Development Status of Next Generation Automotive Radar in EU

ITS Forum 2009, Tokyo, February 26th, 2009

Dr. Rudolf Lachner

Infineon, Program Manager Radar Technology

Never stop thinking

Outline

- Motivation
- Automotive Radar
- Today’s Radar Products
- Frequency Regulation
- KOKON
- Outlook – ROCC
- Conclusion

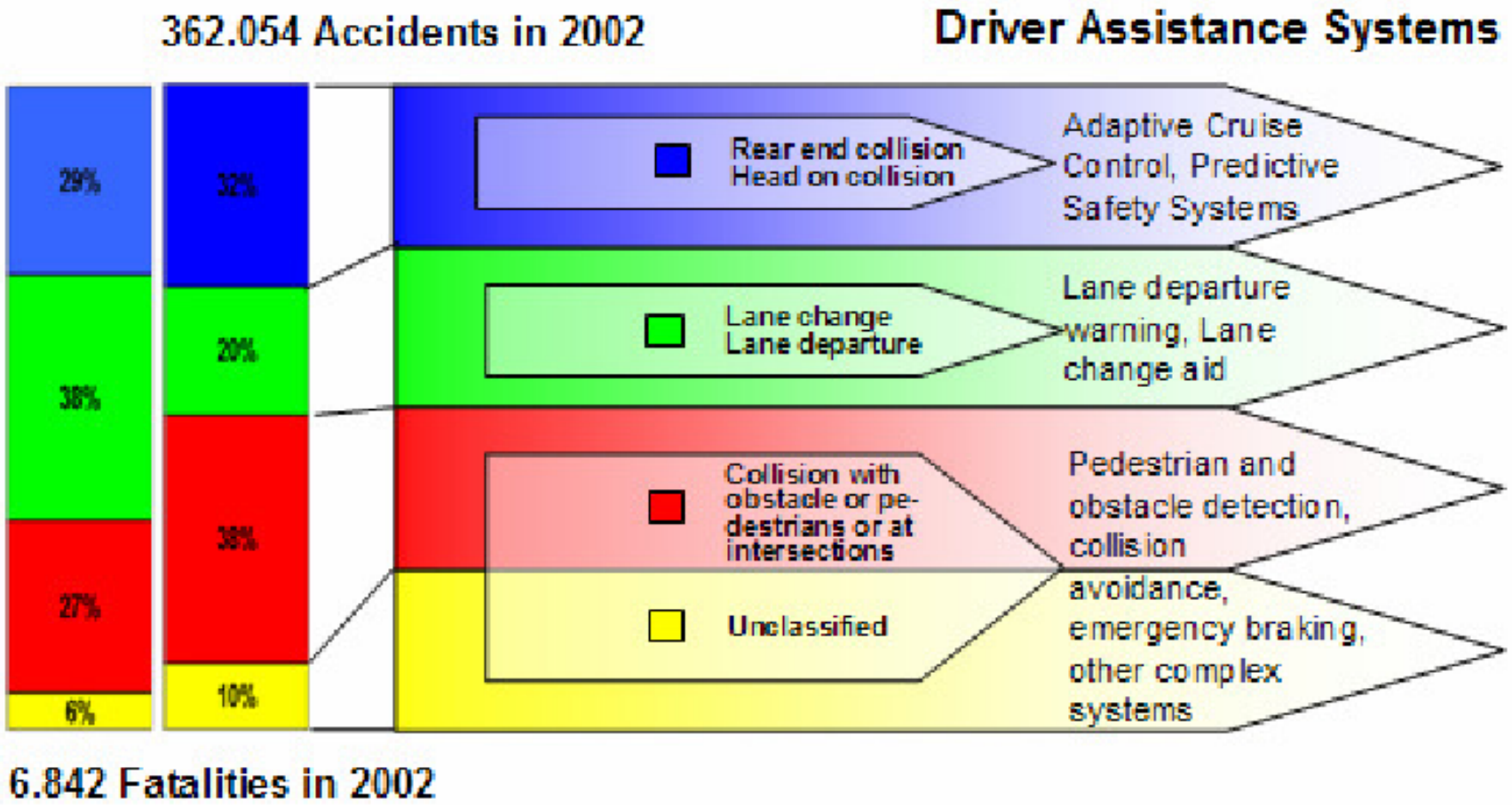
Motivation

- In Europe each year about 1.2 million traffic accidents cause:
- More then 40.000 fatalities!
- Economical damage of more than 200 billion €!
- Human error is involved in over 90% of accidents!

- Traffic jams affect approx. 10% of total road traffic in Europe!
- 50% of fuel consumption is due to traffic jams and inefficient driving!

Source: eSafety – Improving road safety using information & communication technologies, EC communication; http://ec.europa.eu/information_society/activities/policy_link/brochures/documents/intelligent_car.pdf

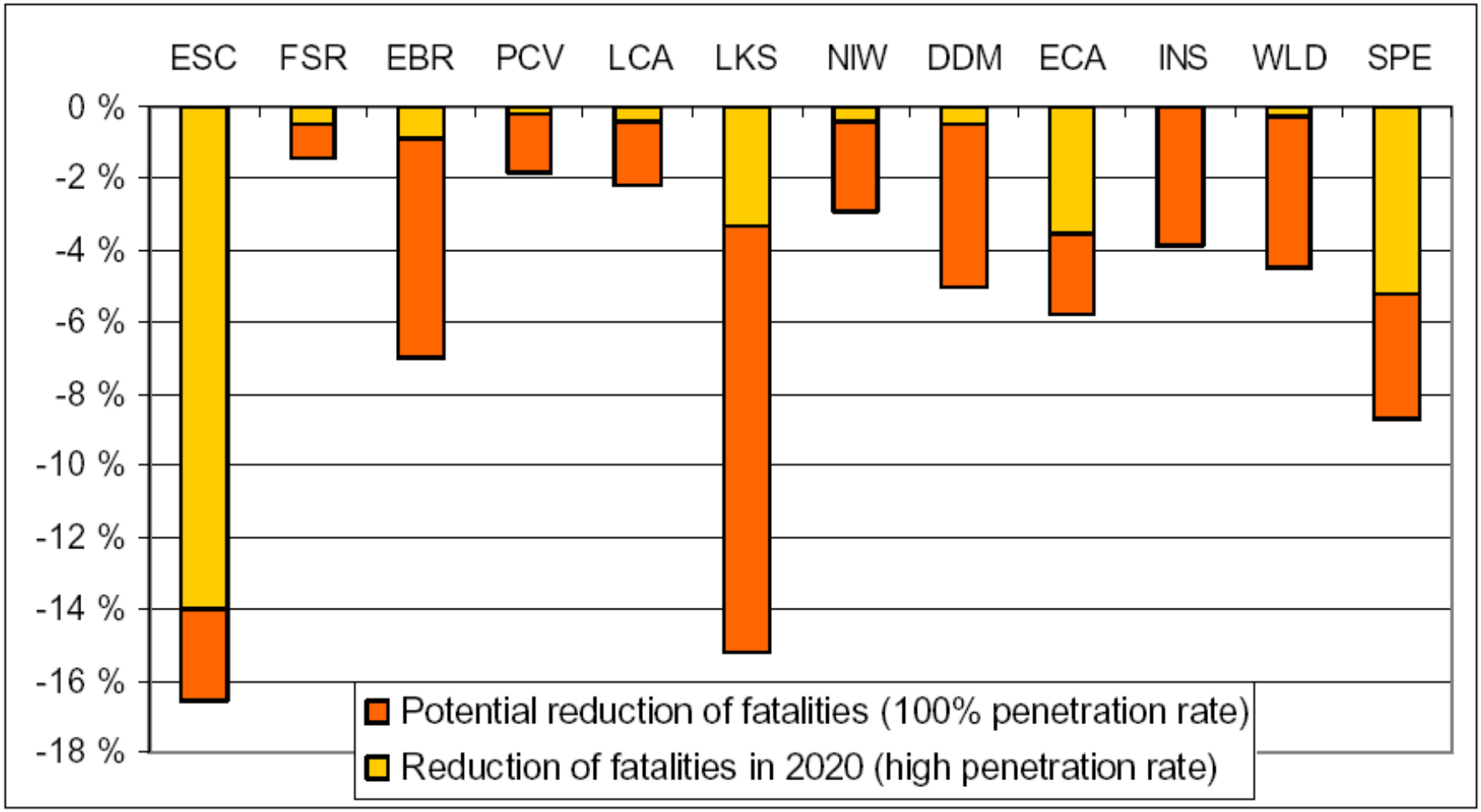
Causes of accidents (Germany 2002)



- 100.000 rear end collisions with 2.300 fatalities
- Almost 20% of all rear end collisions could be avoided by radar technology *)

Source: SEiSS "Exploratory study on the potential socio-economic impact of the introduction of intelligent safety systems in road Vehicles" ; http://www.eimpact.info/results.html
*)Mercedes Benz Press Information, June 2008

Significant potential to improve traffic safety by intelligent vehicle safety systems (IVSS)

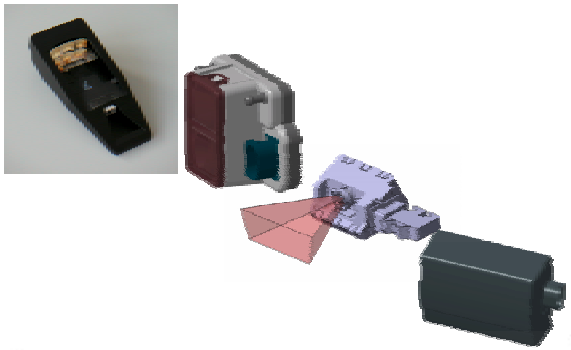


ESC: Electronic Stability Control
FSR: Full Speed Range
EBR: Emergency Brake
PCV: Pre-crash Protection of vulnerable Road Users
LCA: Lane Change Assist
LKS: Lane Keep Support

NIW: Night Vision Warn
DDM: Driver Drowsiness Monitoring and Warning
ECA: eCall (Emergency Call)
INS: Intersection Safety
WLD: Wireless Local Danger Warning
SPE: Speed Alert

Source: eIMPACT; http://www.eimpact.info/results.html

Why radar safety for automobiles ?
Comparison of Different Sensor Technologies



	Short Range Radar	Long Range Radar	Lidar	Ultrasound	Video Camera	3D-Camera	Far IR Camera
Range Measurement < 2m	o	o	o	++	-	++	-
Range Measurement 2..30m	+	++	++	-	-	o	-
Range Measurement 30..150m	n.a.	++	+	- -	-	-	-
Angle Measurement < 10 deg	+	+	++	-	++	+	++
Angle Measurement > 30 deg	o	-	++	o	++	+	++
Angular Resolution	o	o	++	-	++	+	++
Direct Velocity Information	++	++	- -	o	- -	- -	- -
Operation in Rain	++	+	o	o	o	o	o
Operation in Fog or Snow	++	++	-	+	-	-	o
Operation if Dirt on Sensor	++	++	o	++	- -	- -	- -
Night vision	n.a.	n.a.	n.a.	n.a.	-	o	++

Radar is robust and therefore the preferred solution for safety applications !

++ : Ideally suited / + : Good performance / o : Possible, but drawbacks to be expected;

- : Only possible with large additional effort / - - : Impossible / n.a. : Not applicable

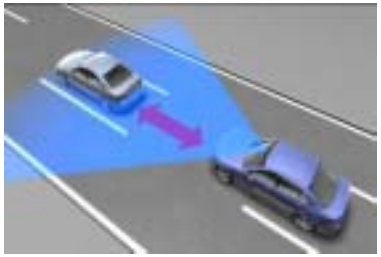
Source: SiemensVDO

Range Classification of Automotive Radars

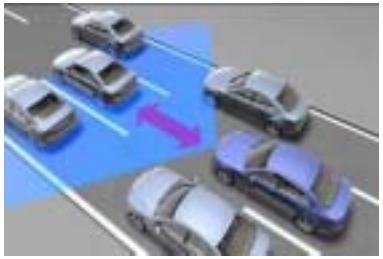
- Long Range Radar (LRR)
  - Range up to 150 – 250 m
  - Vehicle velocity above 30 km/h to 250 km/h
  - Narrow beams to control driving path in front of the car to determine distance of vehicle driving ahead for maintaining minimum safety distance
  - Bandwith below 1 GHz and typical spatial resolution 0.5 m
- Short Range Radar (SRR)
  - Range up to 30 m
  - Speed range from 5 km/h to 150 km/h
  - Wide field of view
  - Bandwith below 5 GHz and typical spatial resolution 0.1 m

Automotive Radar Applications

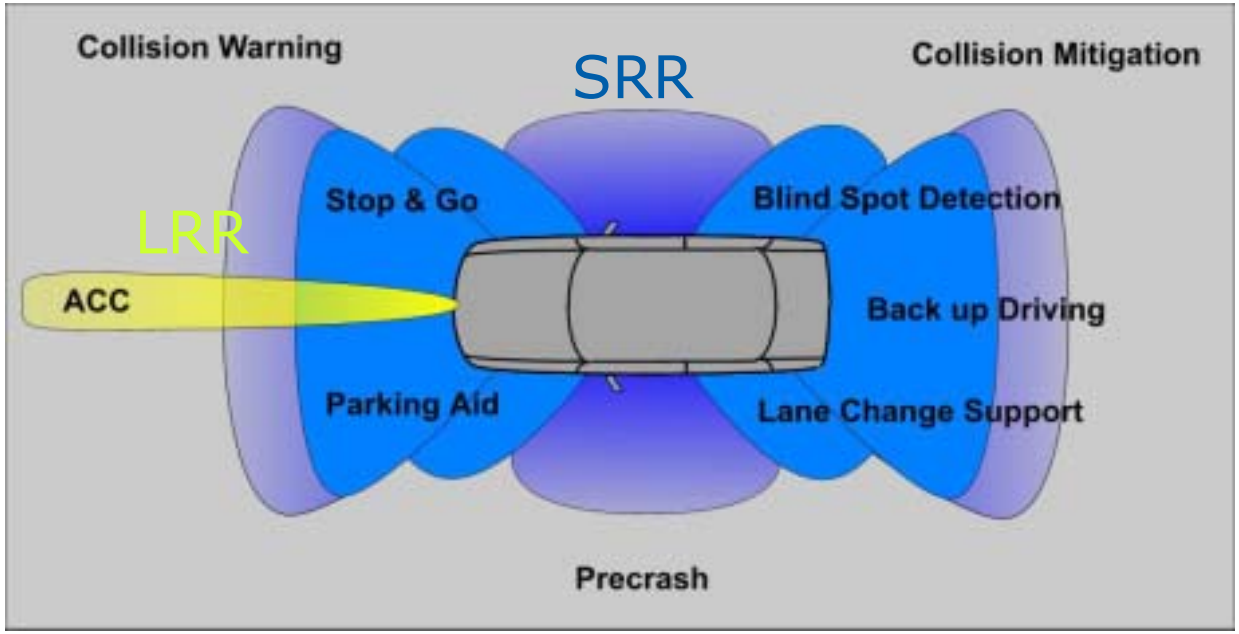
- Adaptive Cruise Control (ACC)
- Collision warning / mitigation / avoidance
- Pre-crash sensing / controlled firing of restraints, airbags / brake boosting
- Stop and go functionality
- Lane change warning, lane change aid
- Blind spot detection
- Parking aid, back drive assistance



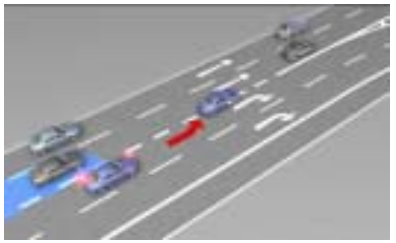
ACC



ACC Stop&Go

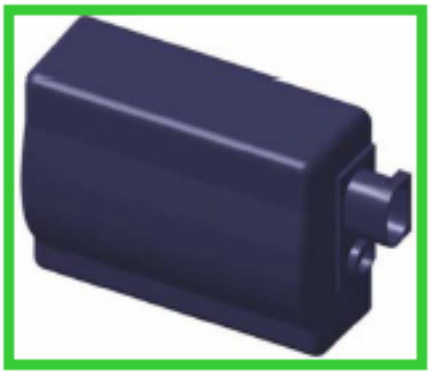


Lane Change Assist



Blind Spot Detection

Long Range Radars (77 GHz)



Conti-Temic ADC

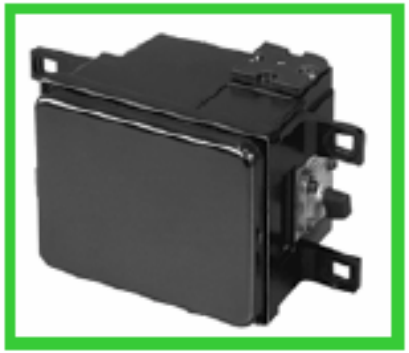
TRW

DENSO

Hitachi

Bosch

Delphi



Fujitsu Ten

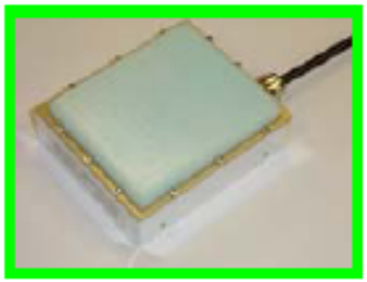
Mitsubishi Electric

Introduced in market

Short Range Radar

Tyco / M/A-Com

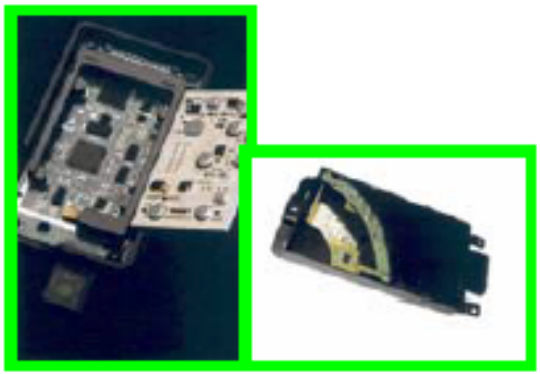
TDK



s.m.s. GmbH

Siemens-VDO

Hella
InnoSent / s.m.s.



Valeo

MTS GmbH

Hitachi

24 (±2.5) GHz

76 - 77 GHz

Radar based safety concept of Mercedes-Benz : Distronic plus, Brake assist plus

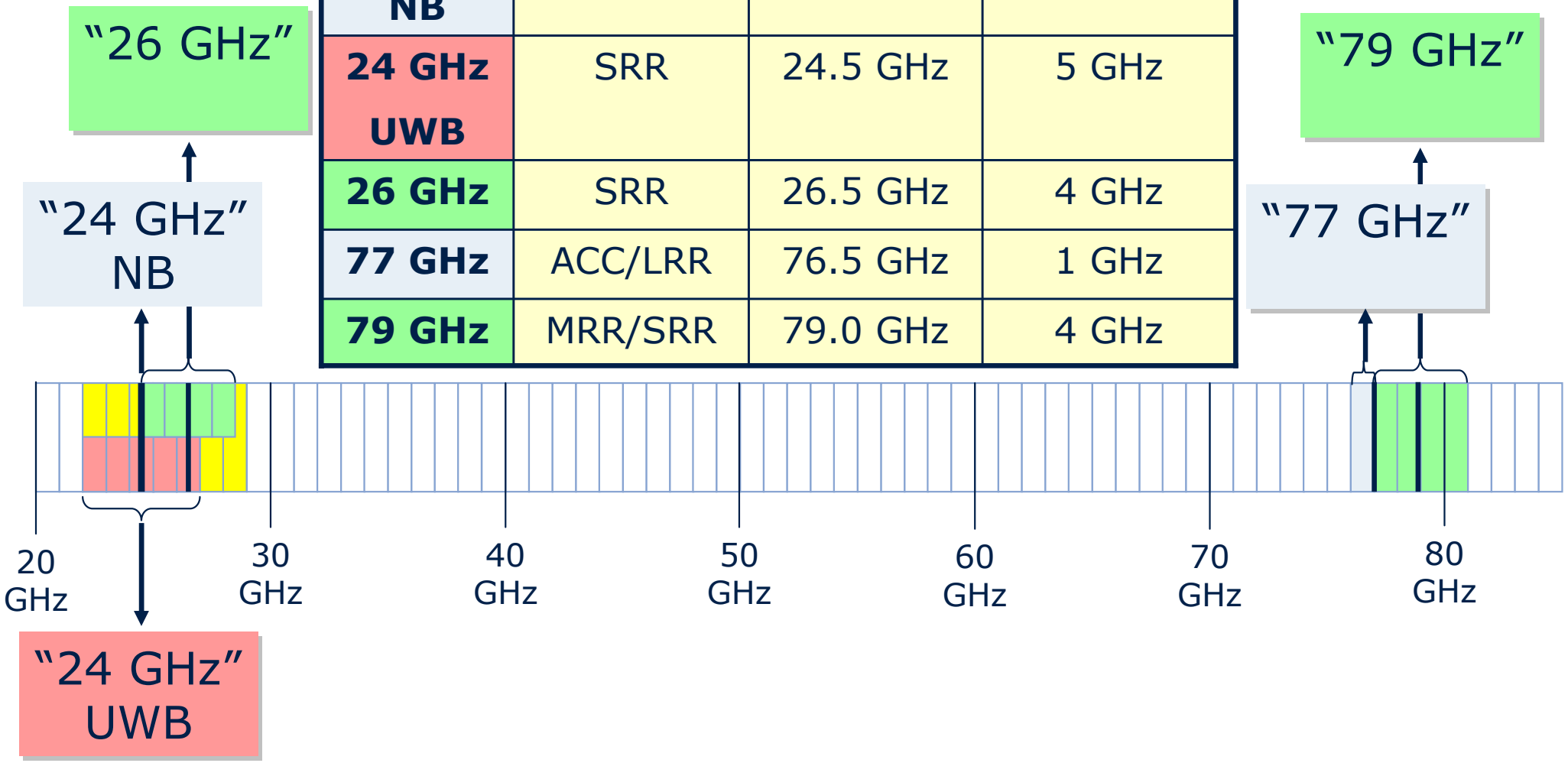
- Introduced in 2005
- 40% take rate S-Class
- >80% in CL coupe Class

Speed Range: 0-200km/h
Distance Range: 0.2-150m
Maximum deceleration 4 m/s^2

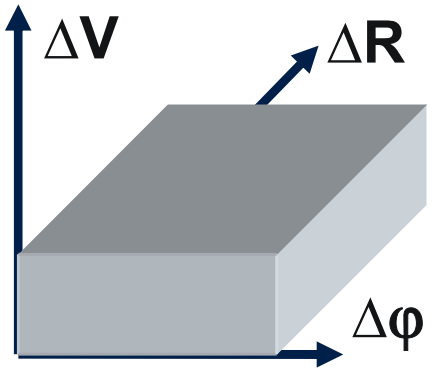
Stop & go assistance:
Automatic braking to stop
Automatic start-up behind preceding vehicle

Frequency Bands for Automotive Radar

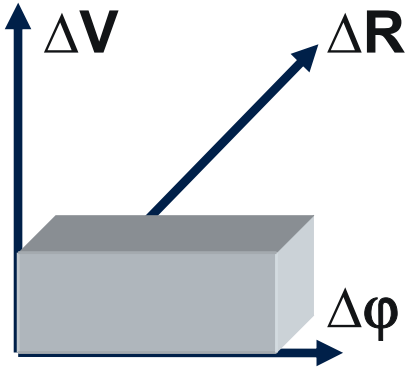
	Application	Center Frequency	Band Width
24 GHz NB	ACC	~24.2 GHz	0.2 GHz
24 GHz UWB	SRR	24.5 GHz	5 GHz
26 GHz	SRR	26.5 GHz	4 GHz
77 GHz	ACC/LRR	76.5 GHz	1 GHz
79 GHz	MRR/SRR	79.0 GHz	4 GHz



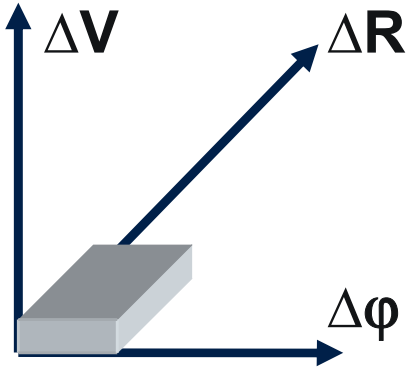
Performance of Radar Systems



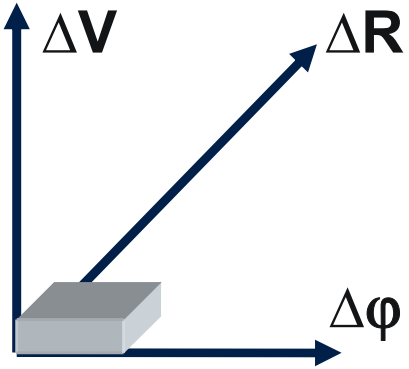
24 GHz
BW ~ 200 MHz
λ=12.5 mm



26 GHz
BW ~ 4 GHz
λ=11.5 mm



77 GHz
BW ~ 1 GHz
λ=3.9 mm



79 GHz
BW ~ 4 GHz
λ=3.8 mm

Sensor Performance

ΔV: Velocity Axis	=> Doppler shift of moving objects is proportional to frequency
ΔΦ: Angle Axis	=> Angular resolution depends on antenna size in relation to wave length
ΔR: Range Axis	=> Range resolution (object discrimination) depends on modulation bandwidth

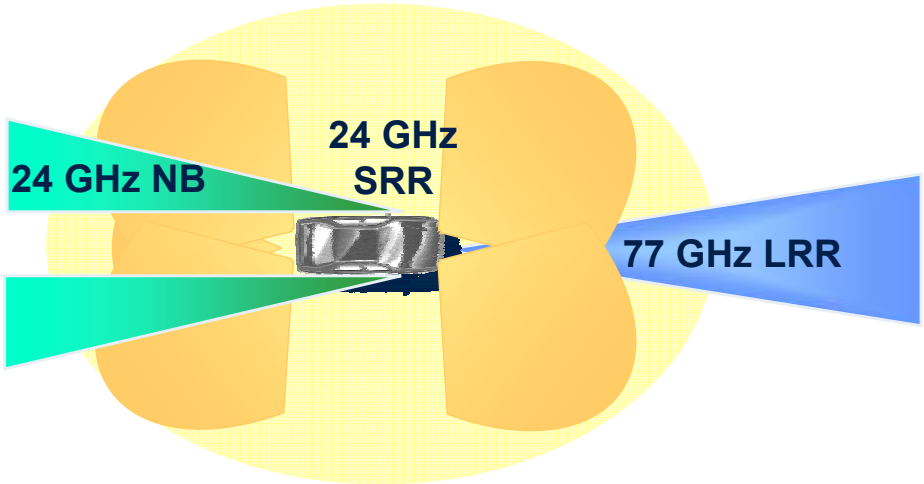
Benefits of SRR in 79GHz compared to 24GHz

- Sensor Size Reduction
  - Antenna size 1/3 of equivalent 24 GHz
  - Or more channels at same mechanical dimension
- Integration
  - Single-Chip and Packaging is possible
- Performance Increase
  - Better speed resolution (3x)
  - Improved Signal-to-Noise ratio
  - Higher output power
  - Robust modulation
- Continous band use
  - Same technology and FMCW architecture as for 76-77GHz can be used
- Platform Concept
  - Re-Use of development effort to reduce R&D cost
  - Re-Use of components in multiple applications

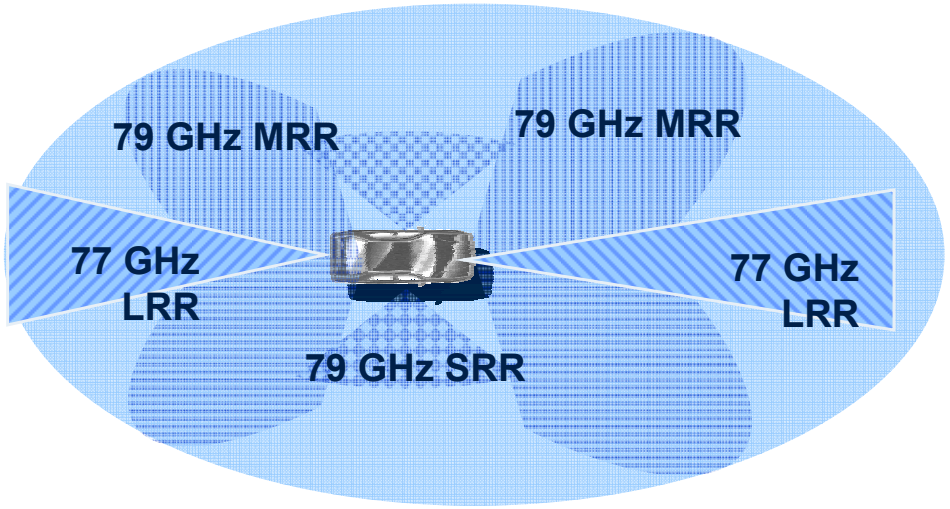
Synergies within Higher Frequency Bands

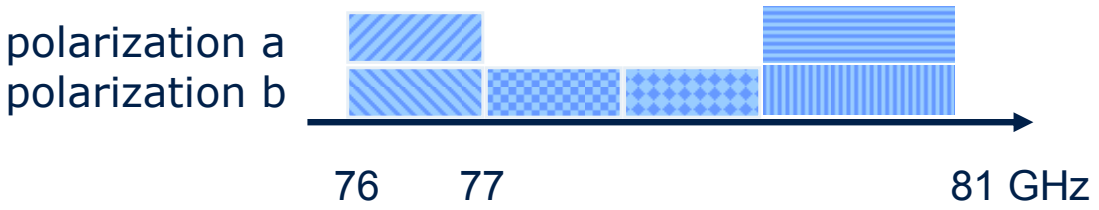
- A full-scaled vehicular safety system requires short, mid & long range radar sensors
- Homogenous technology concept is needed for large mass market deployment
- Lower system cost is only possible with a single technology approach

today's safety system concept

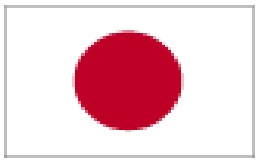


next generation safety system layout



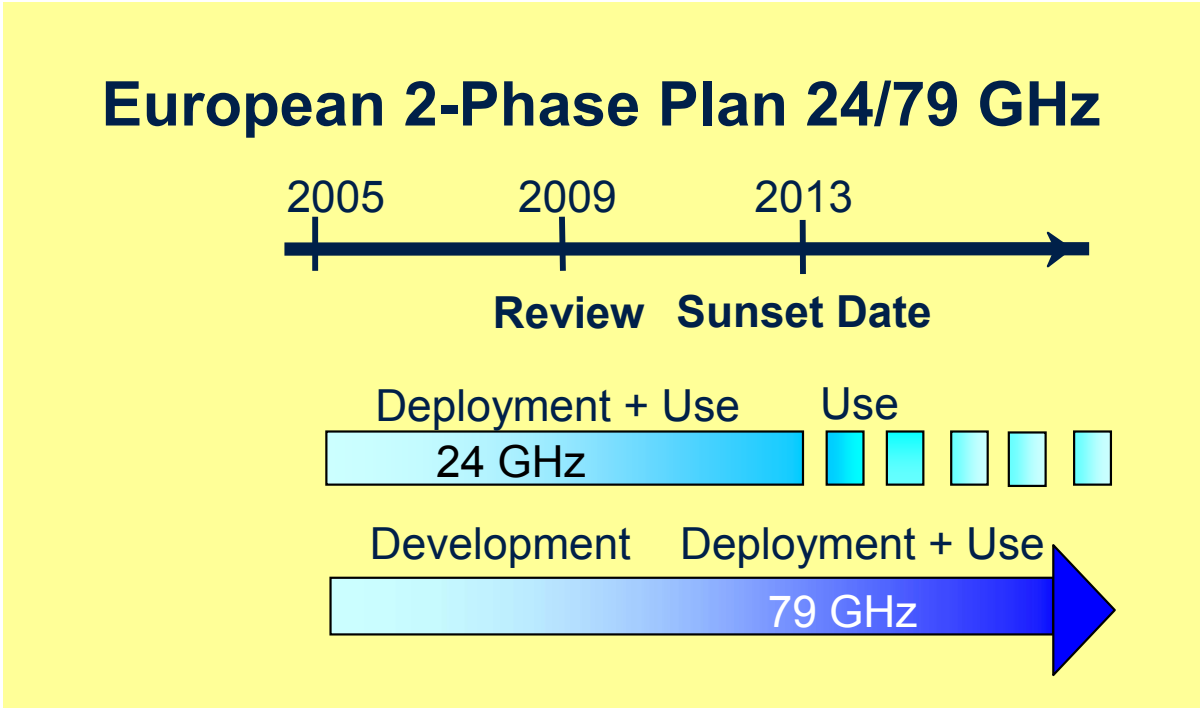


Global Frequency Regulation Status of Automotive Radar Frequency Bands

	24 GHz NB (ISM)	24 GHz UWB SRR	26 GHz UWB SRR	77 GHz LRR	79 GHz SRR
 Europe	200 MHz 20dBm Restr. in UK / F available	5 GHz -41.3dBm/MHz until 2013	4 GHz -41.3dBm/MHz proposed	1GHz 23.5dBm available	4GHz -9dBm/MHz available
 USA	100/250 MHz 32.7/12.7dBm available	7 GHz -41.3dBm/MHz available	4 GHz -41.3dBm/MHz available	1 GHz 23dBm available	No activity
 Japan	76 MHz 10 dBm @antenna port available	Study underway	proposed	0.5 GHz 10 dBm @antenna port available	In discussion

European Regulation: 'Package solution'

European compatibility studies with extreme severe study parameters lead to a EU specific approach



Regulation 24 GHz:
Limited in time and restricted in quantity (7% penetration).
Protection zones for Radio Astronomy Sites

Regulation 79 GHz:
No restriction in time and quantity,
technology not yet available

- Interim solution until 2013 for 24 GHz, to open the market and to allow an early contribution to road safety
- Monitoring and reporting of implementation rate
- Review in 2009

Members of SARA

SARA
Strategic Automotive Radar frequency Allocation

Infineon

- Active Members

DAIMLER BMW Group Autoliv BOSCH Continental

HOGAN & HARTSON JS Consulting C3 GmbH & Co.KG GR Consulting

- Cooperating Members

GM Opel SAAB Valeo Raytheon CEL HELLA

Infineon united monolithic semiconductors ums REHAU Unlimited Polymer Solutions

- Supporting Partners

VW Audi SEAT Skoda FIAT Ford VOLVO JAGUAR MAN

DELPHI TRW AUTOCRUISE sms smart microwave sensors InnoSenT MITSUBISHI ELECTRIC Changes for the Better

TAKATA Visteon

- Mission: Global harmonization for regulations and standards for automotive radar in general (earlier: for UWB SRR only)

SARA SRR Strategy

- 79 GHz itself provides significant design advantages:
  - Size
  - Performance
  - Combined LRR/SRR platform
- Will therefore definitely be the long term choice of SRR products
- But: Indication that mature 79 GHz technology will not be available early enough for seamless transition from 24 GHz in 2013
- Therefore proposal for introduction of 26 GHz SRR (complementary to 79 GHz)
- Only solution that fosters the implementation of 79 GHz SRR Technology (door opener)

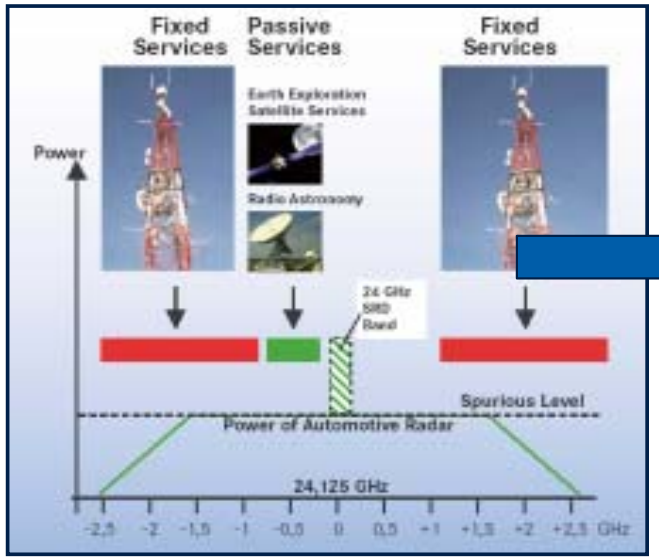
Current European frequency regulation blocks market penetration of SR radar systems

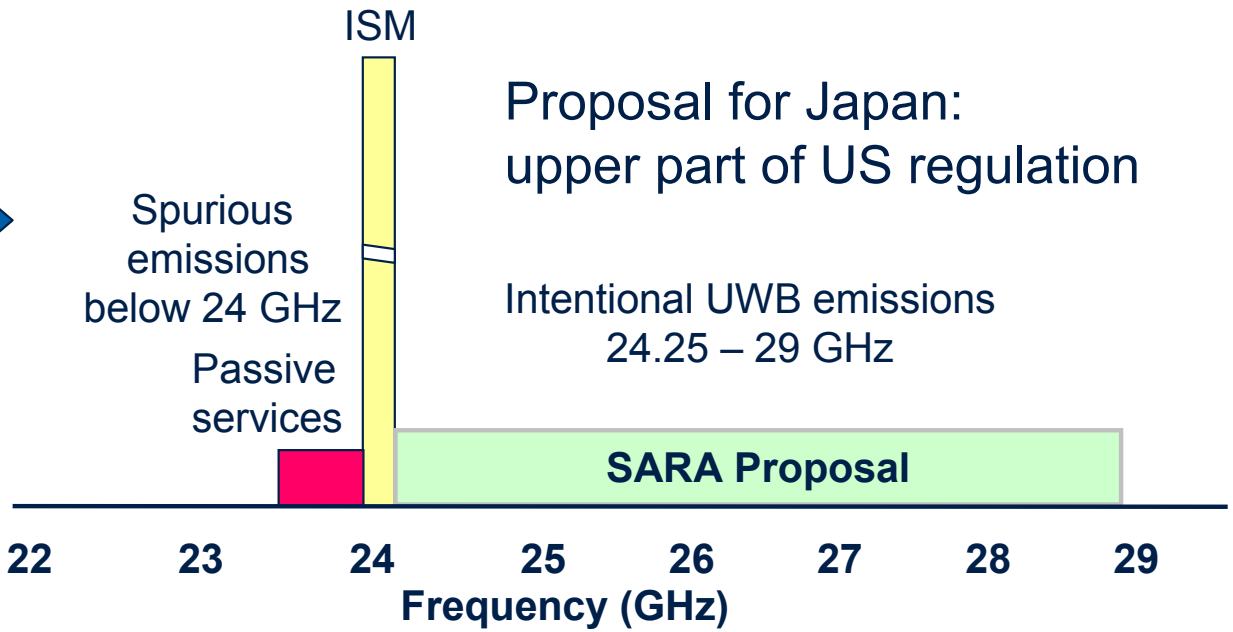
- With three years of experience, SARA sees that market take-up of first generation SRR will be inherently limited due to the 2013 deadline
- Market penetration will grow, but far below 7%

24 GHz UWB market penetration in %

	2008	2009	2010	2015	2020
USA	**0,005**	**0,05**	**0,1**	**2**	**15**
Europe	**0,01**	**0,02**	**0,03**	**0,06**	**0,04**

SARA Proposal (adopted from ETSI)

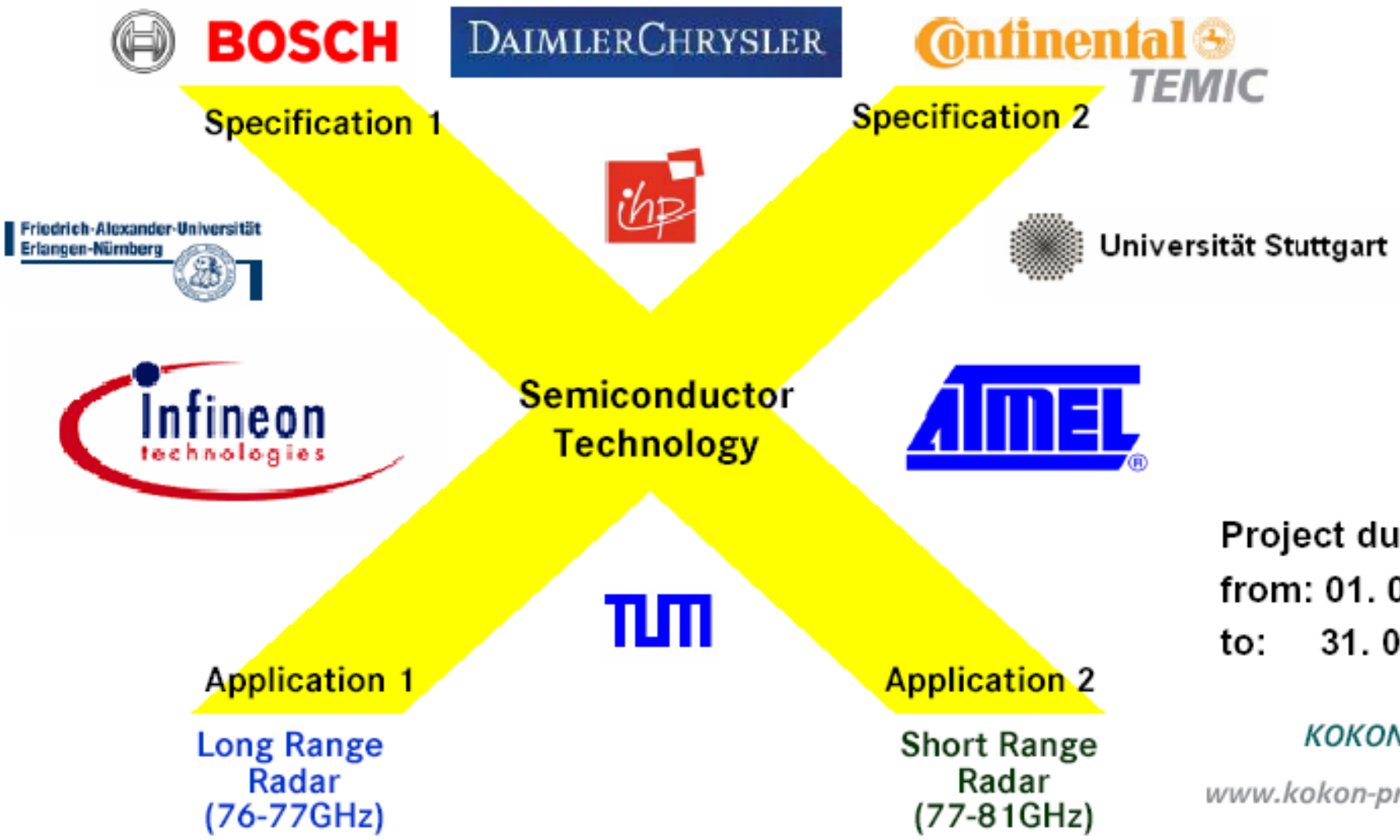




- Intentional emissions into the assigned frequency band 24.25 -29 GHz
- Below 24.25 GHz only spurious emissions
- ISM guard band will protect passive services
- No deactivation for RAS necessary
- Decoupling from ISM - band
- Technology available
- Harmonization of Japanese with US regulation

Automotive High Frequency Electronics: KOKON

- Publically funded by German BMBF



Bundesministerium für Bildung und Forschung

KOKON

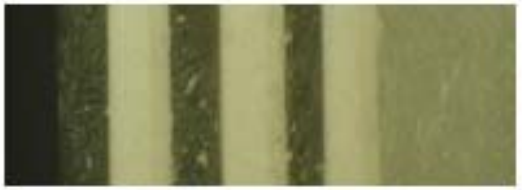
Project duration
from: 01. 09. 2004
to: 31. 08. 2007

KOKON = cocoon

www.kokon-project.com

Investigations by Daimler

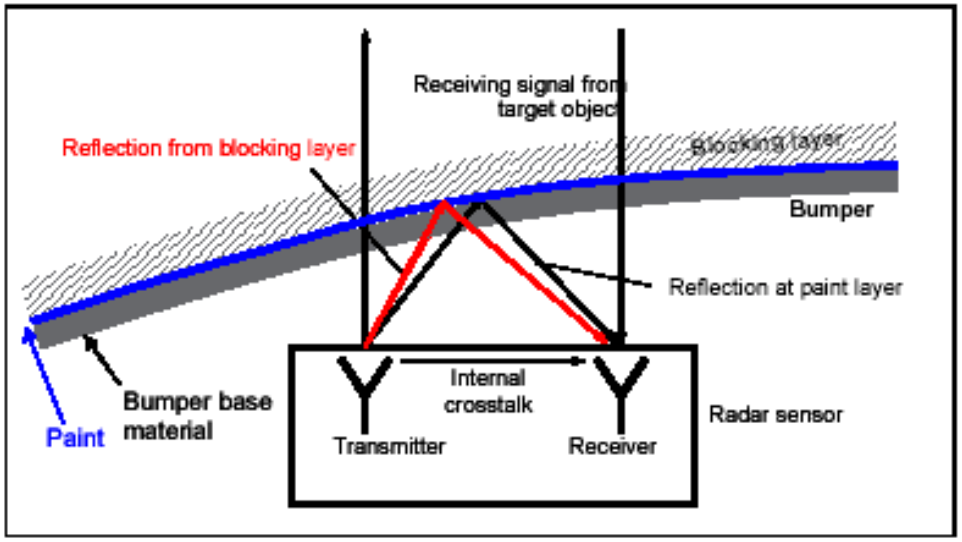
- Influence of bumper materials at 79 Ghz

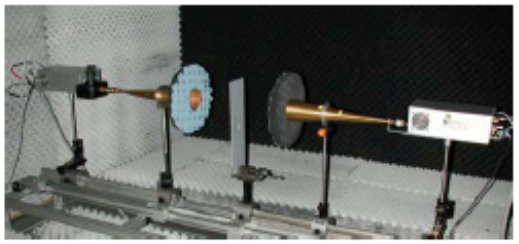


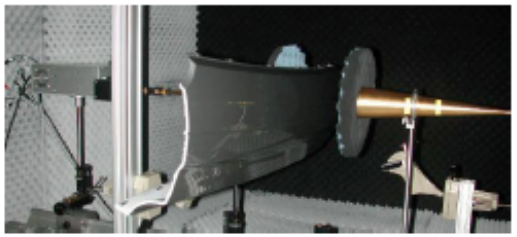
triple coating white

single coating metallic silver

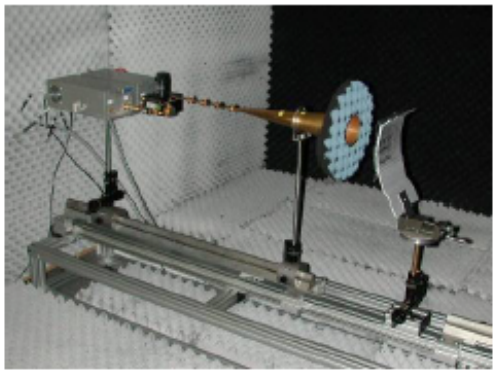
transmission and reflection measurements (70 - 80 GHz)
with 0.1dB calibration accuracy







measurement in transmission



measurement in reflection

Investigations by Daimler

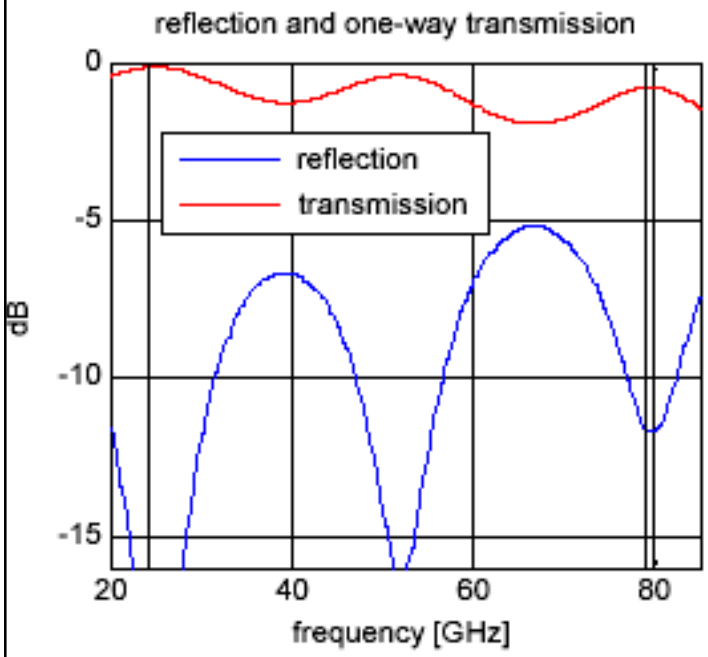
Transmission/reflection at multiple coatings:

example:

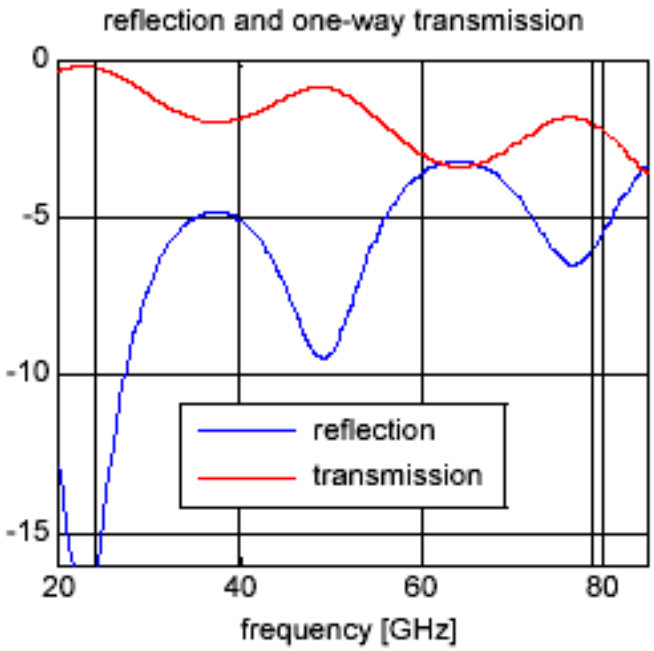
base material: PP/EPDM TV10 3.4 mm

color: gray metallic 15/15/50 µm (primer/topcoat/clear coat)

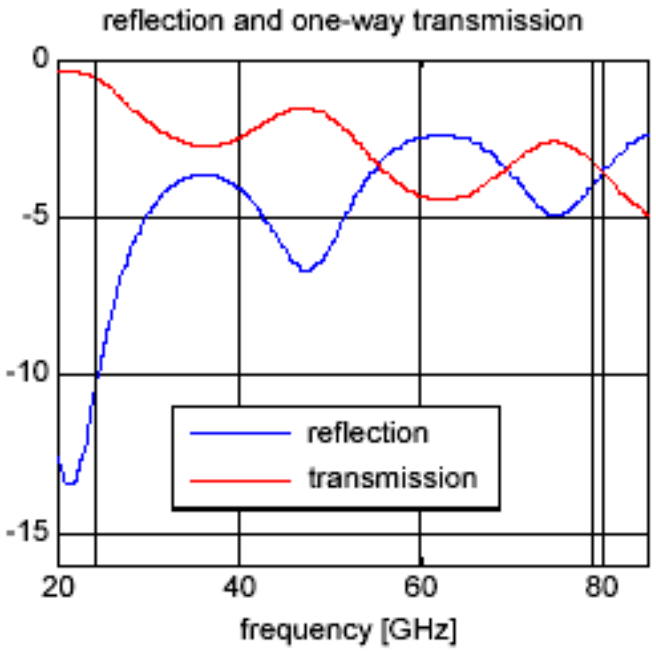
single coating:



double coating:



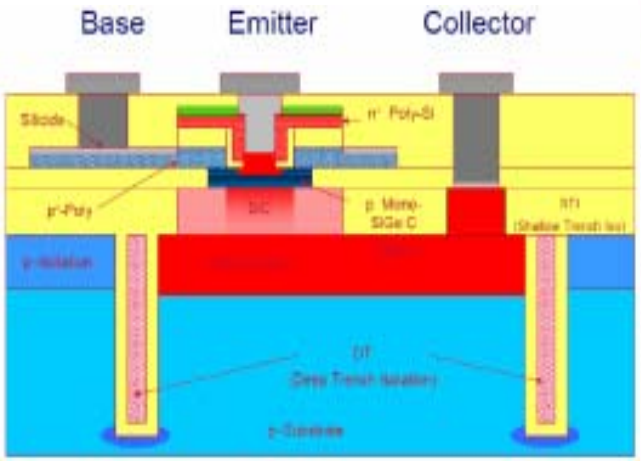
triple coating:



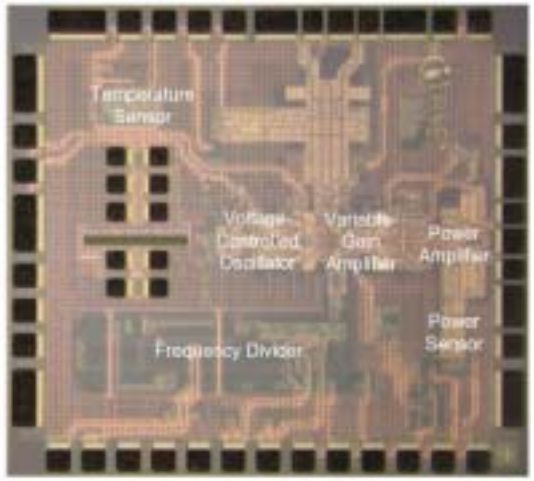
Contribution of Infineon

- Development of 200 GHz Silicon-Germanium Technology
- Design and realization of all 77 GHz / 79 GHz building blocks

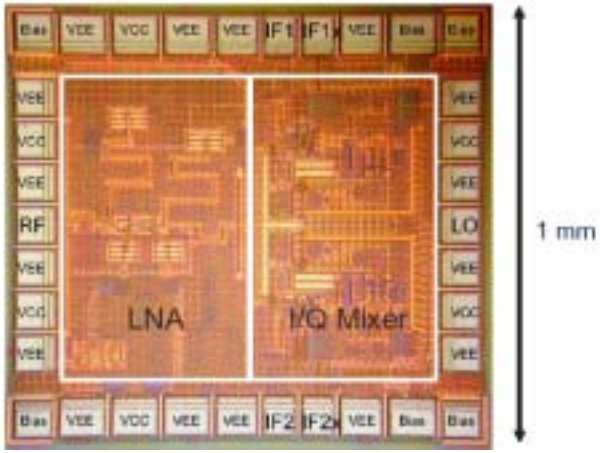
SiGe NPN

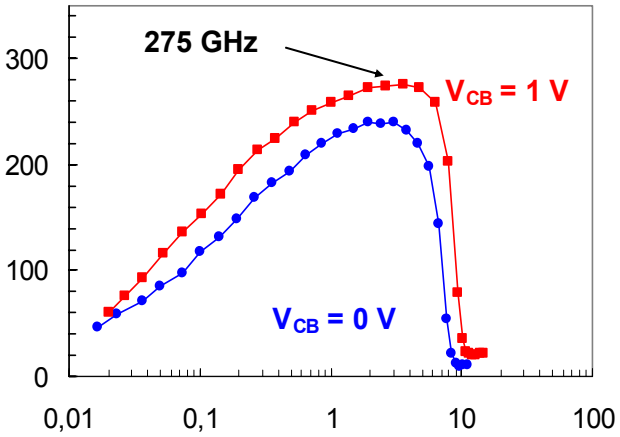


76-81 GHz Transmitter

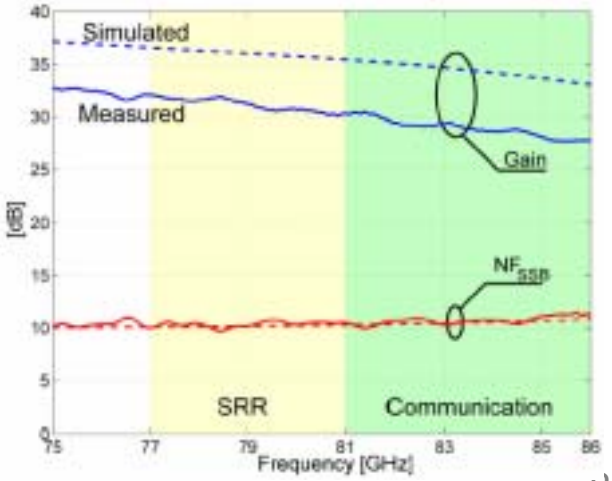


I/ Q Demodulator



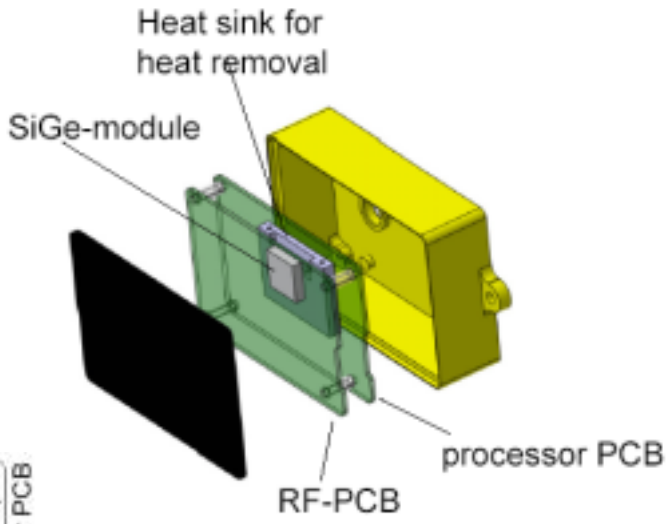


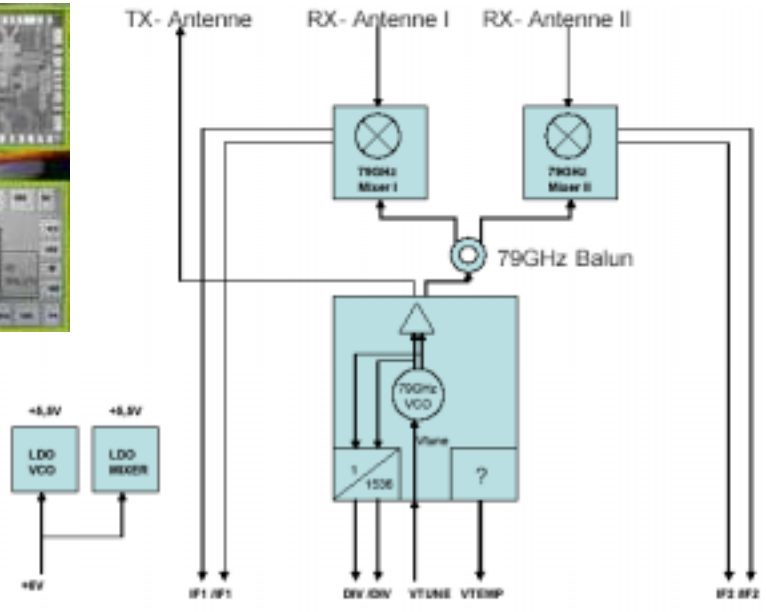
- Center frequency: 77 GHz
- Tuning range: 7 GHz
- Output power: 16 dBm
- Phase noise at 1 MHz offset: -95 dBc/Hz
- Current consumption: 430 mA (VCC = 5.5 V)
- Chip size: 1.865 x 1.69 mm²

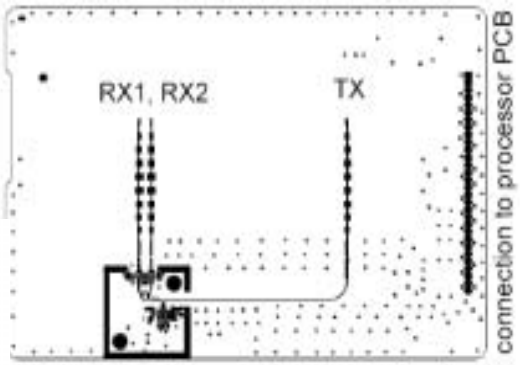


Contribution of Continental

- Design and realization of a 79 GHz short range radar sensor
- Use of SiGe RF components from Infineon
- Same circuits as used by Bosch for LRR demonstrator (center frequency adjusted by metal mask)







F PCB with antennas and footprint for SiGe MMICs

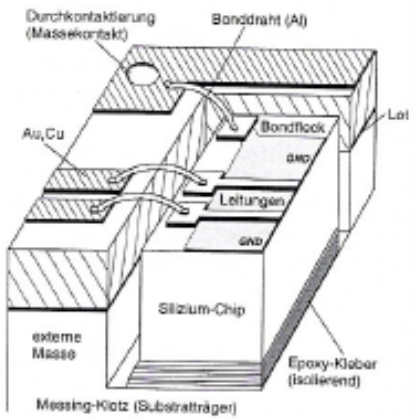
Front side (processor and memory)

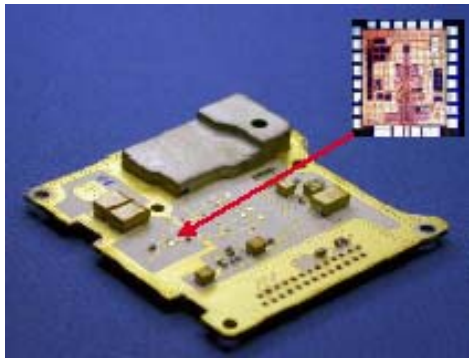
dimensions B x H x T:
98mm x 67mm x 27mm

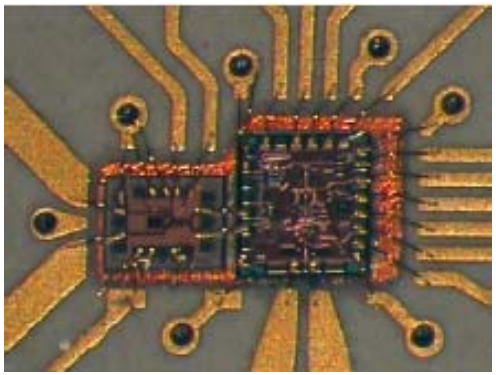
Back side (power supply)

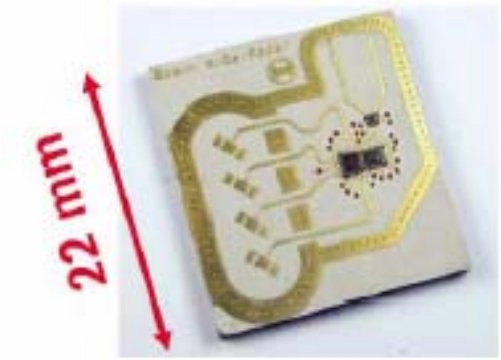
Contribution of Bosch

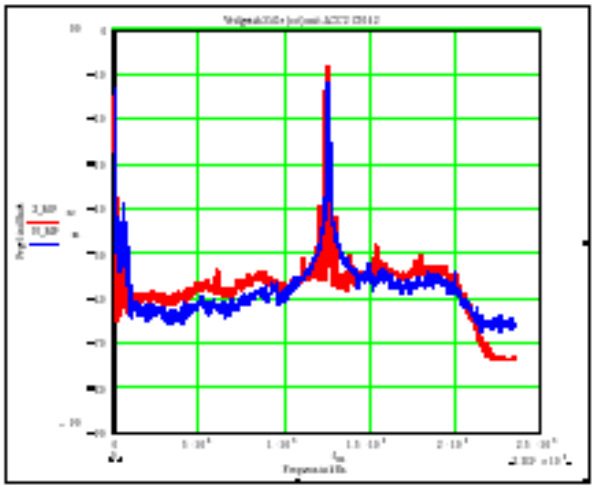
- Demonstration of a fully functional 77 GHz LRR sensor
- Replacement of GaAs components of ACC2 system by SiGe VCO and reference oscillator from Infineon



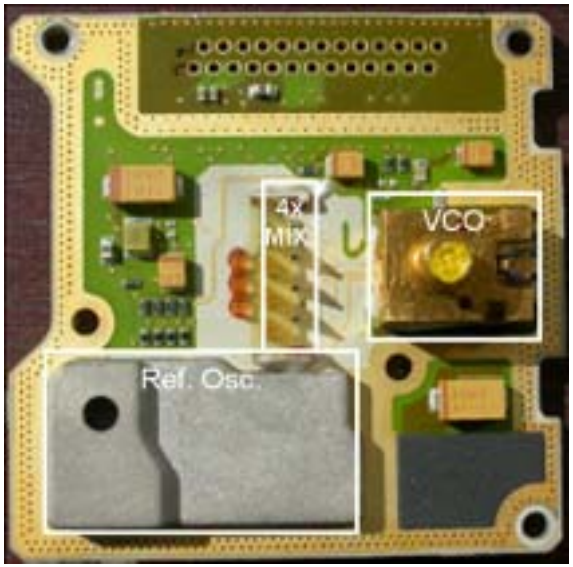








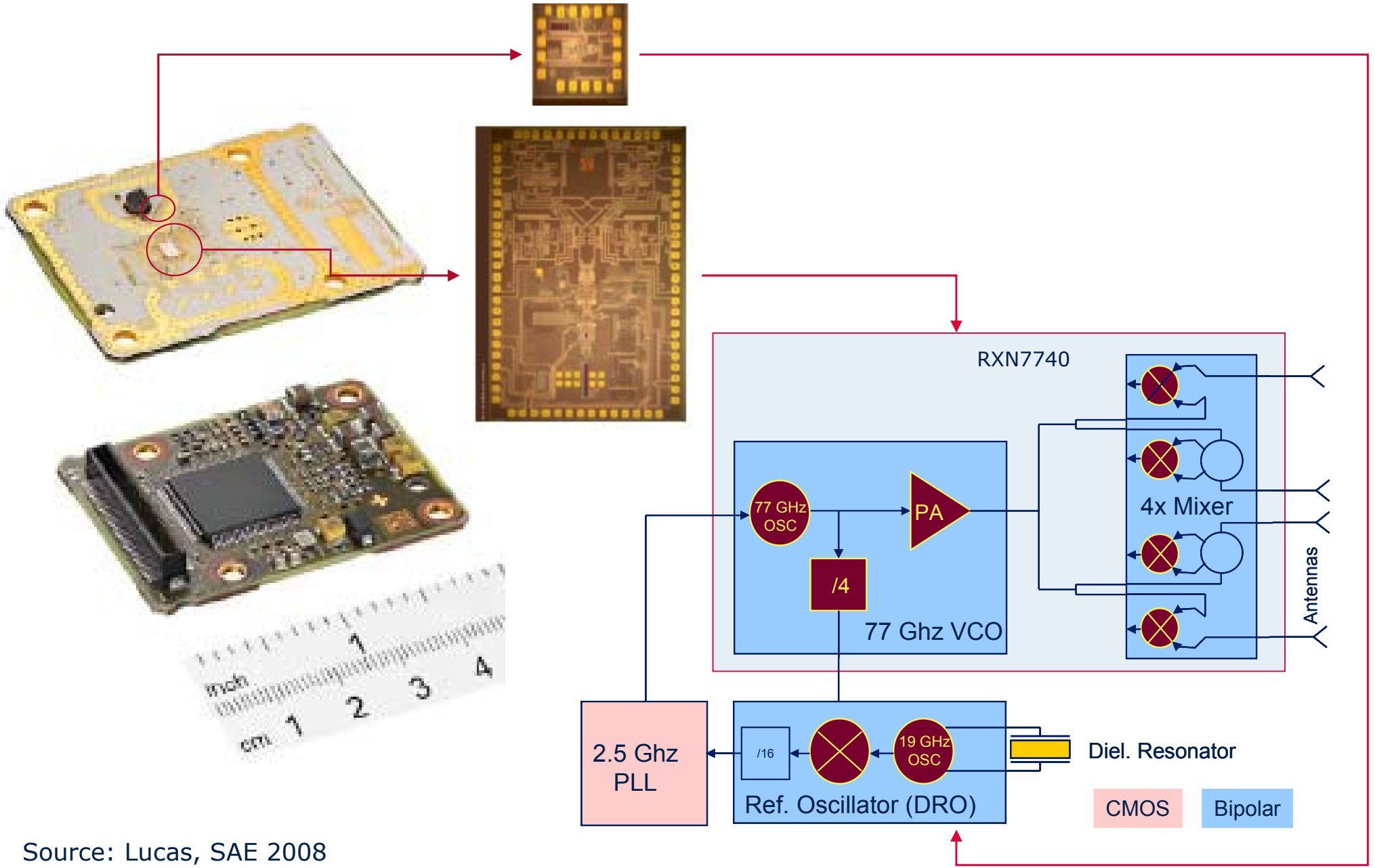
First commercial Silicon-based 77 GHz radar sensor will be introduced in 2009 by Bosch (based on KOKON results)!



LRR2 (GaAs)

New LRR3 (SiGe)

Only 2 SiGe MMICs (Infineon) needed for complete 77 GHz Radar frontend!



Source: Lucas, SAE 2008

Comparision ACC2 vs. LRR3 (Performance)

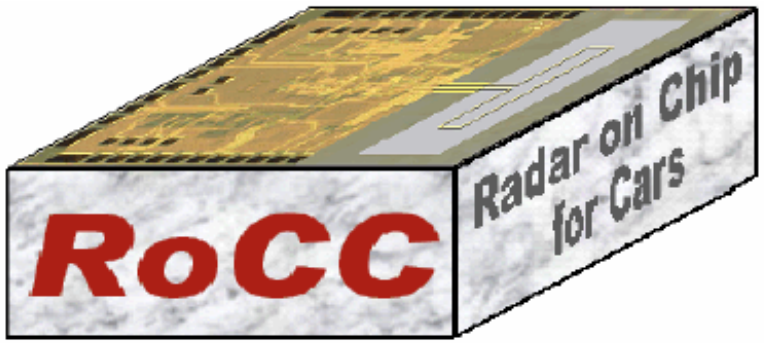
	Unit		Range	Accuracy	Separability
Distance	m	LRR2 (GaAs)	2 – 150	0.5	2
		LRR3 (SiGe)	**0.5 - 250**	**0.1**	**0.5**
Relative Velocity	m/s	LRR2 (GaAs)	–60 to + 20	±0.25	1.5
		LRR3 (SiGe)	**-80 to +30**	**± 0.12**	**0.6**
Angle (Azimuth)	deg	LRR2 (GaAs)	±8	0.4	–
		LRR3 (SiGe)	**±15**	**0.1**	

⇒ Use of cost efficient SiGe Technology in a commercial millimeter wave product can outperform GaAs!

⇒ Extension to 79 GHz is strait forward

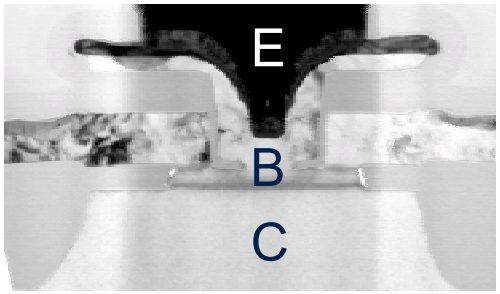
ROCC: Radar on Chip for Cars

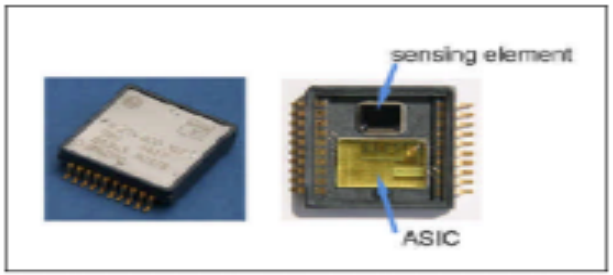
- ROCC is again funded by BMBF (German Ministry of Education and Research)
- Duration: 1/9/2008 until 8/31/2011



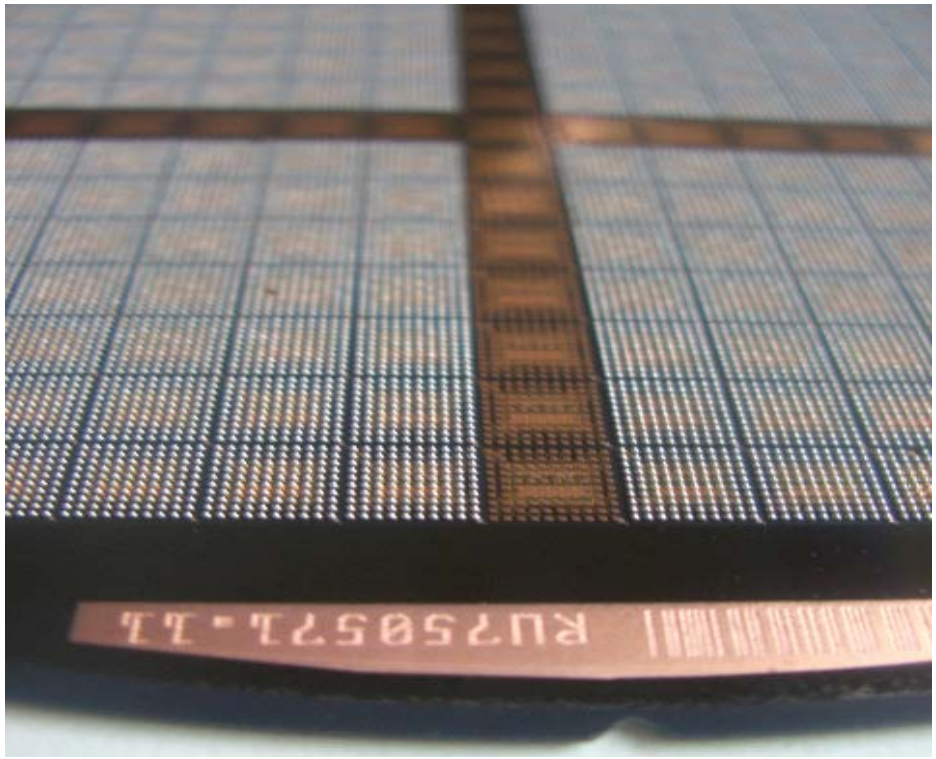
ROCC: Goals

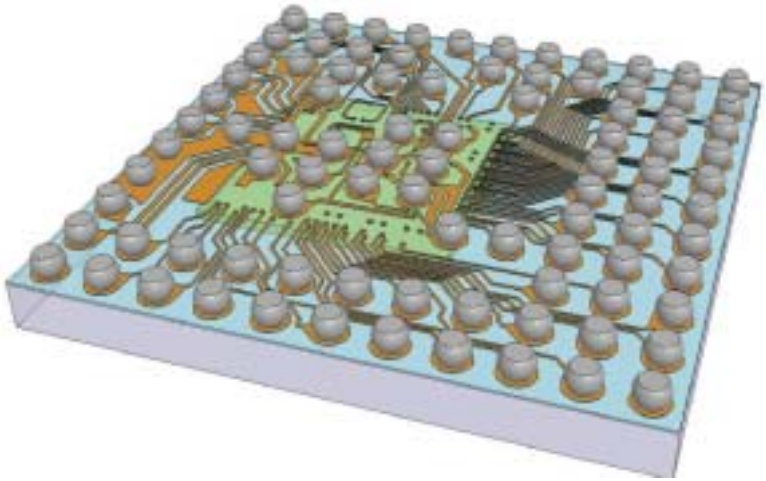
- Reach cost-competitiveness of 79 GHz vs. 24/26 GHz
- Radar sensors of high sensitivity to cope with complex situations
- 76-81 GHz sensor platform adaptable from long to short range
- Universal, low cost radar transceiver (with integrated antennas)
- Improved energy efficiency of SiGe MMICs – strongly reduced power consumption
- 76-81 GHz MMICs in SMD-Package.
- 500 GHz SiGe Technology Base or automotive radar applications (also supported by European DOT5 project)
- Early exploration of frequency ranges > 100 GHz

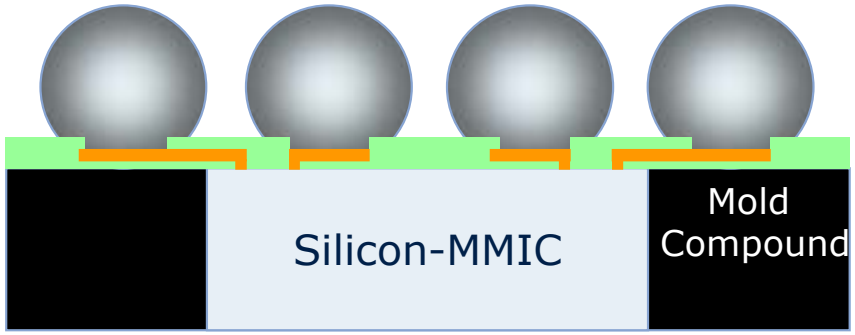


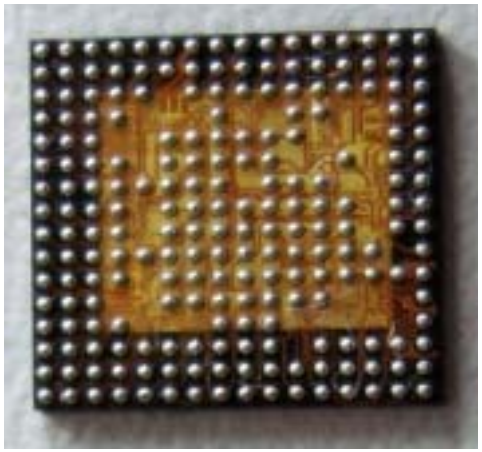


Packaging of 79 GHz Millimeter Wave ICs will soon become reality by Wafer Level Packaging!





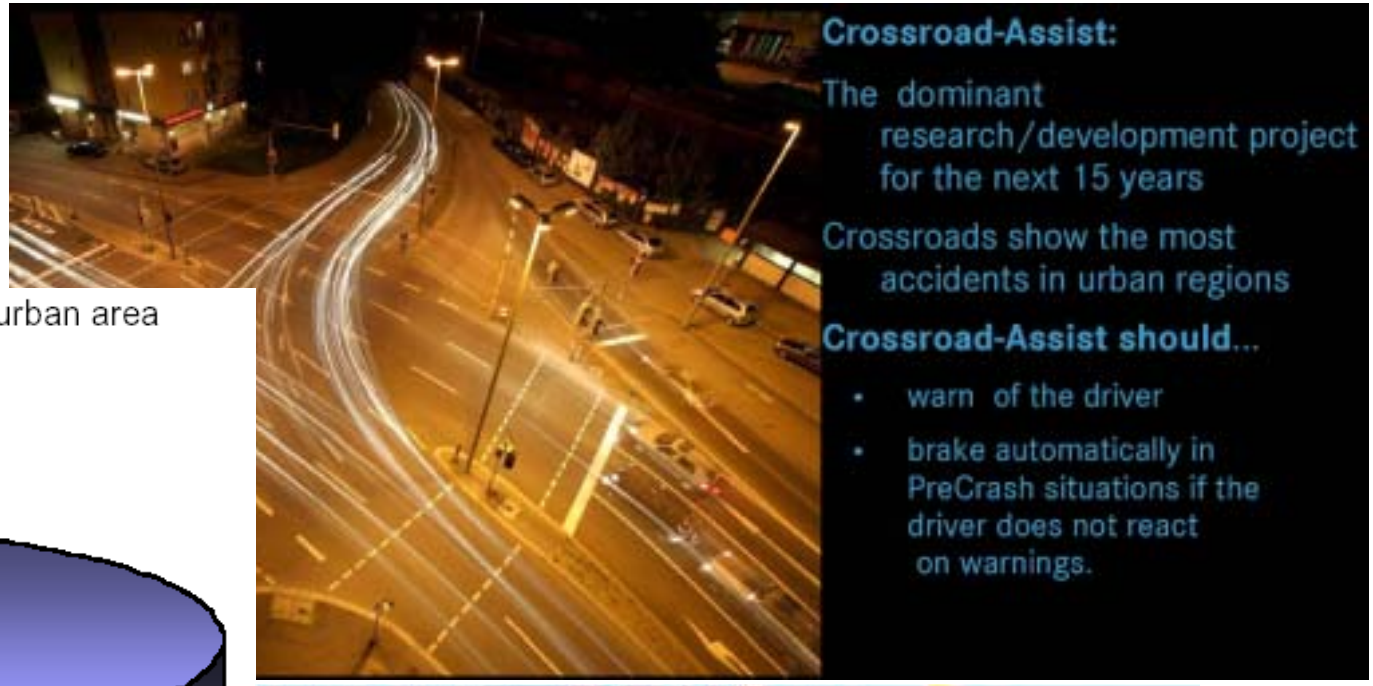


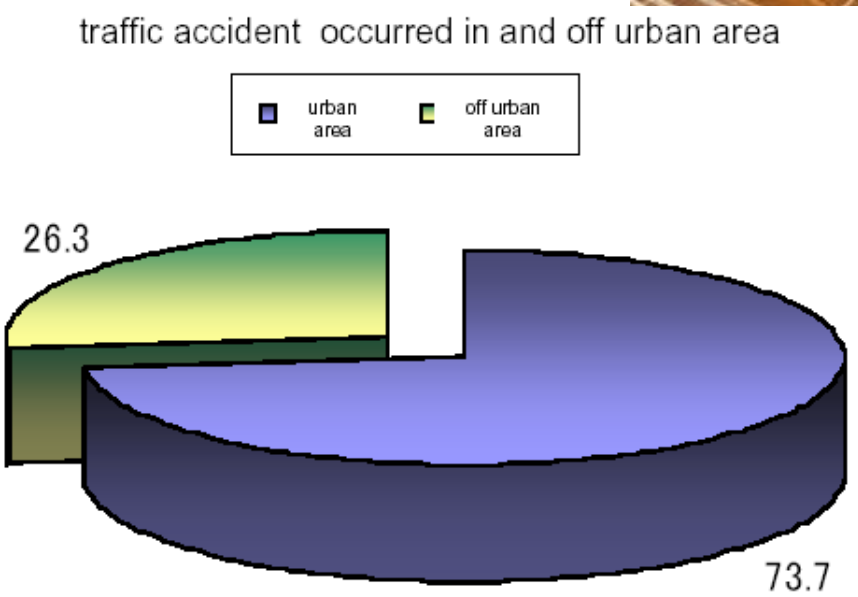


- Advanced packaging technology from Infineon: eWLB (embedded wafer level ball grid array packaging)
- Very good millimeter wave properties
- Reproducible, low loss and reliable SMD assembly of MMICs feasible

Next step into future radar applications

- Handling of much more complex situations in urban environment





Source: Japanese Institute of Accident Research and Data Analysis (2006)

Conclusion

- Radar technology is seen as an essential part of future intelligent vehicle safety systems (IVSS)
- Large potential of IVSS to reduce traffic causalities significantly
- A full-scaled vehicular safety system requires short, mid & long range radar sensors
- Today's market penetration of SRR technology is still negligible small (0.02%!)
- Lack of global frequency allocation hinders faster market penetration and rapid progress in automotive radar technology
- Japan and Europe should step ahead and jointly promote frequency allocation at 79 GHz and 26 GHz to accelerate implementation of radars on mid and low priced cars.
- The heterogeneous multi-GHz technology approach (26/77) may only work during first market proliferation phase and has only a door opener functions
- On long term the only reasonable technology platform to serve both short, mid and long range performance requirements is at 77 & 79 GHz
- Silicon-based semiconductor and module technology is ready for low cost and high volume production of high performing automotive radar sensors in the 76-81 GHz range


Thank you very much for your attention!

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Never stop thinking