On-chip antennas for low cost single-chip 60 GHz radar

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22/10/2014

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Where innovation starts

Outline

1. Introduction
2. Radar antenna requirements
3. On-chip antenna design and use of PCB to improve performance
4. Results
5. Conclusions

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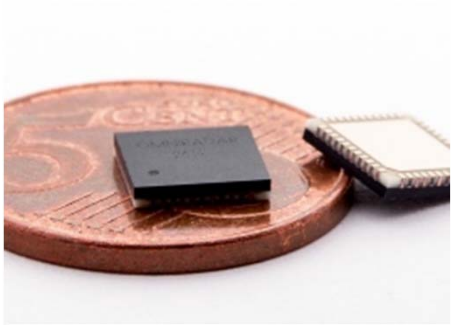
Omniradar

OMNIRADAR

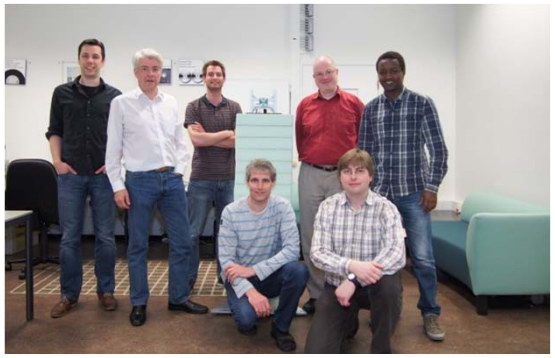


A fully integrated 60 GHz high bandwidth radar frontend with antenna's

Vision

to be a major supplier of innovative integrated radar IC's

for consumer, industrial and automotive markets



Applications

- Truck safety
- Presence sensing
- Smart-lighting
- Door-openers
- Level-gauging
- Height/distance measurements
- Speed
- Traffic Monitoring

Why millimeter-wave radars?

	24 GHz NB Radar	24 GHz UWB Radar	77 GHz Radar	79 GHz Radar	Mono Video	Stereo Video	PMD Sensor	Far IR Sensor	Near IR Sensor	Laser Scanner	Ultra-sonic
Operation in dust or hail											
Operation in fog or snow											
Low sun and dazzling											
Day and night operation capability											
Sensor blockage risk (e.g. dirt on sensor)											
Mounting constraints on vehicle											
Surface/Cover transparency constraints											

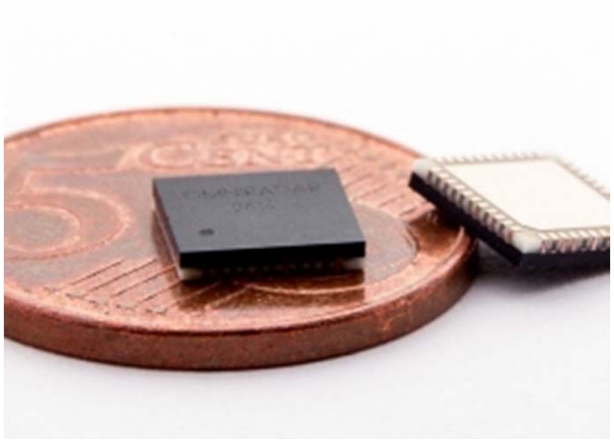
= good performance = fair performance = bad performance

MOSARIM FP7 project

- **Most sensors cannot handle harsh environments**
- **Millimeter-wave radar sensors offer better performance in various environmental conditions**

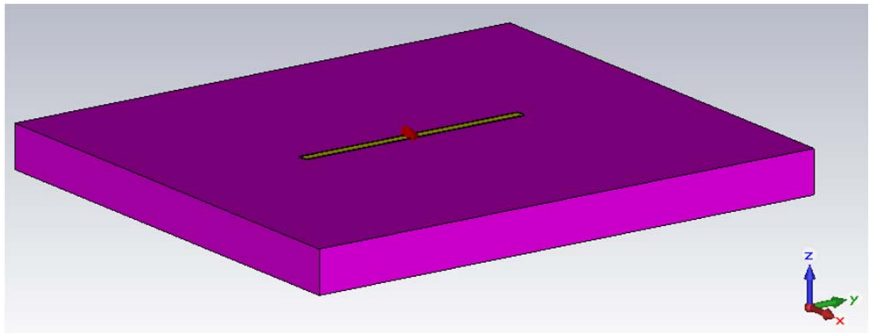
Why 60 GHz ISM band?

- 7- 9 GHz bandwidth → high resolution
- Wavelength = few millimeters → antenna integration with front-end circuit
- Integrated design
  - Significant cost reduction



On-chip antenna design challenges

- **Because of low resistivity and high relative permittivity**
  - **Low radiation efficiency**
  - **Low gain**
  - **Substrate modes**
  - **Back radiation**
    - **not desired for some applications!**



- **Improved performance**
  - **At increased cost**
    - **Change of the process**
    - **Additional design process**

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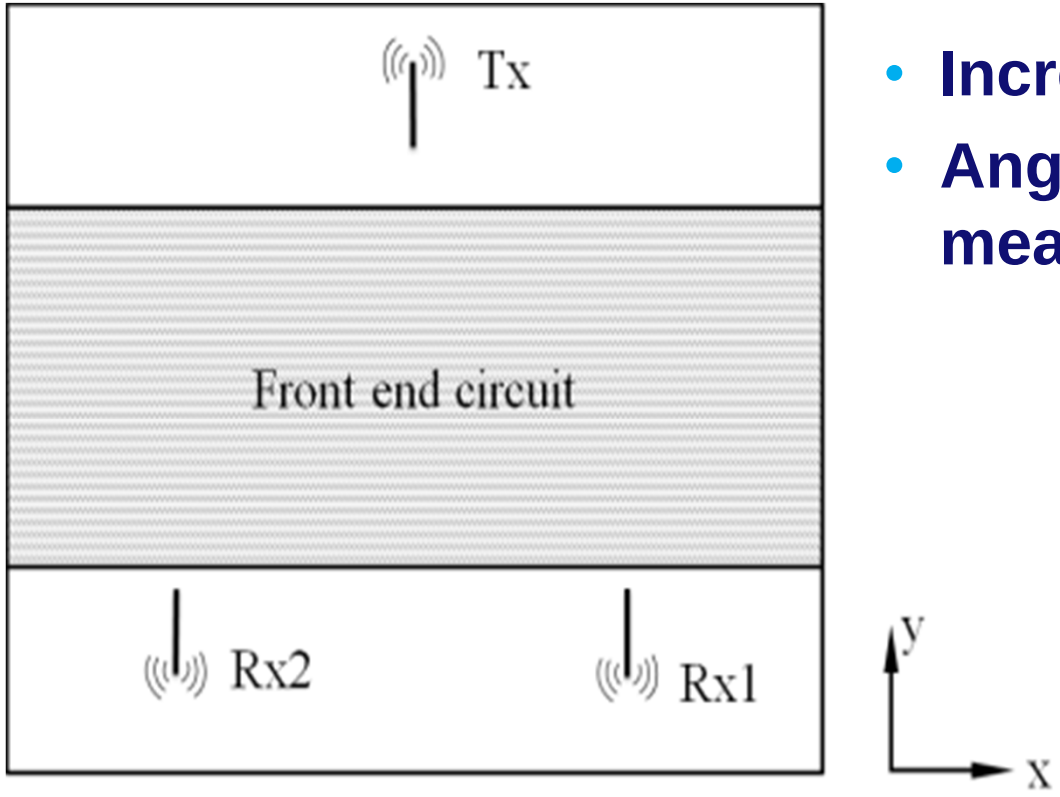
On-chip radar antenna requirements

- **Improved**
  - **Gain**
  - **Radiation efficiency**
  - **Substrate mode suppression**
- **Manufacturability on standard silicon process**
- **Integration of at least three antennas on silicon**
- **Smooth broadside pattern**
- **Isolation greater than 25 dB**
- **Low cost**

Radar antenna configurations



- **Increased isolation**
- **Angle-of-arrival measurement along x-axis**

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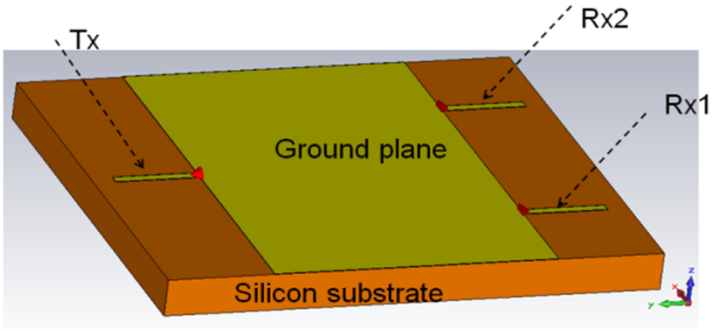
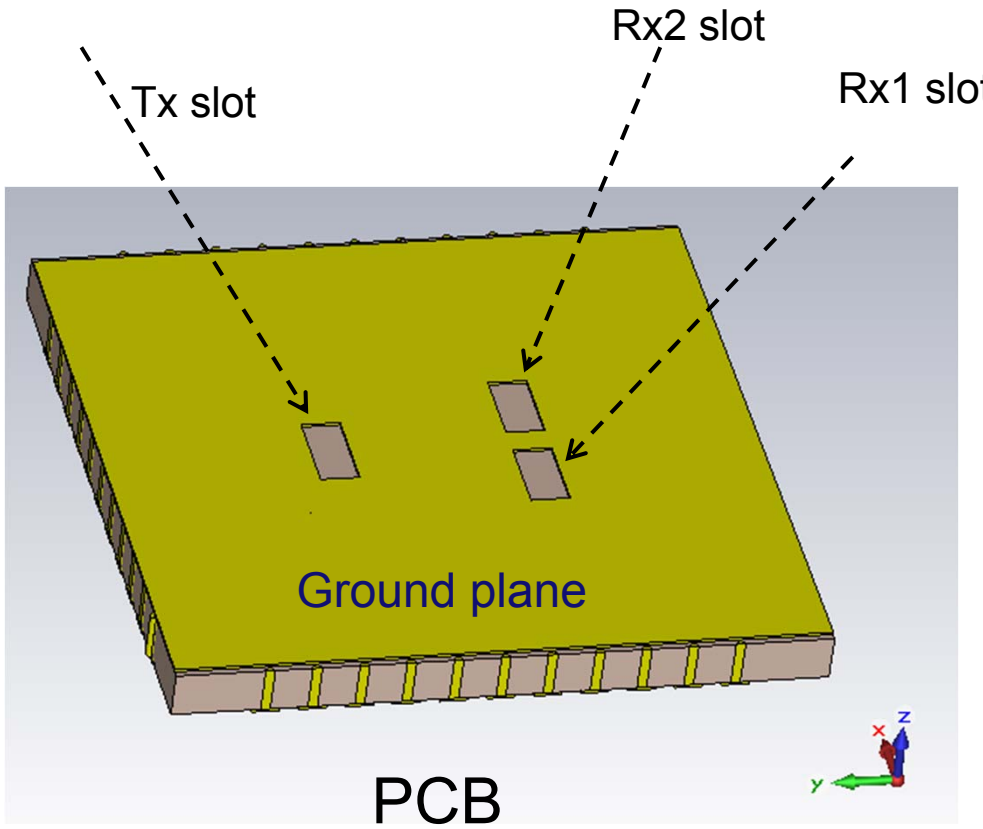
On chip monopole type antenna



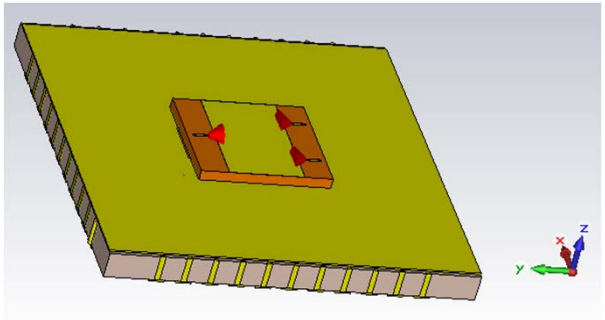
On-chip monopole Antenna type

- Low cost design
- Can be design in standard process
- Characteristic
  - Bad matching
  - Low efficiency
  - Radiation pattern maximum is towards the edges of the silicon

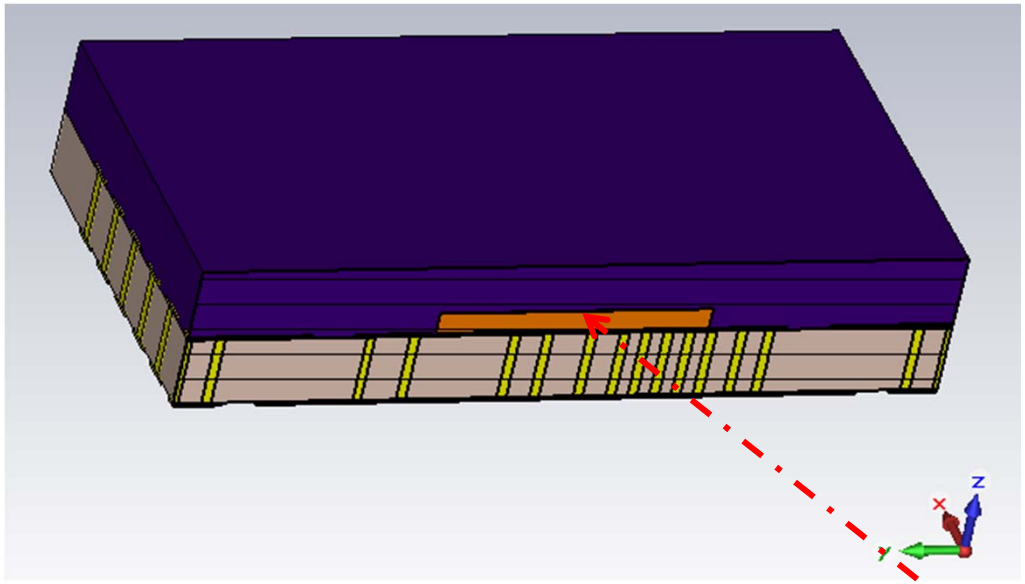
On chip monopole combined with wide slot on a PCB

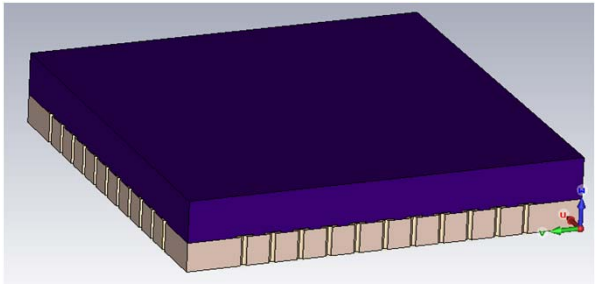


- **PCB**
  - **Rogers substrate**
  - **Ground planes on top and bottom of the rogers**
  - **Via walls around the slot**



Environmental protection layer

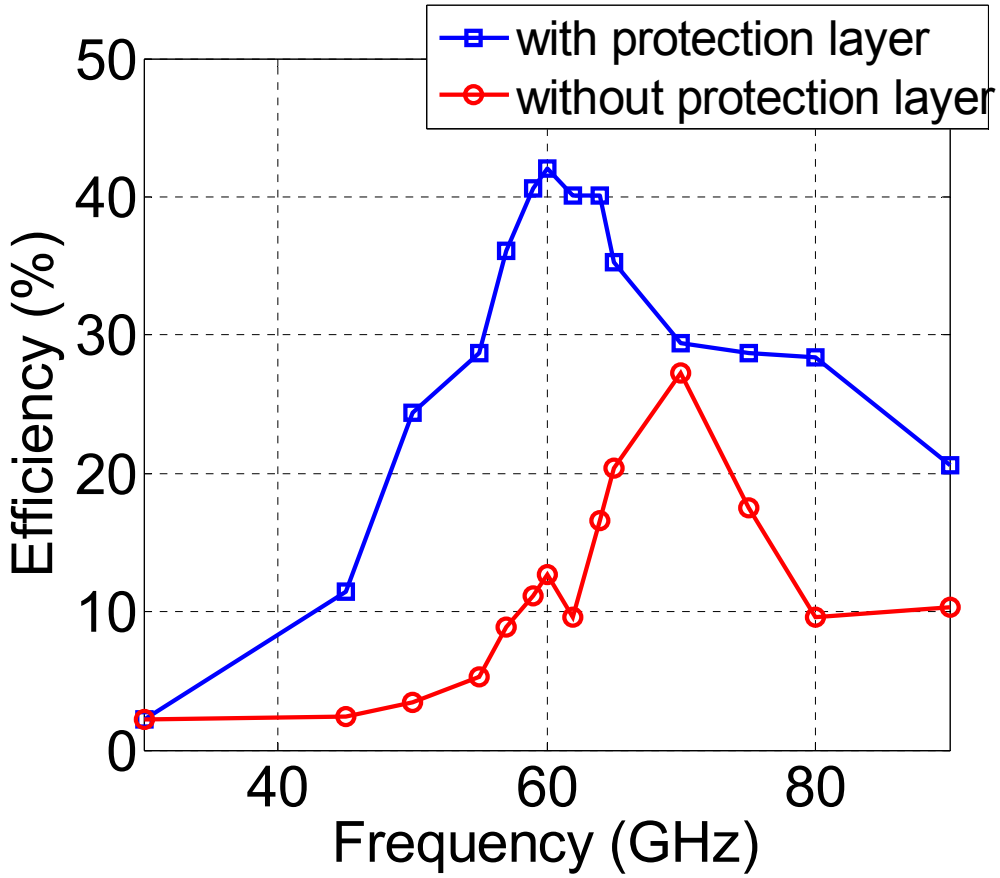




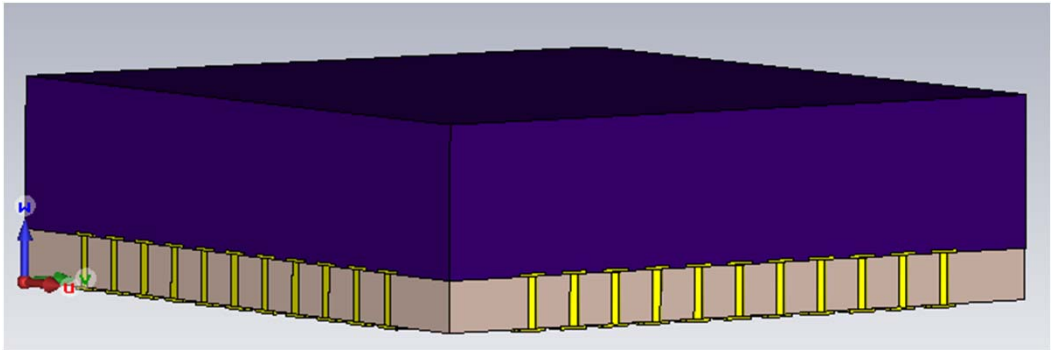
- **Protection layer**
  - **Increases gain**
  - **Increases efficiency**
  - **Can also be detrimental**

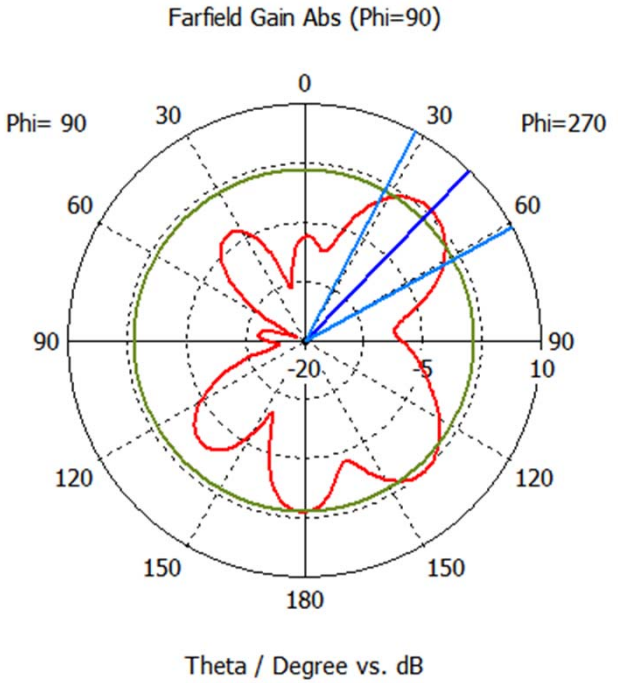
On-chip antenna

Environmental protection layer effect



Environmental protection layer effect





- Thick layer → increases surface waves
- Thin layer → doesn't improve performance

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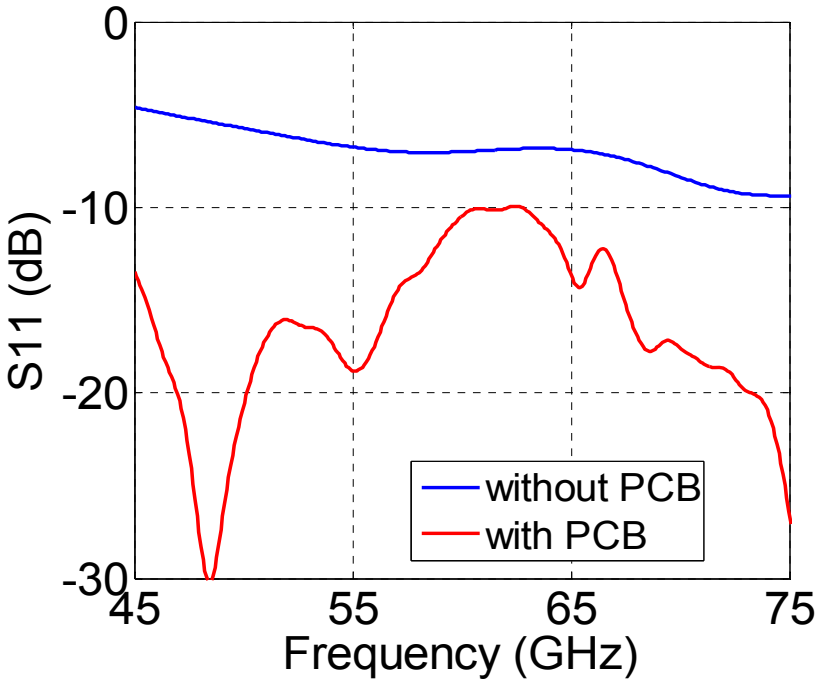
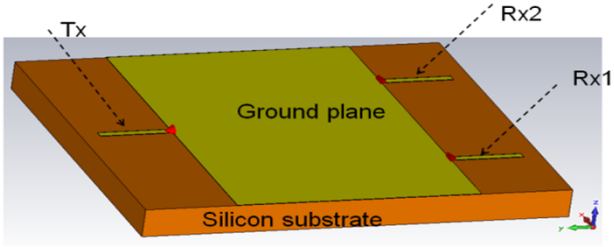
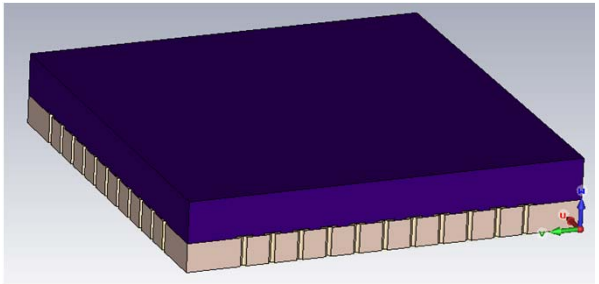
Simulated matching



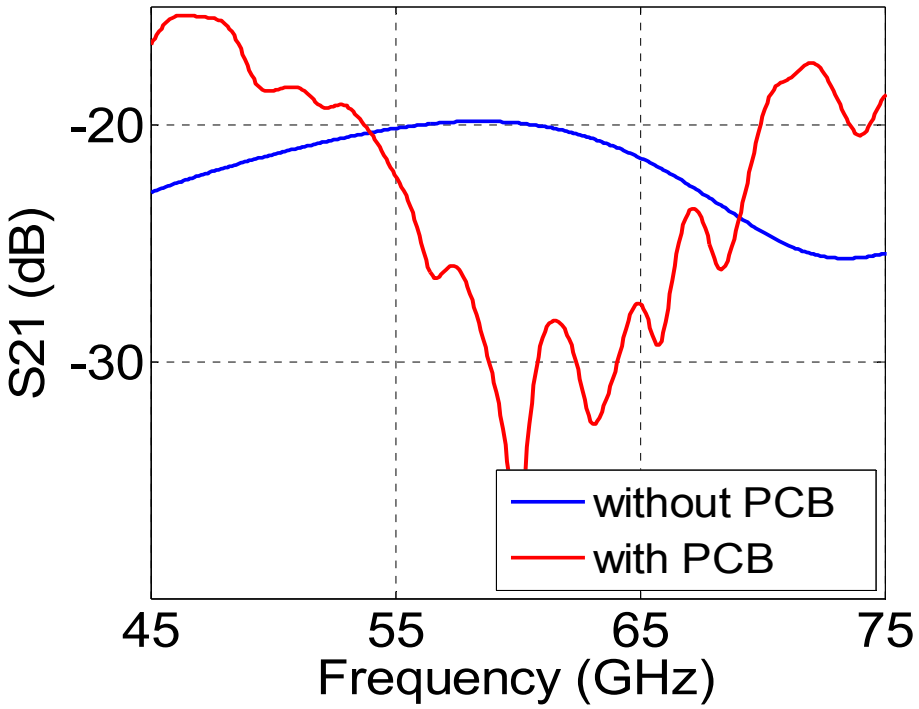


Without PCB



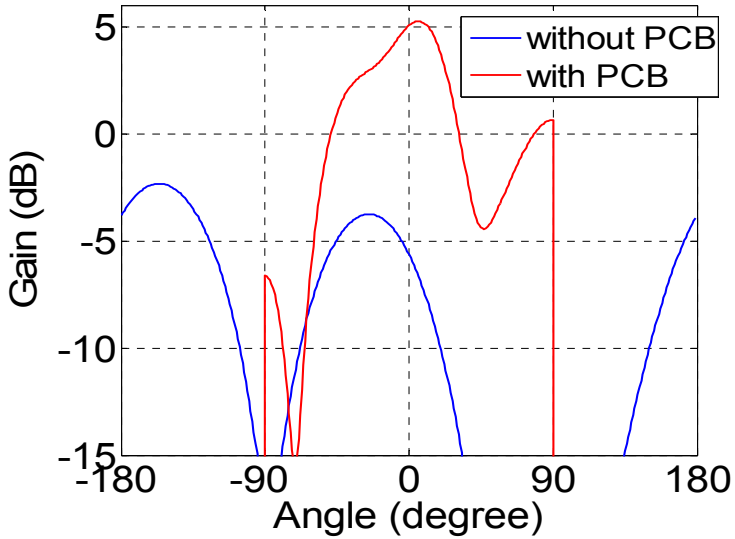
With PCB

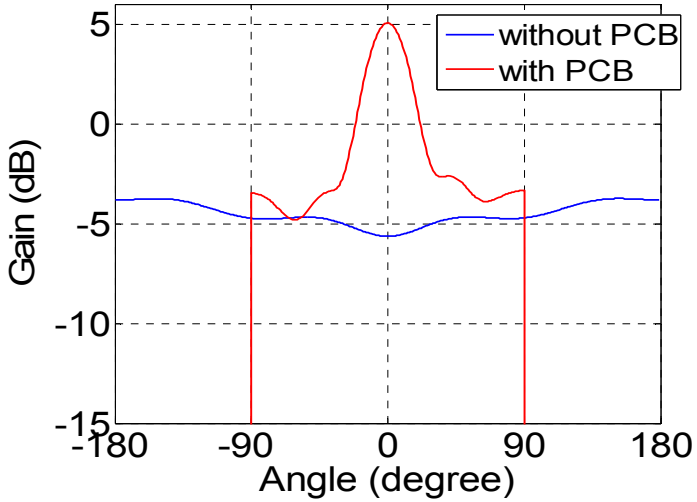
Simulated mutual coupling



- **27 dB isolation**
- **7 dB better**

Simulated radiation pattern





- **5 dBi gain with PCB and -2.5 dBi gain without**
- **10 dB gain difference in broadside**
- **Ripple free broad side radiation pattern with the PCB**
- **No backward radiation**

Radar antenna pattern measurement setup

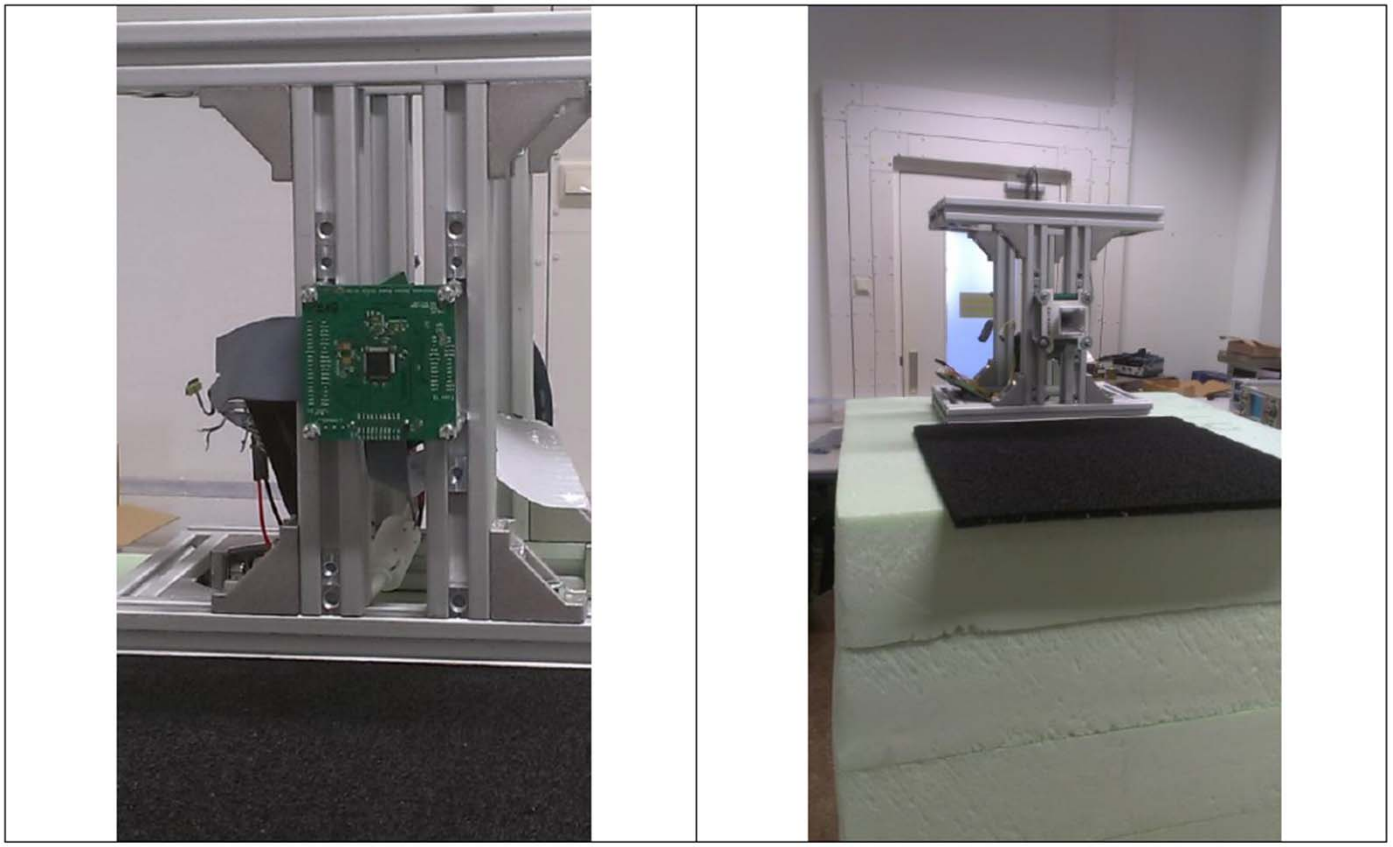
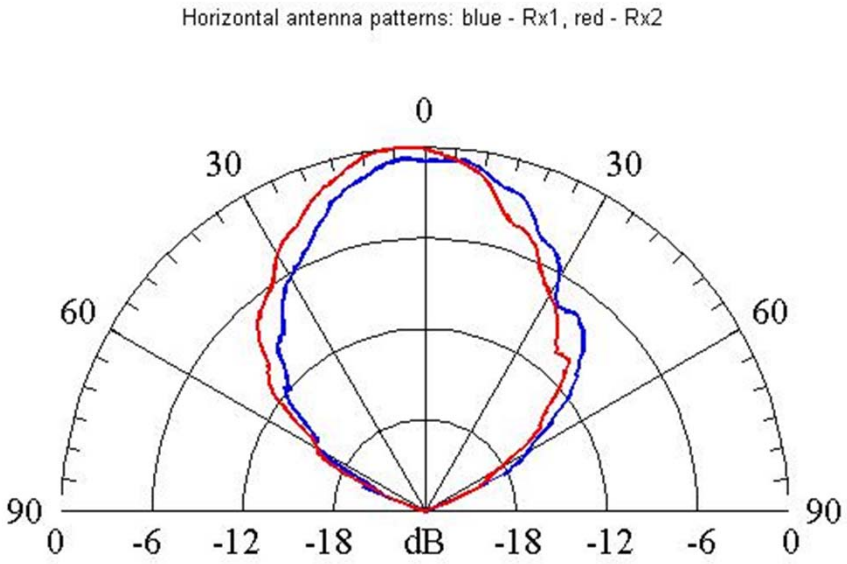
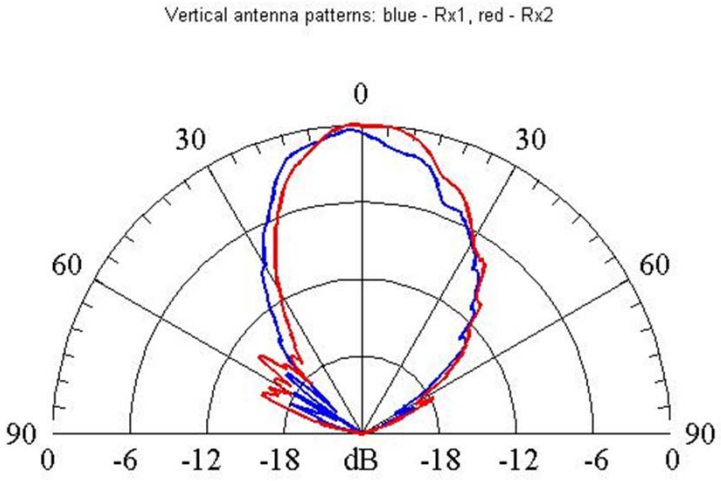


Fig. 1. Plain PCB with RIC60A v.3 and with horn.

Antenna pattern measurement – combined Tx and Rx



H-plane



E-plane

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Conclusions

- On-chip antenna integration for radar application is feasible
- Monopole combined with PCB and environmental protection layer
  - Increases gain
  - Suppresses substrate mode propagation
  - Ripple free broadside pattern
  - Improves isolation