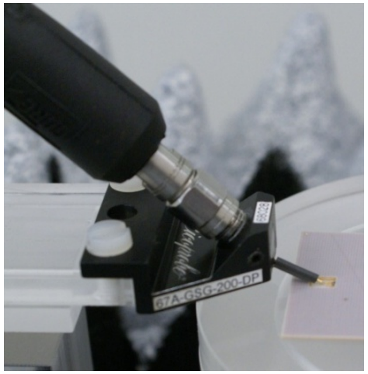
Wideband antenna for 60 GHz wireless LAN

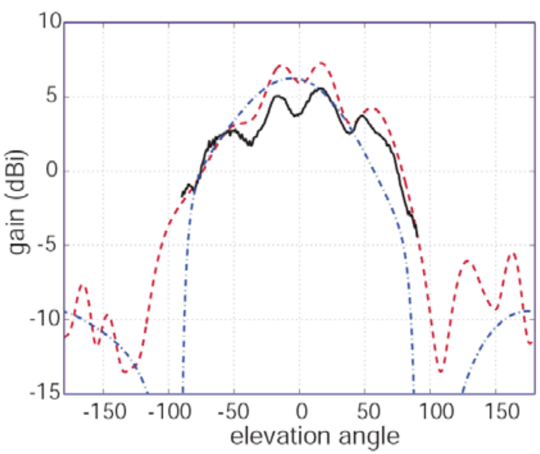


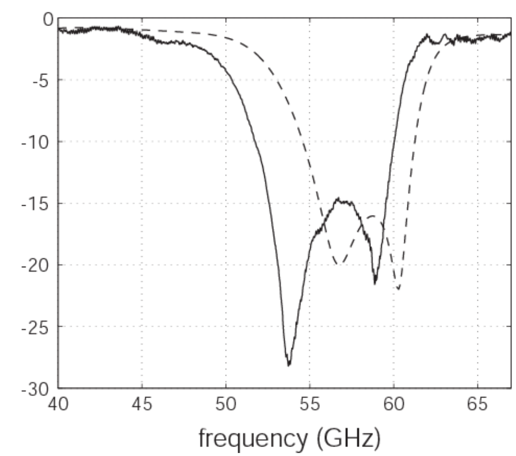






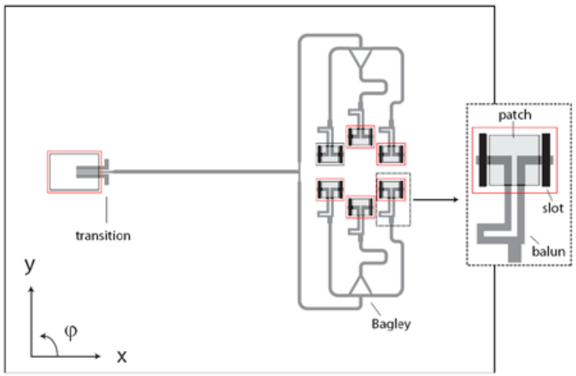
- Balanced-fed aperture-coupled patch antenna
  - realised in printed circuit-board
  - no vias
  - high radiation efficiency
    - >80%
  - bandwidth
    - 10-15 %

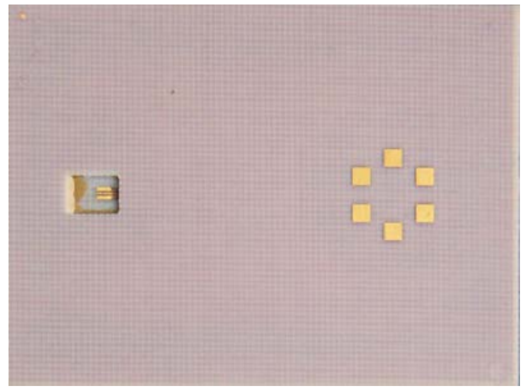


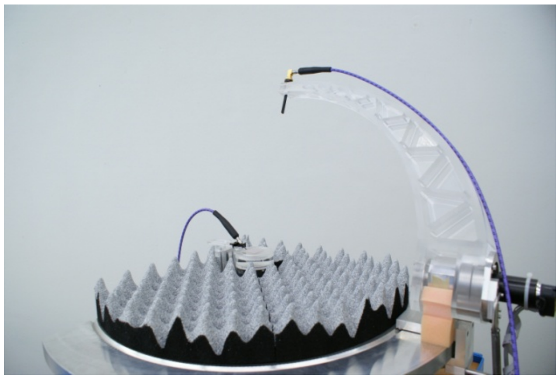


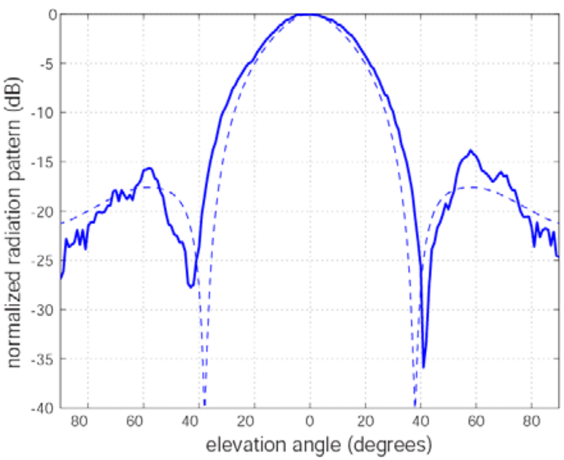
- measurements (**solid**)
- simulation [CST] (**dashed**)
- simulation [Spark] (**dash-dot**)

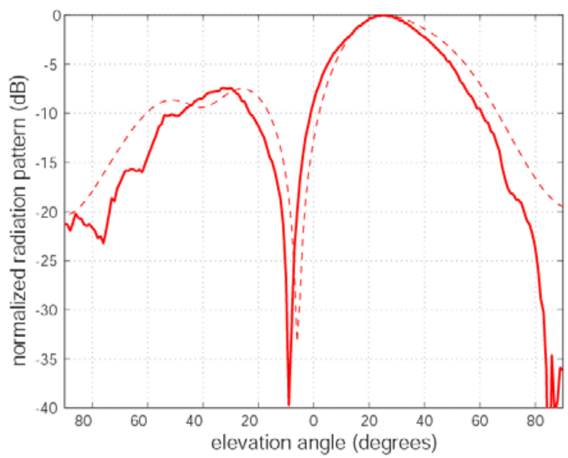
Beam scanning with planar antenna array

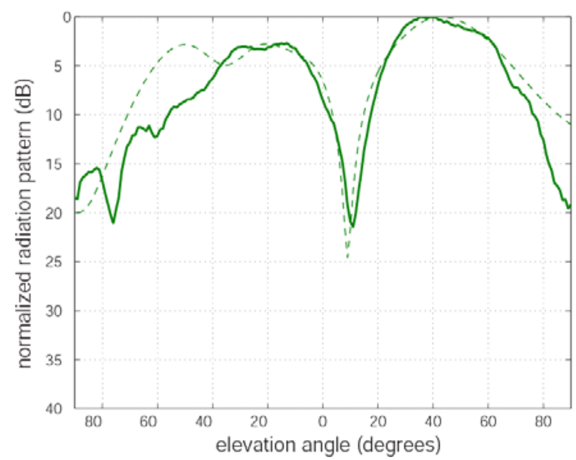












- simulation (dashed)
- measurement (solid)

Planar array has limited scan range

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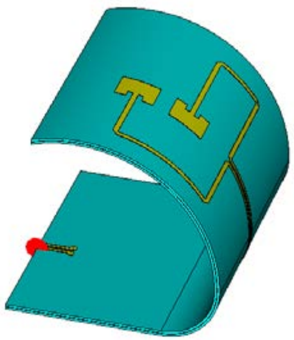
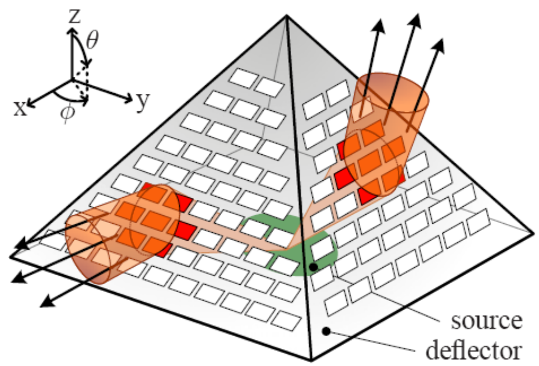
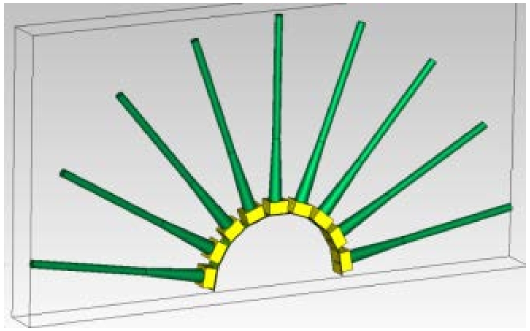
Wide-angle beam scanning with high Gain



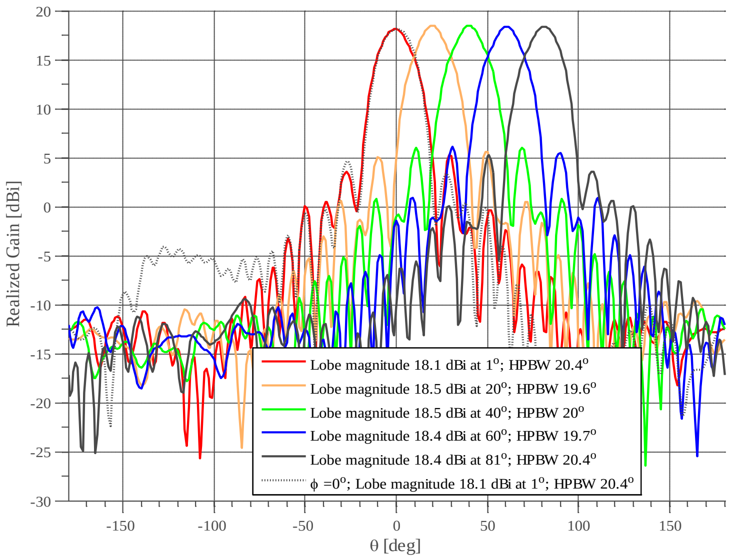
Bended array (LCP)



Passive deflector

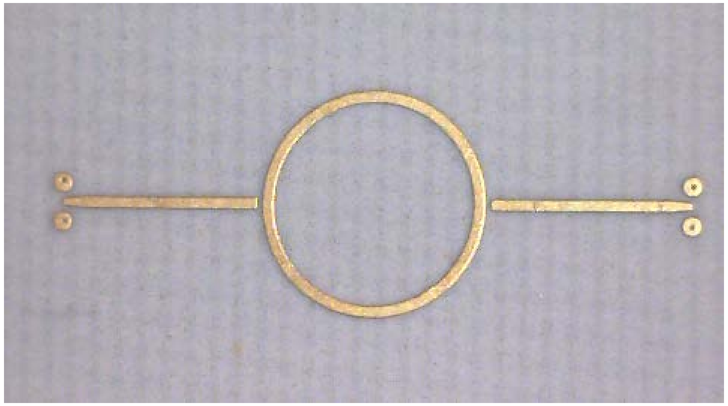


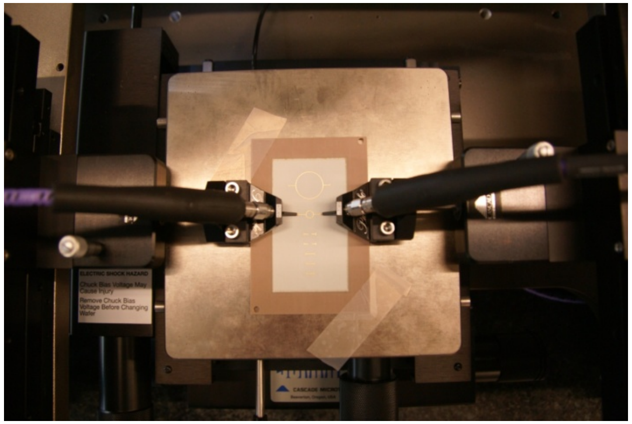
Dielectric rod antenna array
(with beam switching)

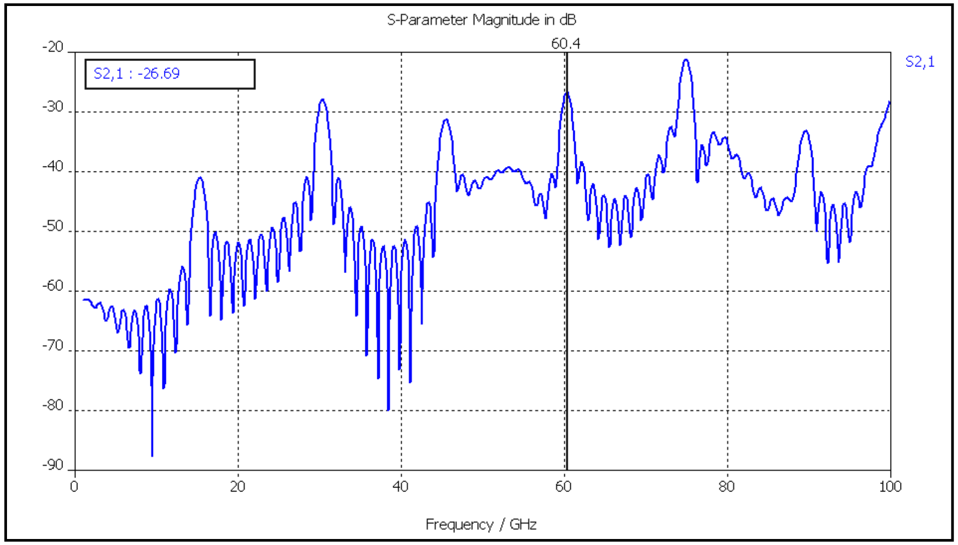


Constant antenna gain during beam scanning

Material characterization using microstrip ring resonator (MRR)







$$f_{0,n} = \frac{cn}{L\sqrt{\varepsilon_{\mathrm{eff}}}}$$

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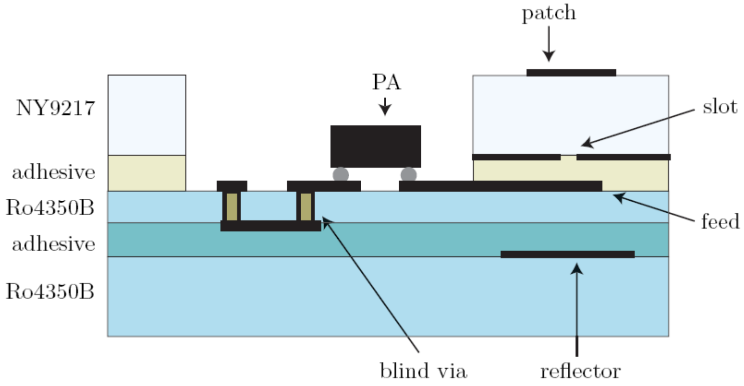
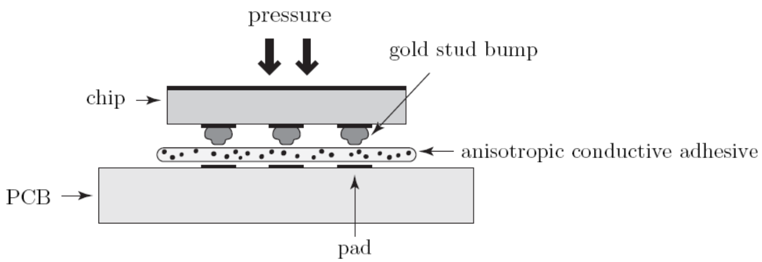
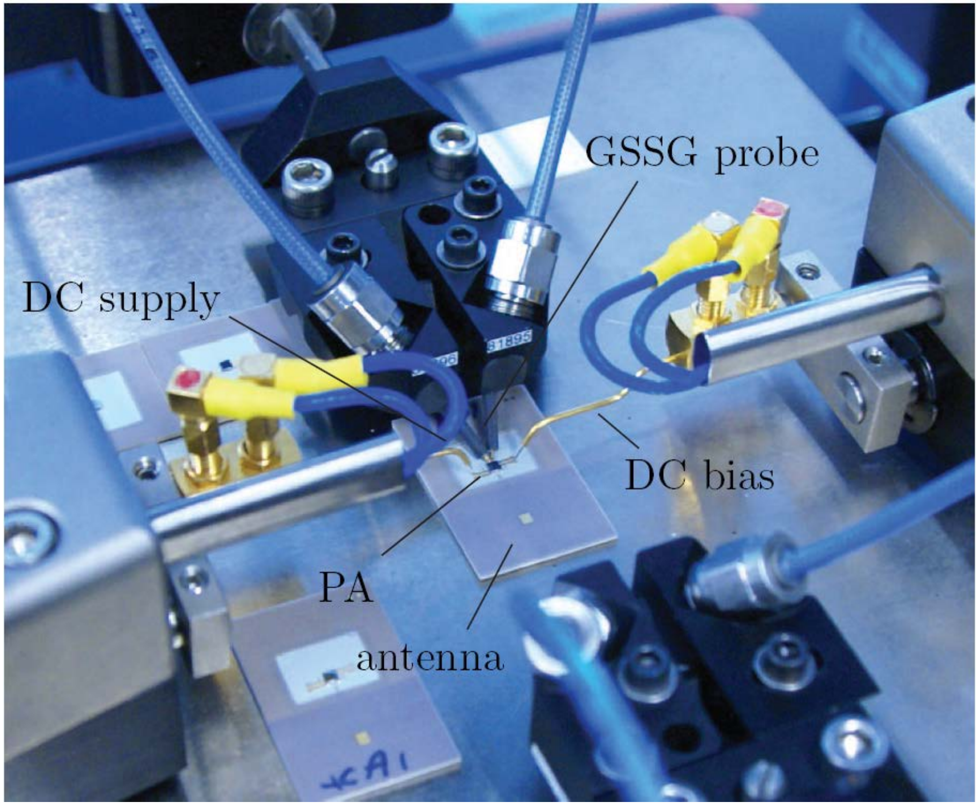
Packaging, flip-chip integration and probing







Circular polarisation

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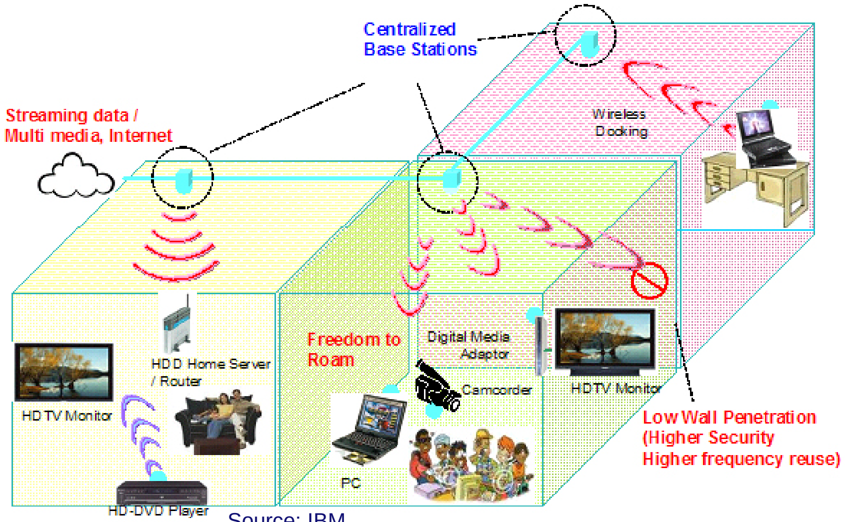
Motivation Circular polarisation

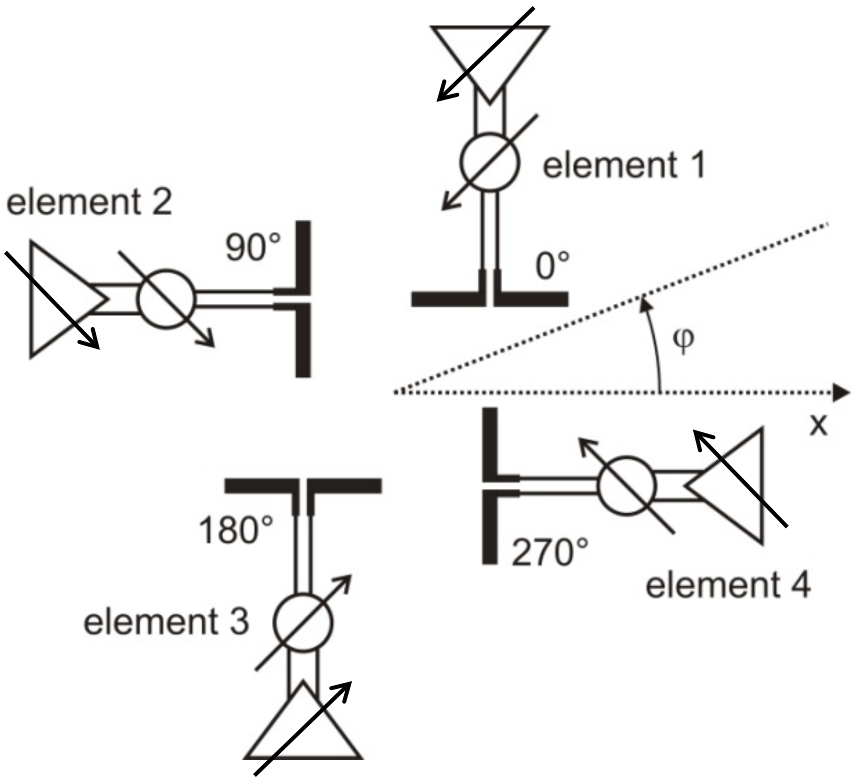
- **Several emerging mm-wave applications:**
  - **60 GHz wireless communications**
  - **Imaging/security (e.g. 94 GHz)**
- **Electronic beamsteering required**
- **These applications benefit from Circular Polarisation:**
  - **Robust link**
  - **Improved resolution**



Source: IBM

Sequential Rotation Technique

- **Introduced by John Huang* in 1986 for non-scanning arrays.**
- **Create Circular Polarisation (CP) with linearly polarised elements.**

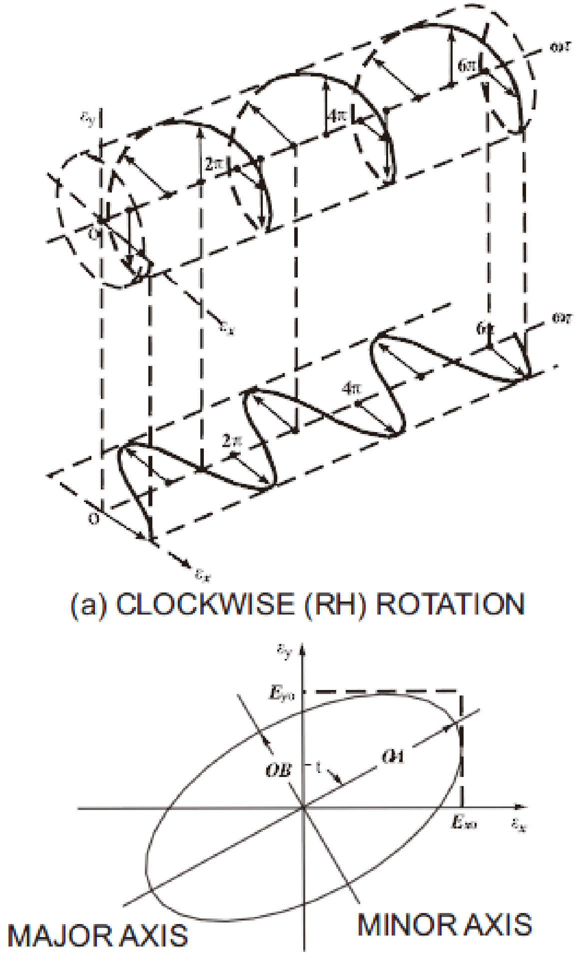


- **Basic cell is a 2x2 dipole array**
- **Each element has:**
  - **Phase shifter (PHS)**
  - **Variable amplitude (VAT)**

*J. Huang, “A technique for an array to generate circular polarization with linearly polarized elements,” in *IEEE Transactions Antennas and Propagation,* vol. 34, no. 9, Sept. 1986, pp. 1113-1124.

Axial Ratio definition

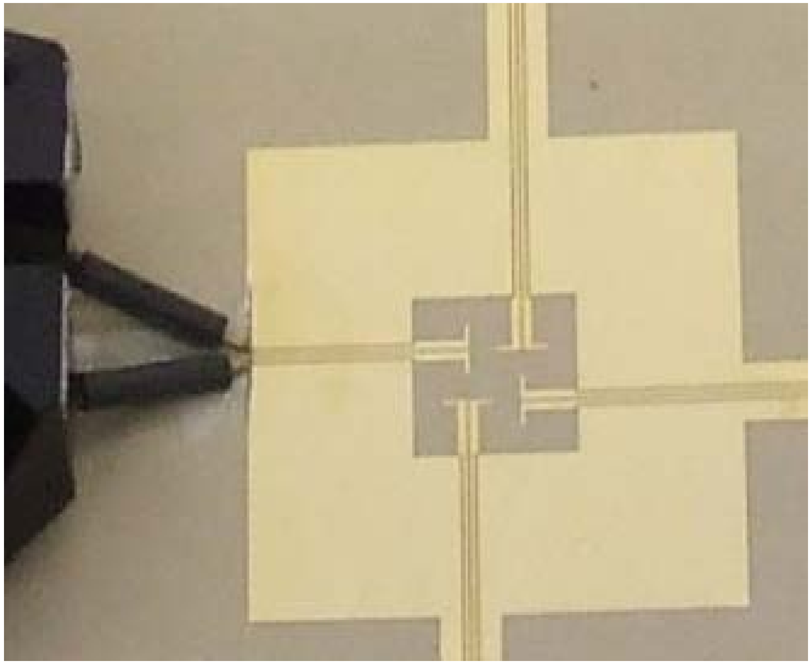
$$AR = \frac{Major\_axis}{Minor\_axis} = \frac{OA}{OB},$$



Source: Wikipidia

Experiments with 60 GHz demonstrator

- **Configuration:**
  - **2x2 array with printed dipoles on RO3003**
  - **Sequential rotation**
- **Element patterns (co&cross) are measured**
- **Total beams patterns obtained with post-processing.**



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Axial ratio with and without calibration Scan angle θ_0=25°

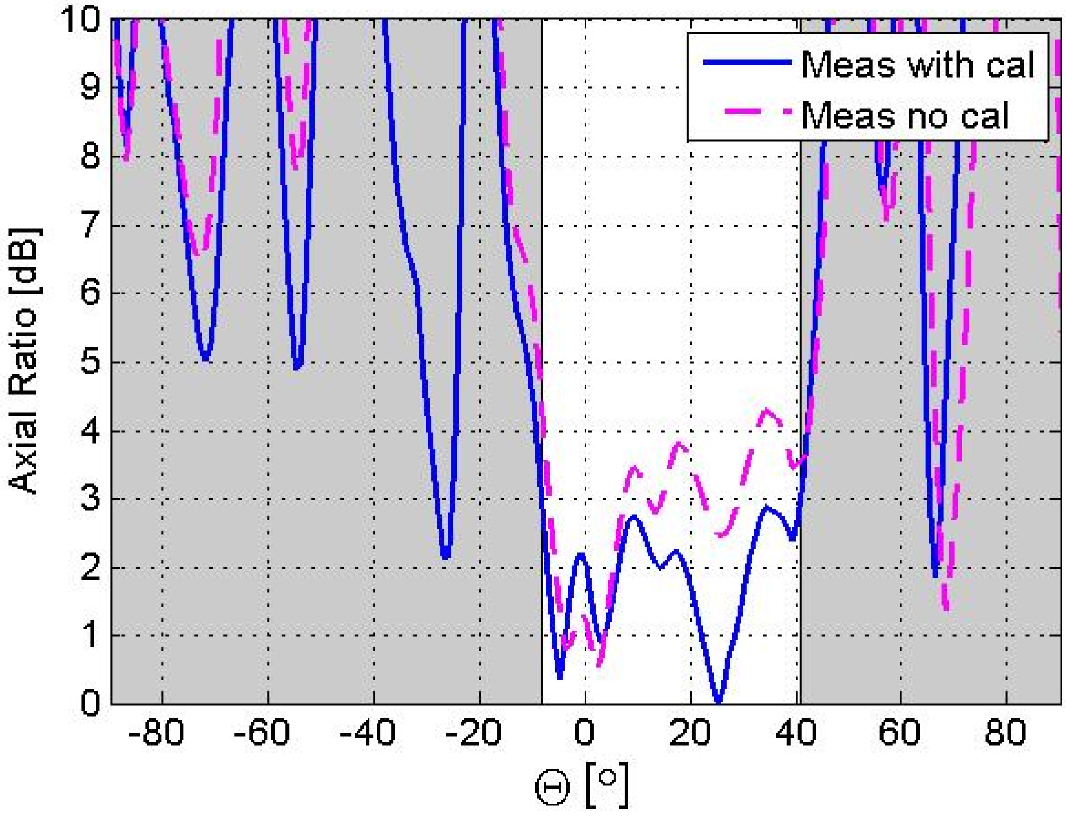

Fig.10. Measured Axial Ratio of the 60 GHz test array with and without calibration for a scan angles of θ_0=25° (φ_0=0° plane).

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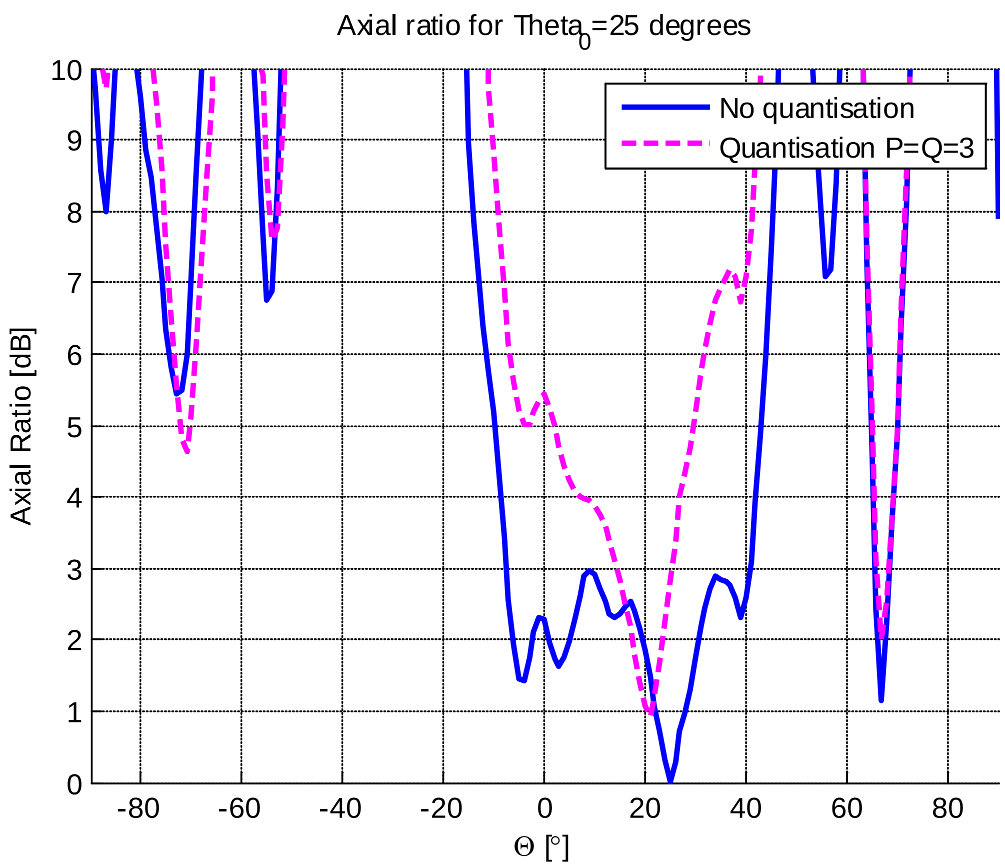
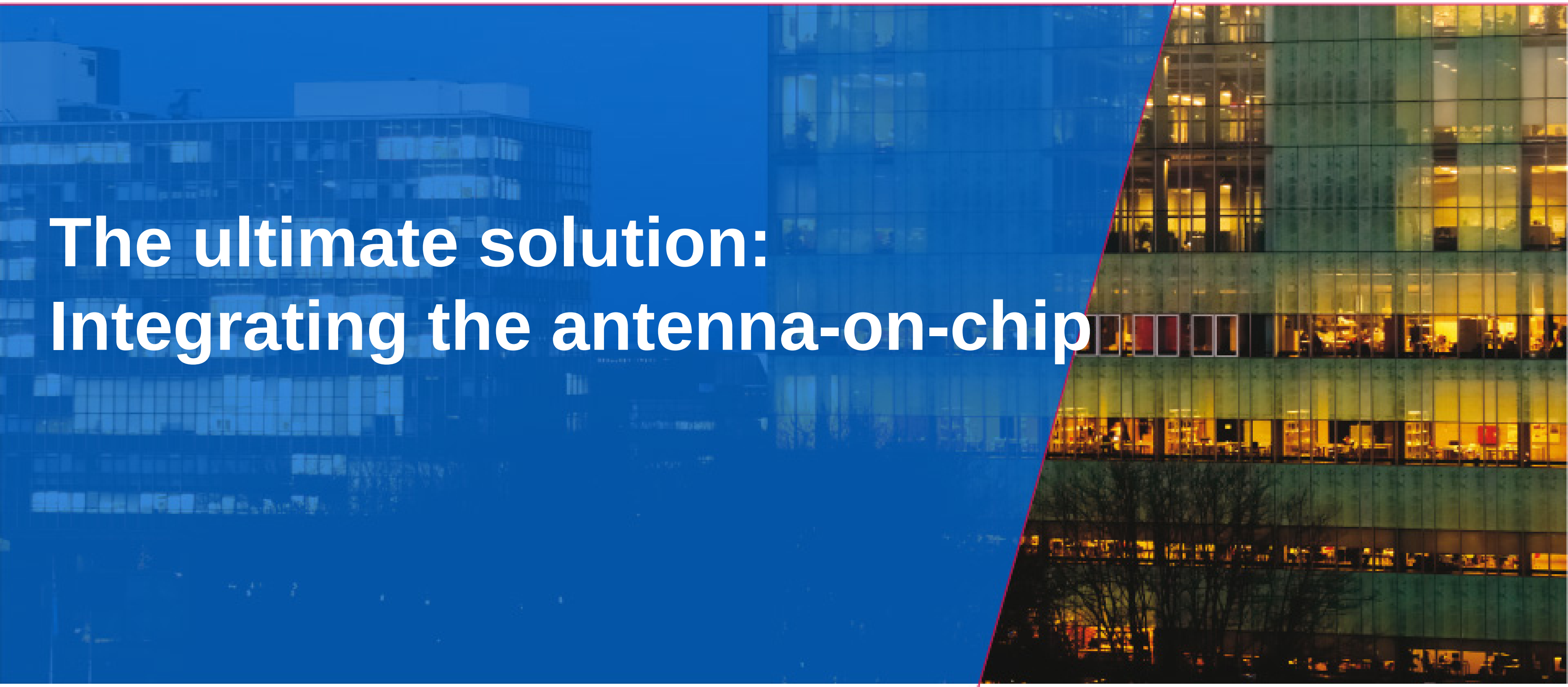
Axial Ratio for 2x2 array based on measured element patterns

- **Configuration:**
  - **2x2 sub array**
  - **P=Q=3 bits**
  - **Scan angle 25 deg**
  - **With calibration**
  - **60 GHz, $\varphi_0 = 0^\circ$ plane**





The ultimate solution: Integrating the antenna-on-chip

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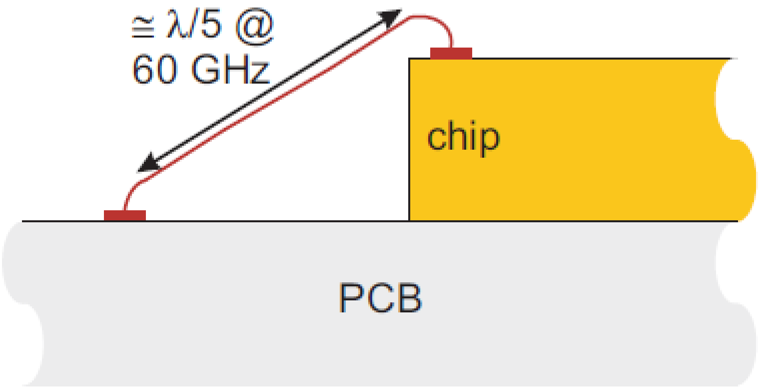
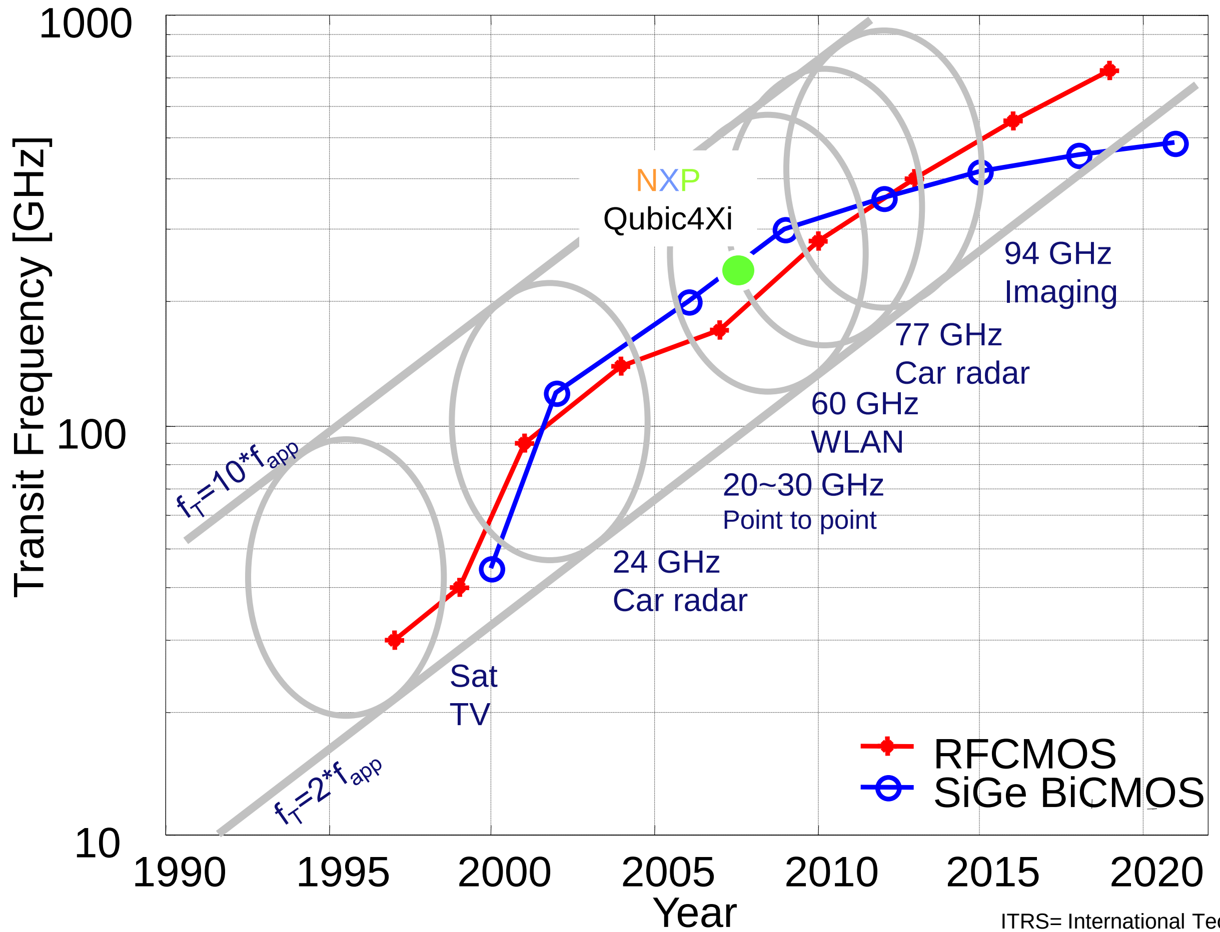
Why having an antenna on chip?

- Avoid the "getting the signal on/off chip" problem
- Direct matching of the antenna and LNA/PA possible
- Antenna size at mm-waves (~ 1mm) makes it possible and cost-effective

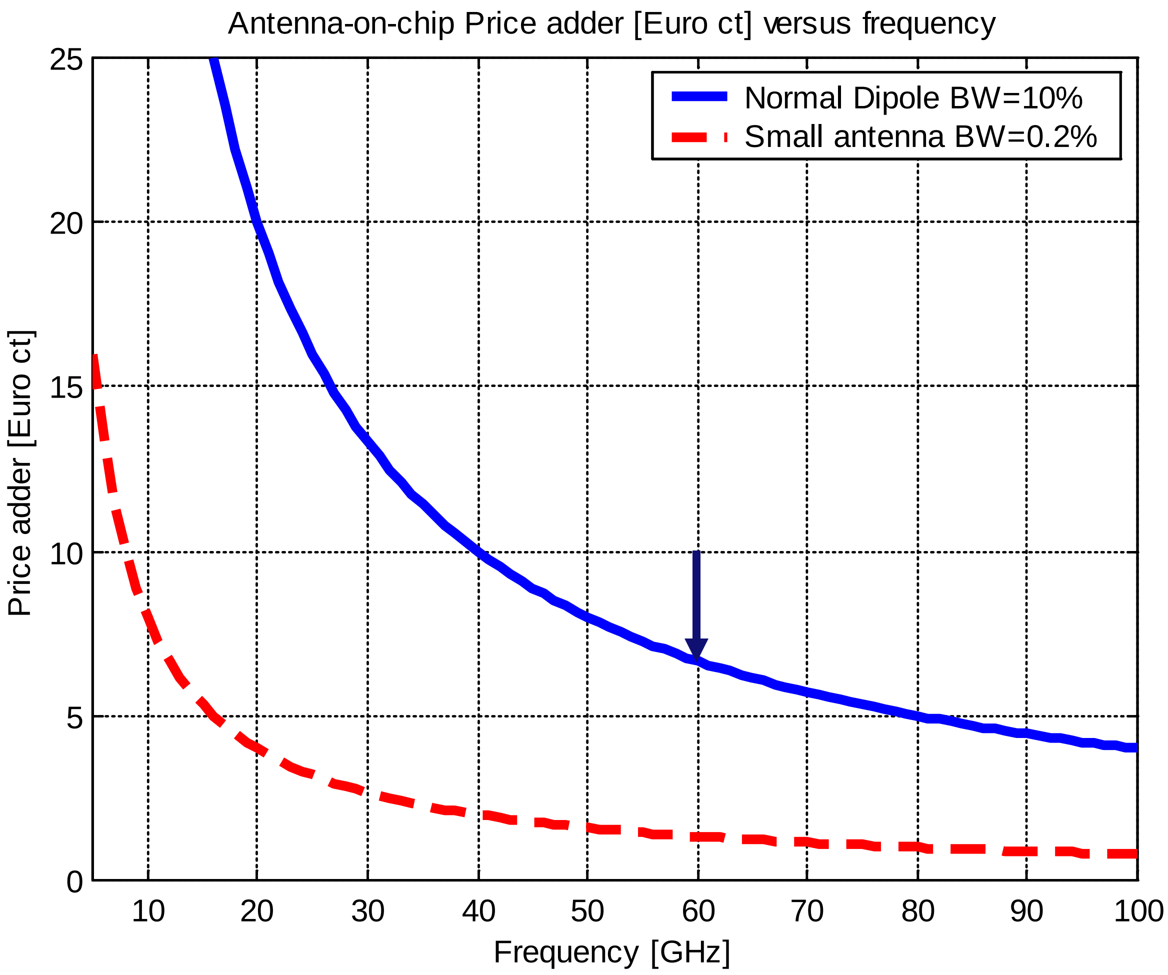


Ft of IC Technology vs Year [ITRS] & applications



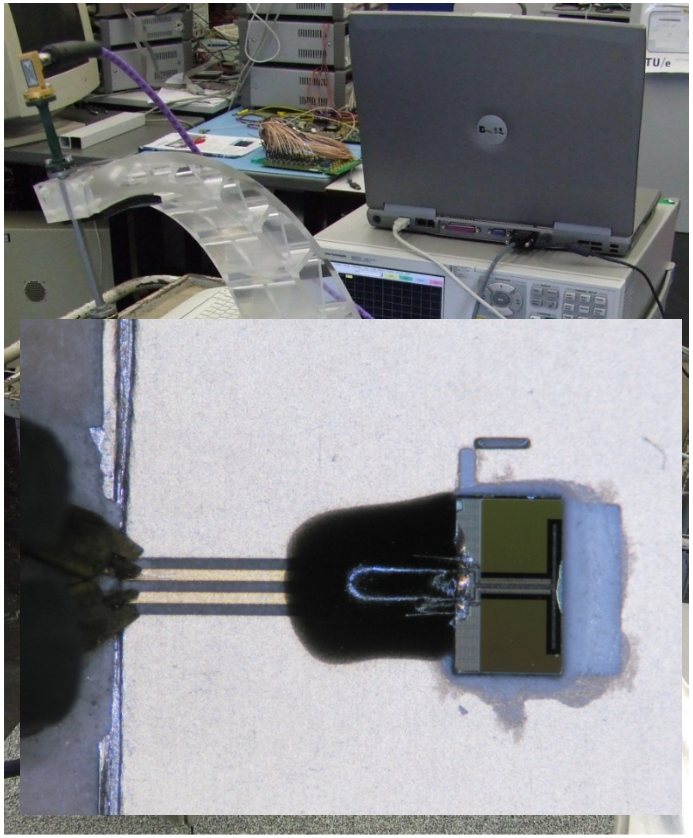
ITRS= International Technology Roadmap for Semiconductors

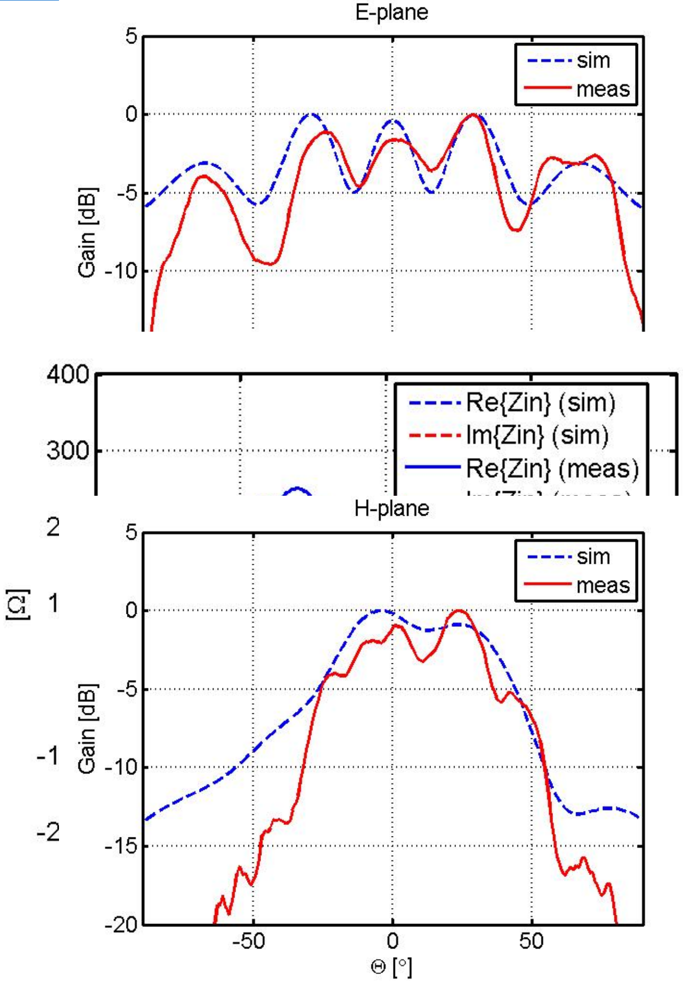
Cost of Antenna-on-Chip (AoC)



+ Lower test cost
+ Lower package cost

AoC research at TU/e





➔ Prototypes in BiCMOS and CMOS65 technology

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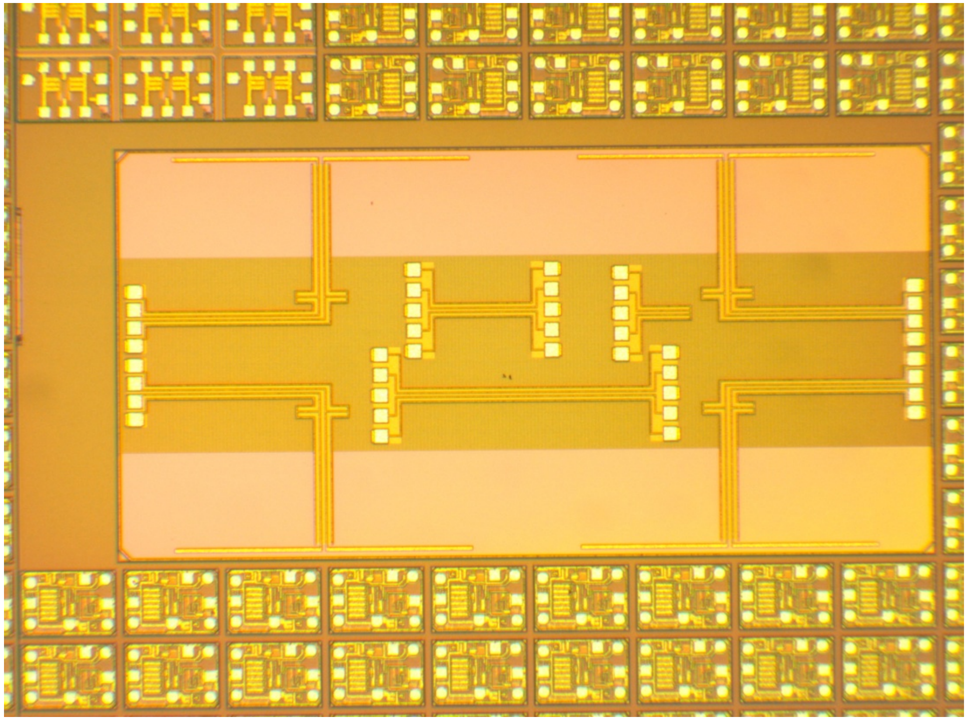
Array-on-Chip

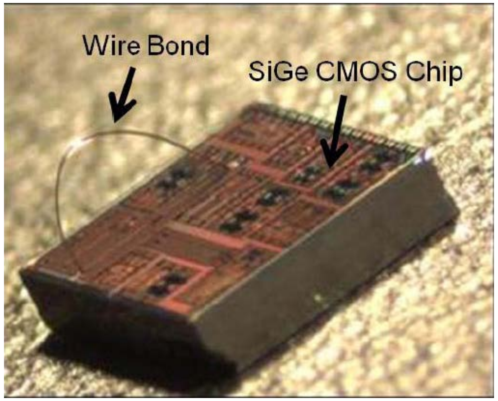
Photograph of 2x2 array in BiCMOS



Bondwire Antennas

Equivalence between wire antenna on car versus on chip

60 years later



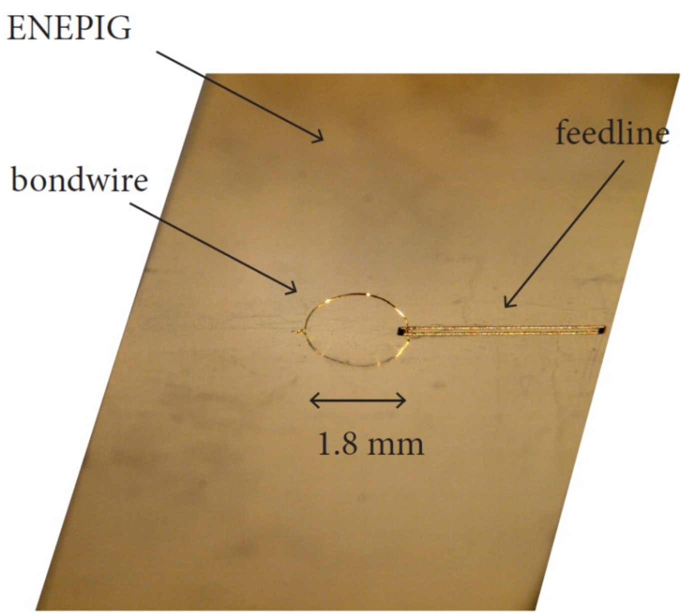
Wire antenna on Car (WoC)

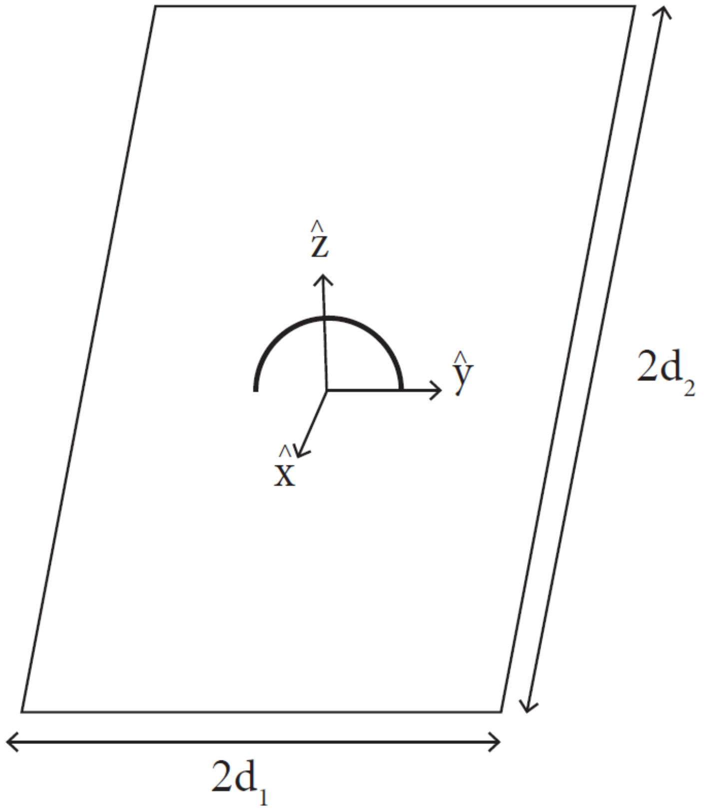
- f=90 MHz
- L_wire=1.6 m
- L_car=4 m
- L_car/L_wire=660

Wire antenna on Chip (WoC)

- f=60 GHz
- L_wire=1.3 mm
- L_chip=6 mm
- L_car/L_chip=660

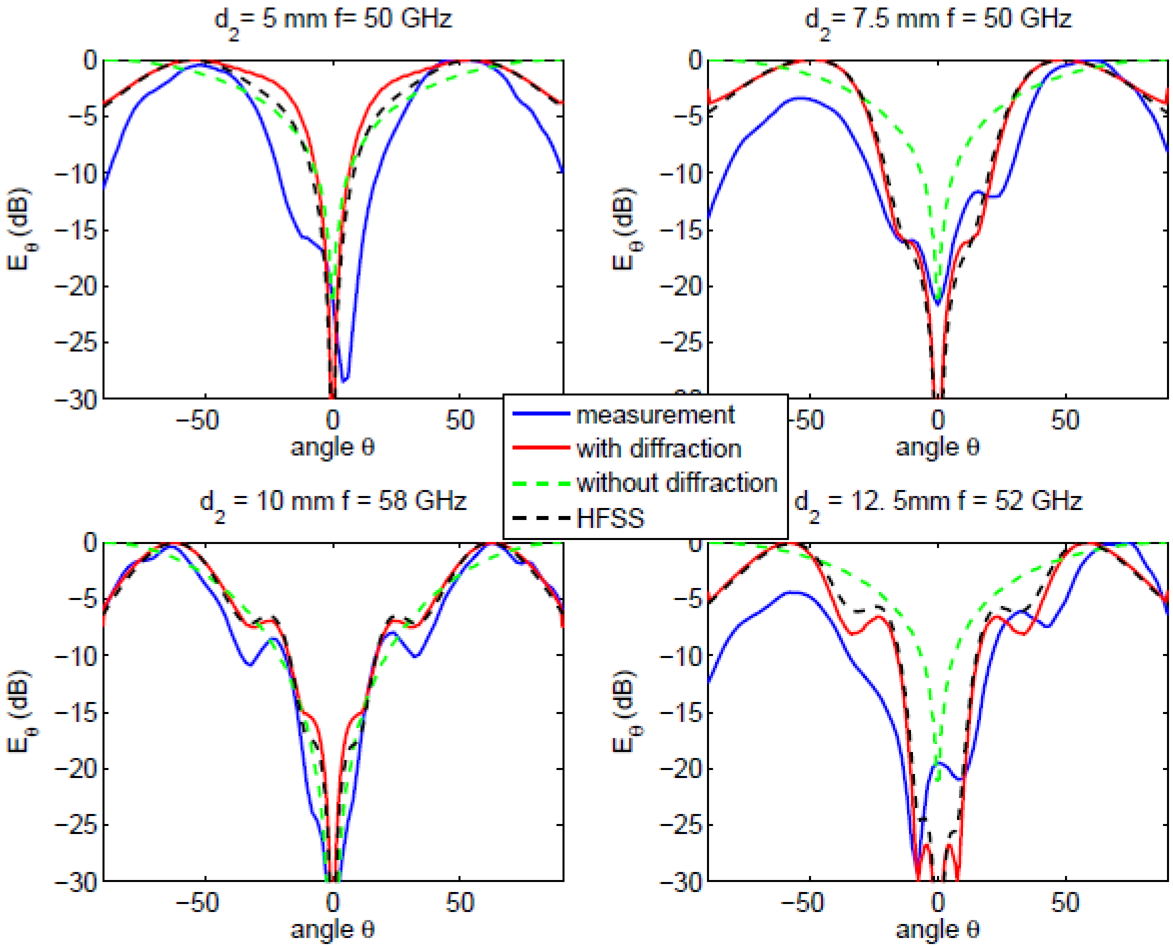
Bond Wire Antenna Experiments at 60 GHz





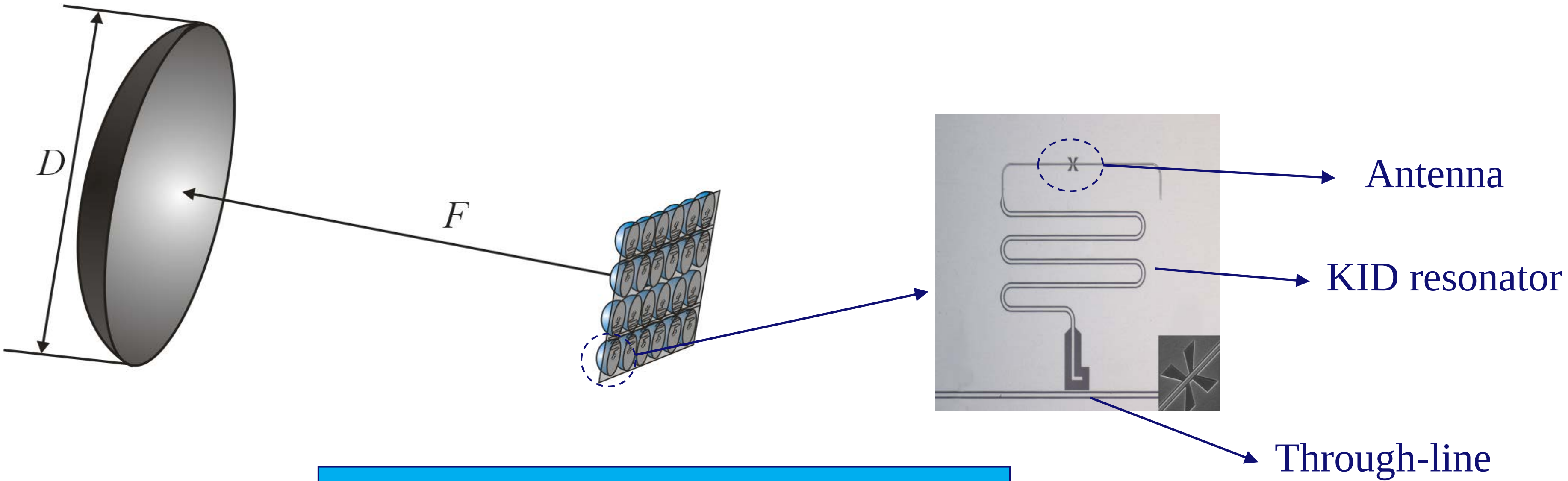
Bond Wire Antenna

Measurement results for varying ground plane sizes



THz antennas

Antenna-coupled Kinetic Inductance Detector in Focal Plane Array for THz imaging



SPICA mission for deep space science:

•High sensitivity (NEP~10^{-19} W/√Hz)
•Octave Bandwidth
•Thousands of pixels

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KID=Kinetic Inductance Detector (www.sron.nl)

mm-wave measurement facility

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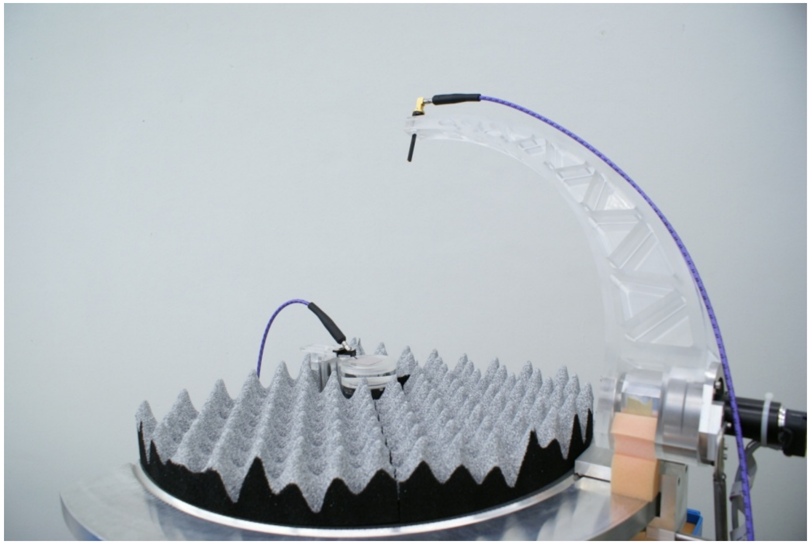
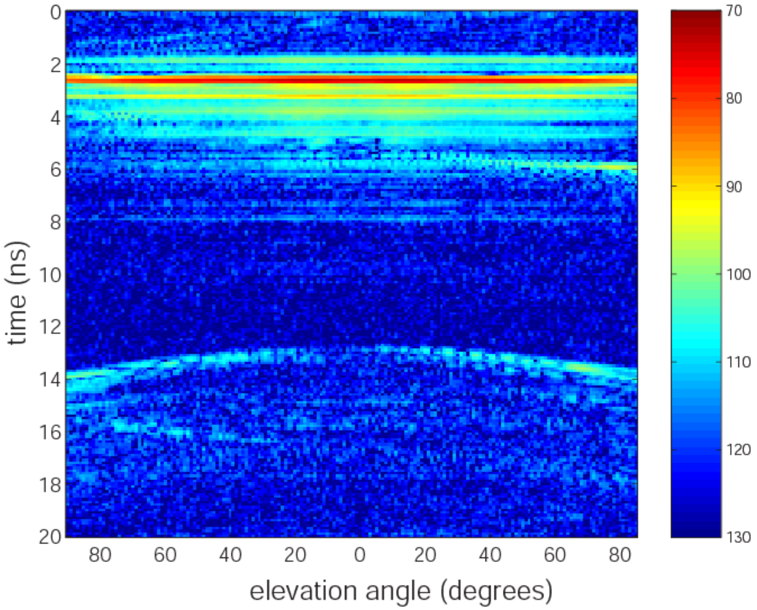
“Old” Echoic antenna measurement system





Reflections need to be removed by time-gating.

Accurate alignment, positioning and probing of the antenna is difficult.

⇓

New measurement system.

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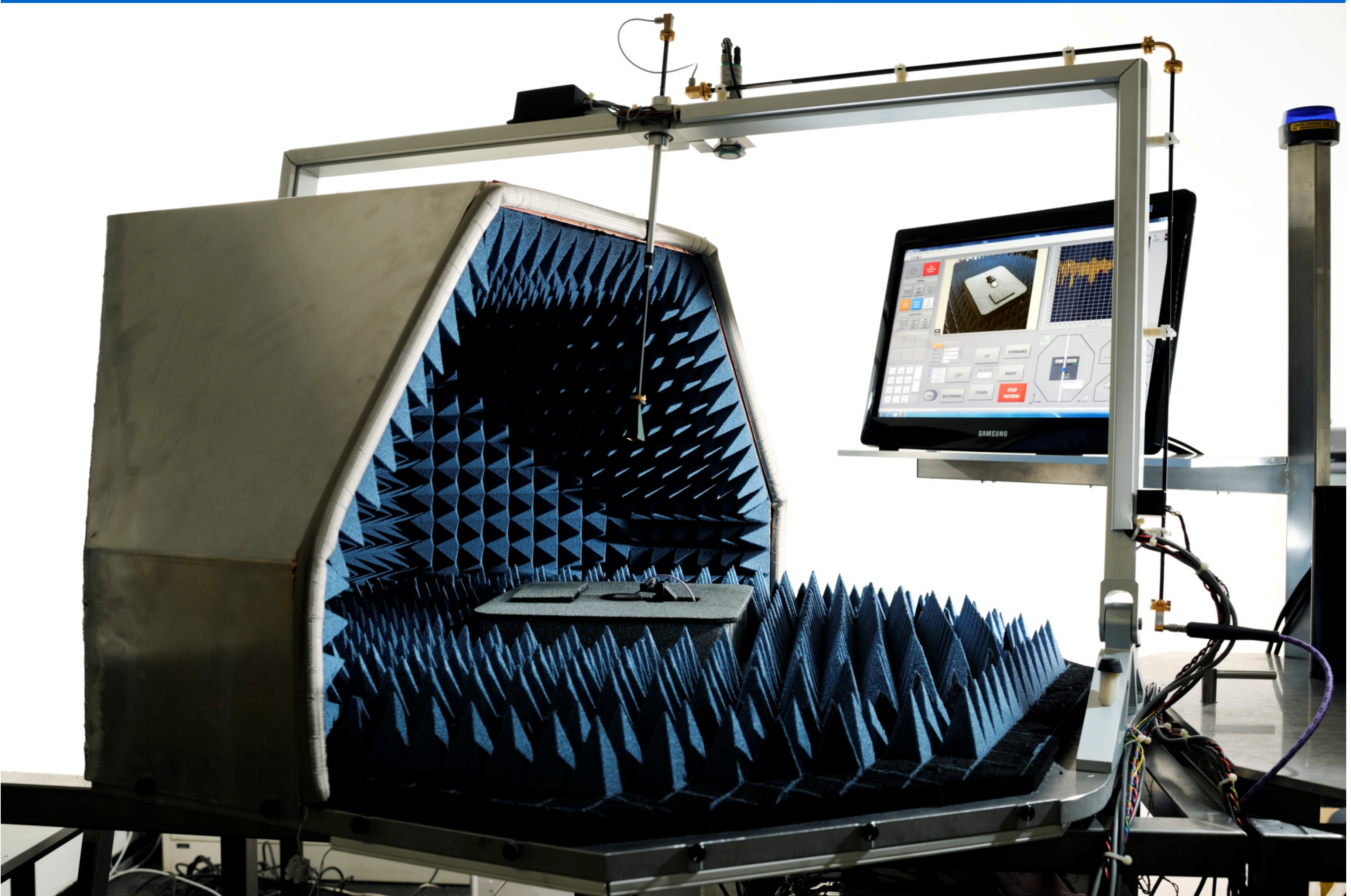
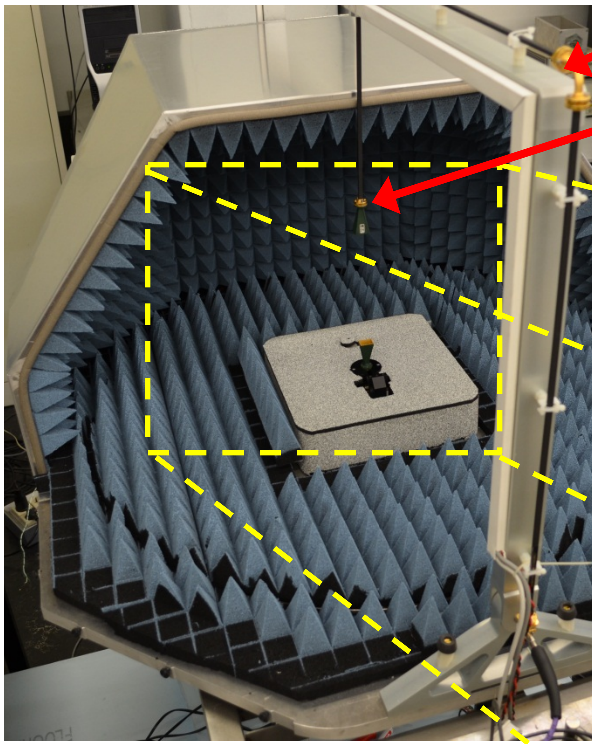
Anechoic antenna measurement system

- **Goals for the new setup:**
  - **Measurement setup without any environmental disturbance**
  - **Accurate alignment of the Antenna Under Test (AUT)**
  - **Accurate, defined and reproducible probing of the AUT**
  - **Defined and reproducible measurements**
  - **Easy to use for scientific research**

New facility (official opening 8-9-2011)



Anechoic antenna measurement system

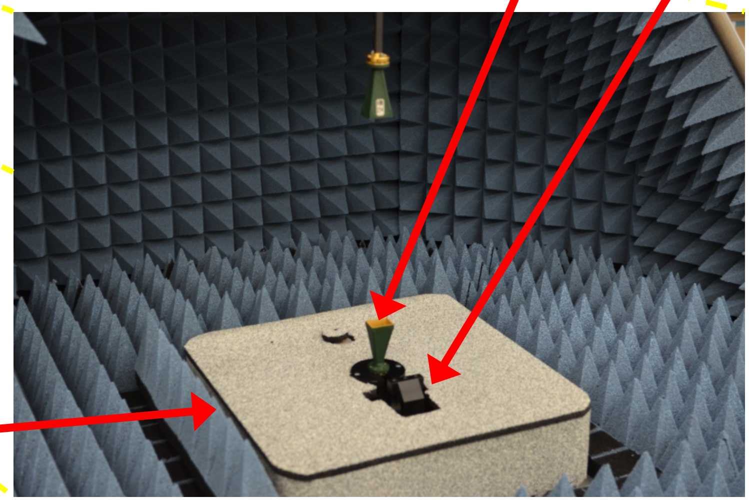


Scan arm for the radiation pattern

Reference gain horn antenna

Modular AUT holder

Probe Station



Translation table

Anechoic antenna measurement system

- **Features**
  - The chamber is fully EM anechoic
  - Controlled alignment for the AUT in relation to the reference antenna
  - Modular table setup for different antenna or EM device configurations
  - Bottom and top probing
  - Temperature and vibration monitored and webcam view during measurement
  - Currently we can measure up to 67 GHz. Future extension planned.

- **Measurements:**
  - S11, S12
  - Cross, Co, H- and E-field (Complete H-field radiation pattern with bottom probing)
  - Half 2D and 3D radiation pattern

Netherlands Antenna Framework (NAF)

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NAF - List Of Participants

3TU.

16 companies/institutes/centres – 55 attendees

WMC Twente Institute for Wireless and Mobile Communications

SRON Netherlands Institute for Space Research

Royal Netherlands Navy
Ministry of Defence

Erasmus MC Universitair Medisch Centrum Rotterdam

SSBV

ASTRON

IP2 solutions

esa

METASENSING

Zelectronix

NXP

THALES

TNO innovation for life

TDK EPCOS

Holst Centre
Open Innovation by IMEC and TNO

CATENA

TU/e Technische Universiteit Eindhoven University of Technology

Universiteit Twente
de ondernemende universiteit

TU Delft
Delft University of Technology

Conclusions

- **Antenna activities @ TU/e are shown**
- **Balance of (EM-) modelling, application and experimental know-how.**
- **Netherlands Antenna Framework (NAF) started**
- **New investment in experimental facilities.**
- **New antenna facility planned in new EE building**