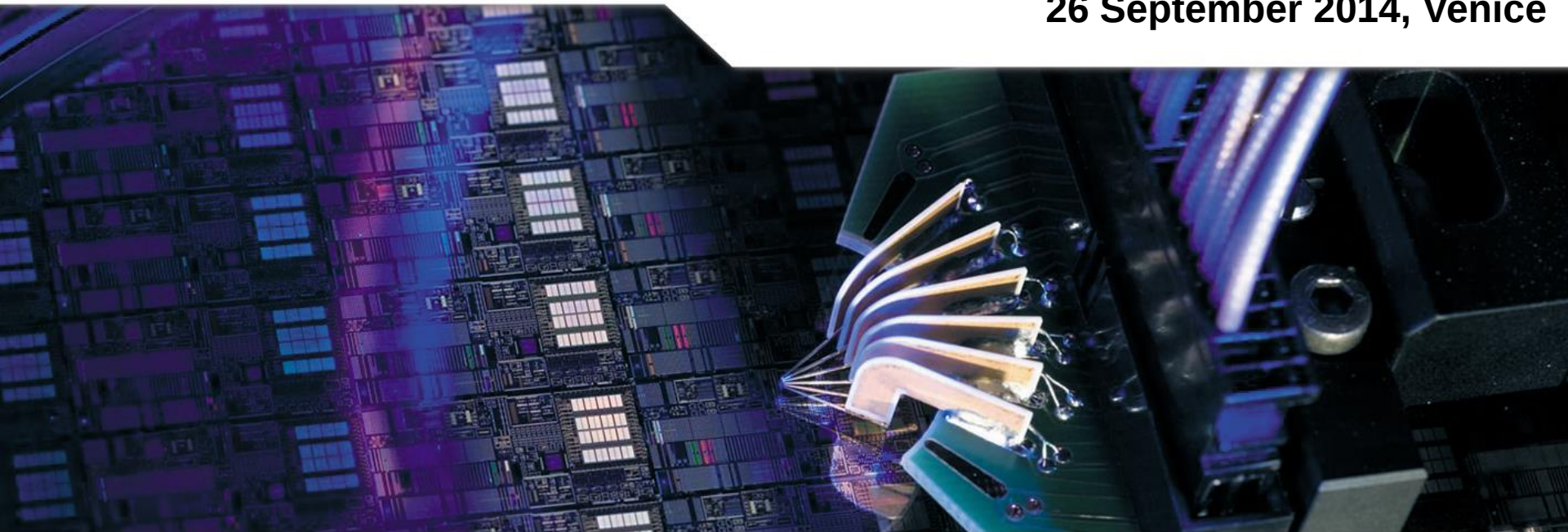




From Research to Industry:
Highly integrated mm-wave transceiver for
automotive radar applications
Erich Kolmhofer
DICE GmbH

**THz-Workshop: Millimeter- and
Sub-Millimeter-Wave circuit
design and characterization
26 September 2014, Venice**





Contents

- Why Automotive Radar?
- Infineon B11HFC Technology
- System Partitioning Bipolar vs. BiCMOS
- Functional Safety
- Conclusion



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Why Automotive Radar?

- In Europe each year about 1.3 million traffic accidents cause:
 - More than 40.000 fatalities
 - Economic damage of more than 200 billion € per year
- Human error is involved in over 90% of accidents
- Automotive radar help drivers to
 - Maintain a safe speed
 - Keep a safe distance
 - Avoid overtaking in critical situations
 - Safely pass intersections
 - Avoid crashes with vulnerable road user
 - Reduce severity of an accident
 - Drive more efficiently



en.wikipedia.org/wiki/Rear-end_collision#mediaviewer/File:Car_accident_-_NSE_Malaysia.jpg



http://en.wikipedia.org/wiki/File:401_Gridlock.jpg

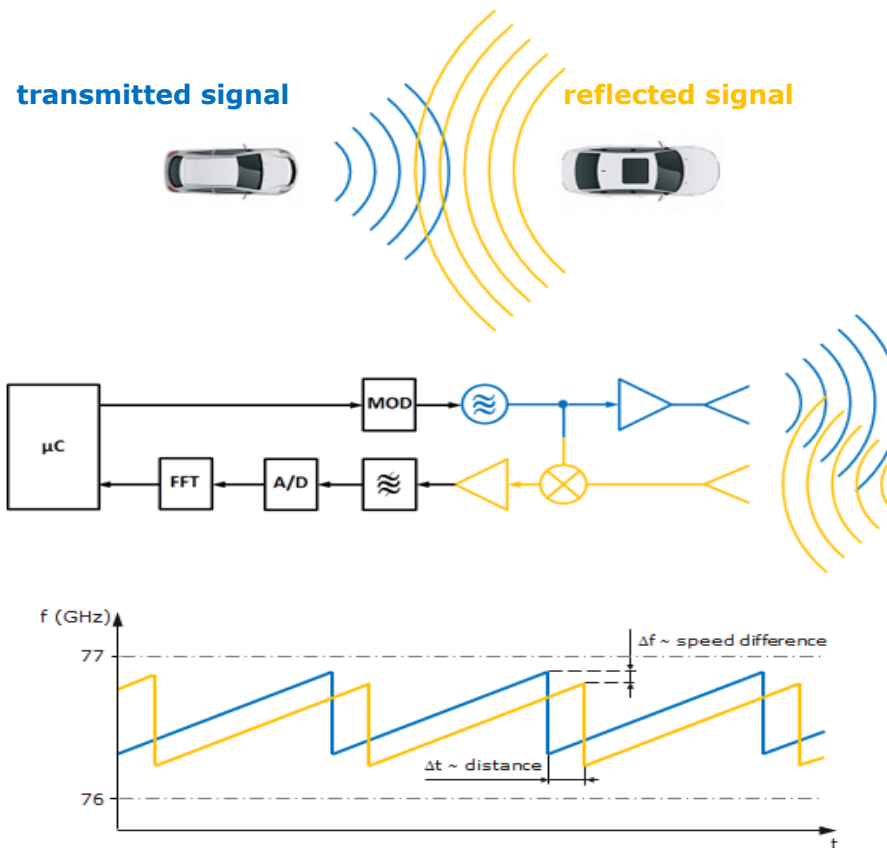
<http://creativecommons.org/licenses/by-sa/3.0/>

FMCW Principle of Typical Automotive Radars

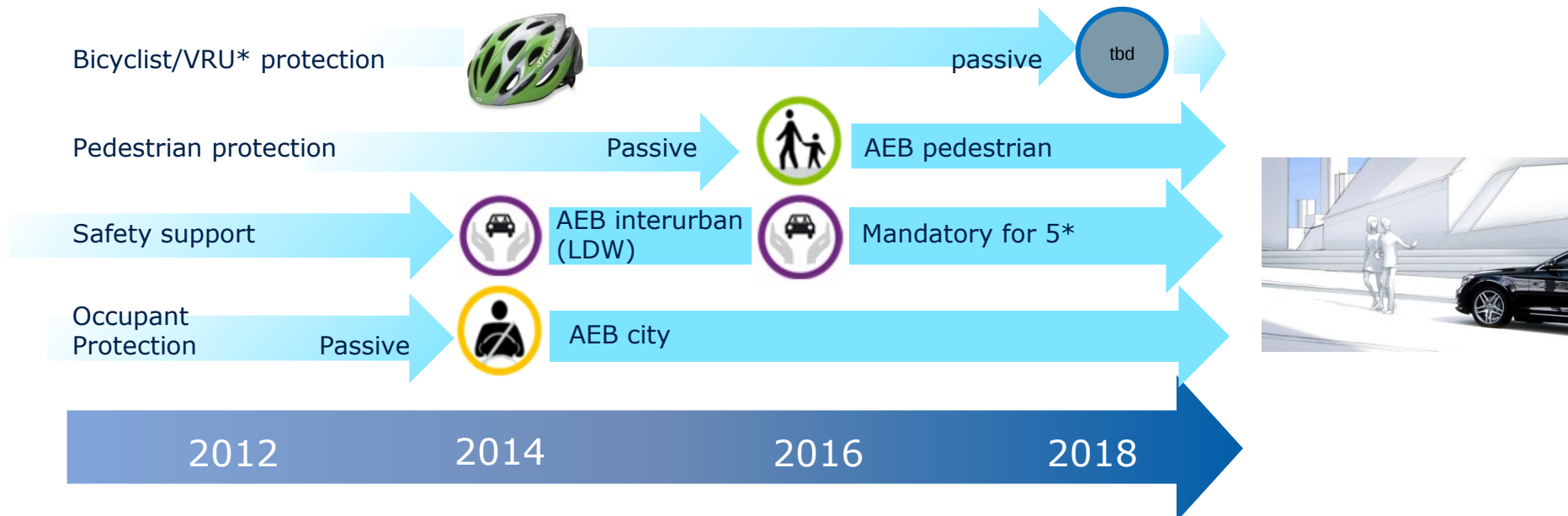
Radar Application

Radar Front-End

Signal Processing



The Safety Market - EuroNCAP is a strong driver



- EU - OEMs consider 5 Stars a MUST and add required technology to new platforms
- From 2016 onwards 5-Stars is not possible without radar/camera
- Radar/Camera combination standard equipment for EU cars
- Other regions expected to follow the EU with several years delay (e.g. Korea in 2016)
- From 2018 e.g. bicyclist protection is expected raise the bar further

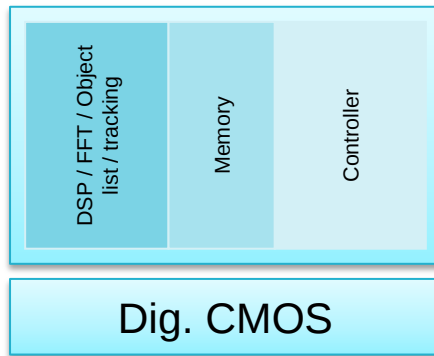
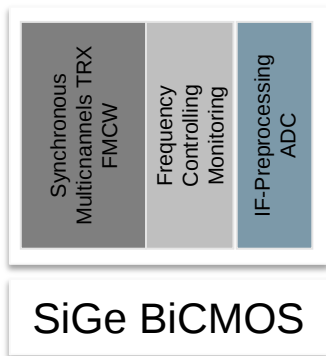
VRU = vulnerable road user



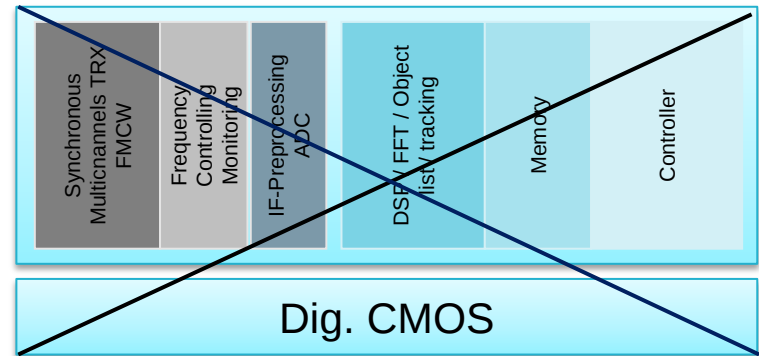
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Why BiCMOS? System Partitioning!



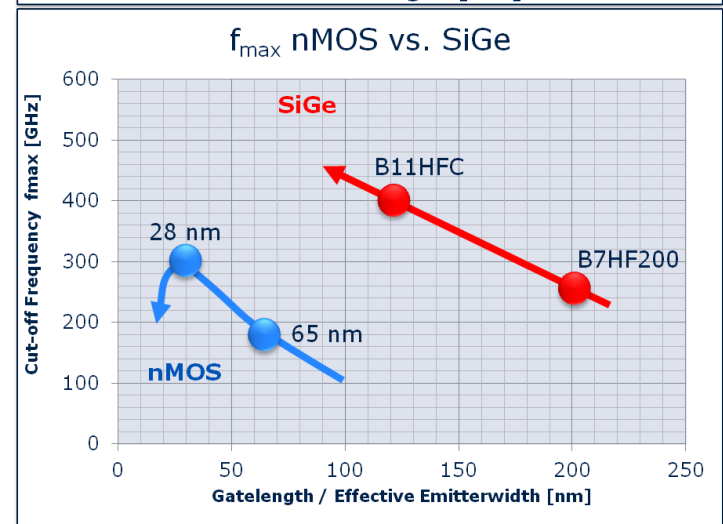
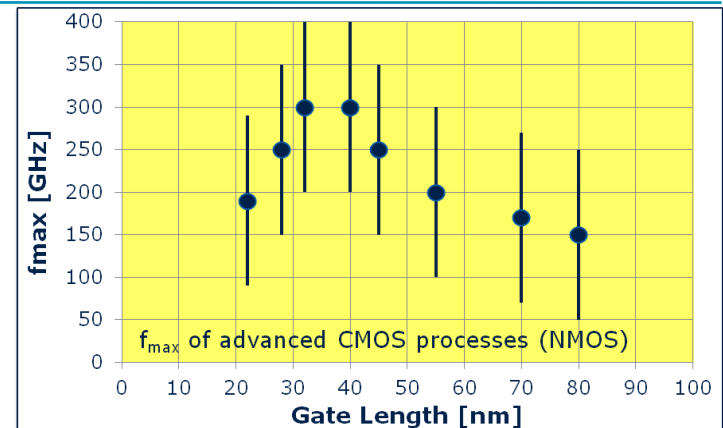
- Optimum technologies for RF / analog / mixed signal and digital functions
- High performance SiGe ($f_{\max}=400$ GHz) for lowest power consumption, phase noise, highest linearity and output power
- High performance MC can utilize most advanced digital CMOS
- Optimized and stable RF/AMS section for use with scalable MC solution
- Optimized cost / performance trade-off



- Inferior performance of RF/AMS section if implemented in advanced digital CMOS
- MC would always lack behind state-of-the-art as development cycles with RF/AMS included take much longer time
- Waste of expensive CMOS area for non-shrinkable analog functions
- Up-scaling to higher channel count by employment of multiple single chip units not cost-efficient (redundant MCs) or even not possible

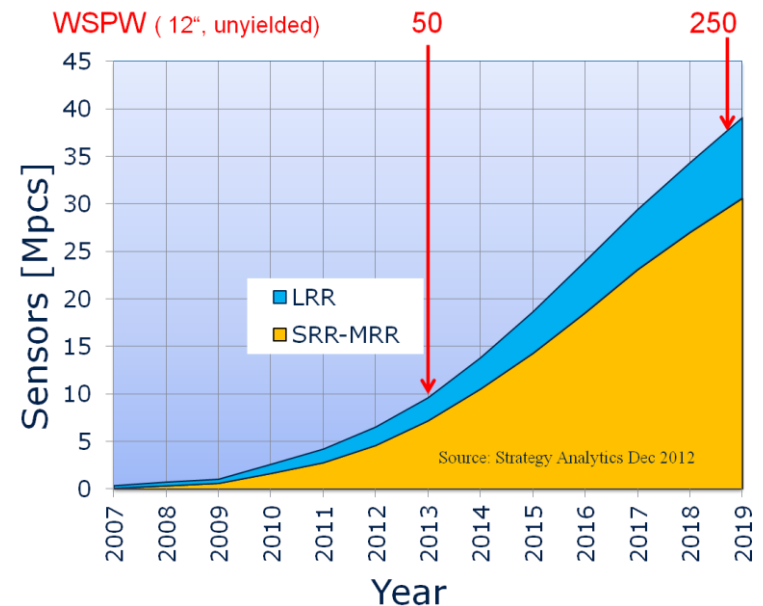
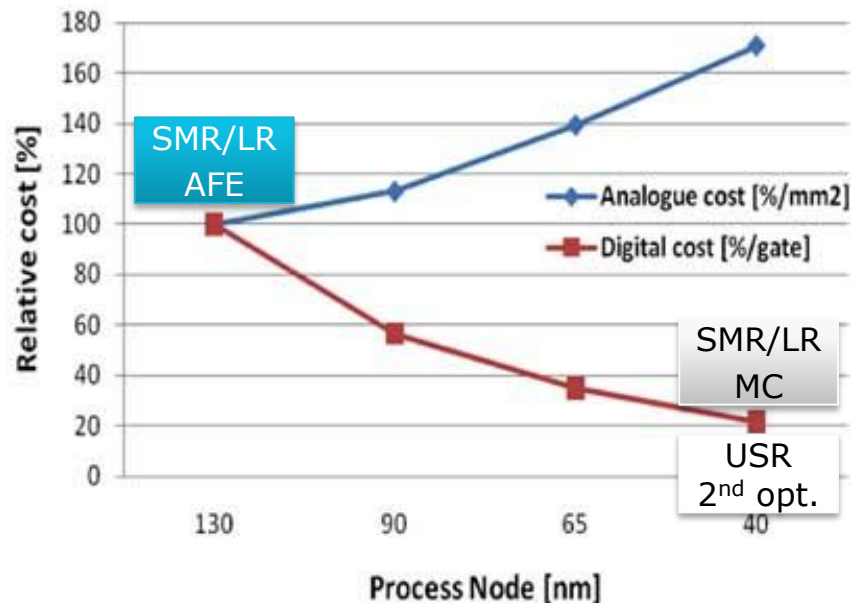
Why BiCMOS? Technology Advantages!

- Rule of thumb: $f_{\max} \geq 3 \times f_{\text{op}}$ (e.g. to enable good noise behavior of LNAs)
 - $f_{\text{op}} = 80 \text{ GHz} \rightarrow f_{\max} = 250 \text{ GHz}$
 - SiGe 0.3 μm (IFX B7HF200) comparable to 40nm CMOS
-
- To cope with $f_{\max}$ drop over temperature and to achieve required design margins, and lower power consumption:
 $f_{\max} \geq 5 \times f_{\text{op}}$
 - $f_{\text{op}} = 80 \text{ GHz} \rightarrow f_{\max} = 400 \text{ GHz}$ is desirable
 - Performance of 0.13 μm SiGe (next generation IFX B11HFC) superior to 28nm CMOS



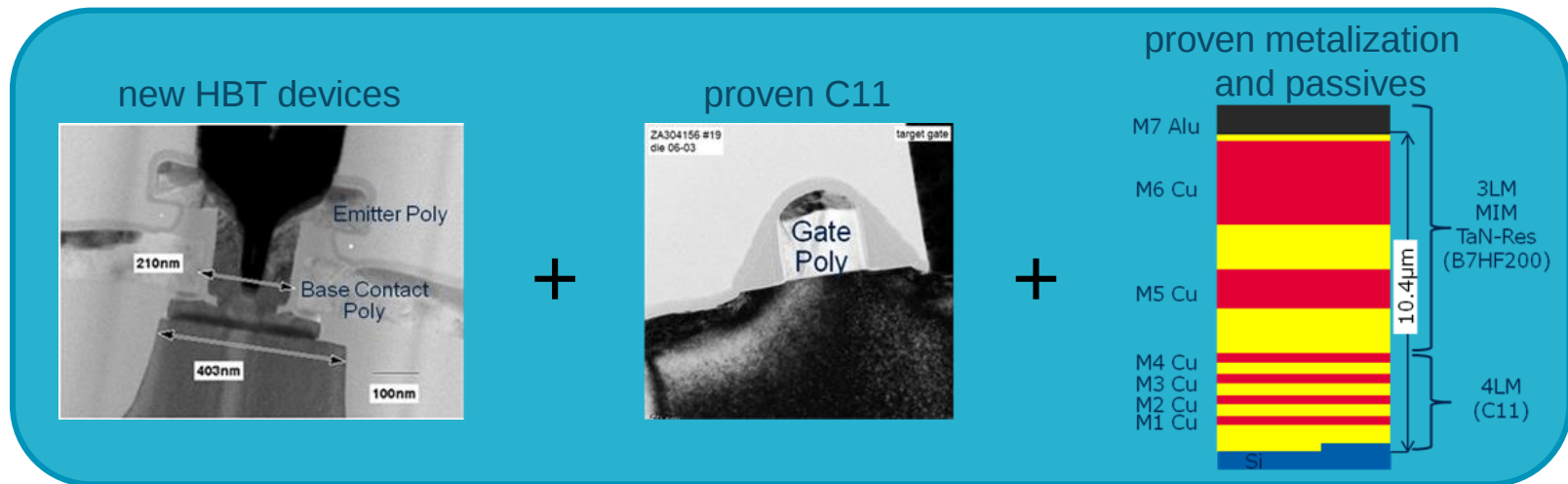
Why BiCMOS? Economy!

- Relative cost for analog RF circuit portion increase over CMOS nodes, as Silicon area needed for analog parts does not shrink
- Even if 40mio radar chipsets (SMR/LR) are manufactured in 2019 (s. Strategy Analytics, 2012) this will only result in 250 CMOS wafer starts per week (wspw) worldwide (300mm). If such volume is shared between different suppliers, there is not enough volume to do proper yield learning.



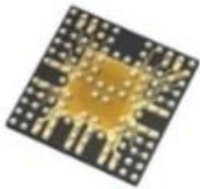
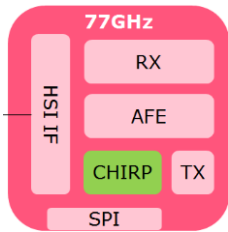
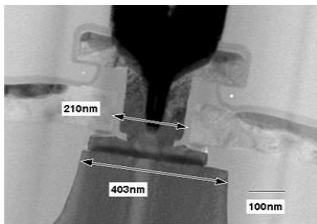
DOT7 BiCMOS Approach by Infineon

- B11HFC (130 nm / 400 GHz) SiGe BiCMOS is a combination of new SiGe HBT devices, a standard 130 nm CMOS process (C11N) and the mmWave metal back end of line and passives from proven IFX B7HF200 technology



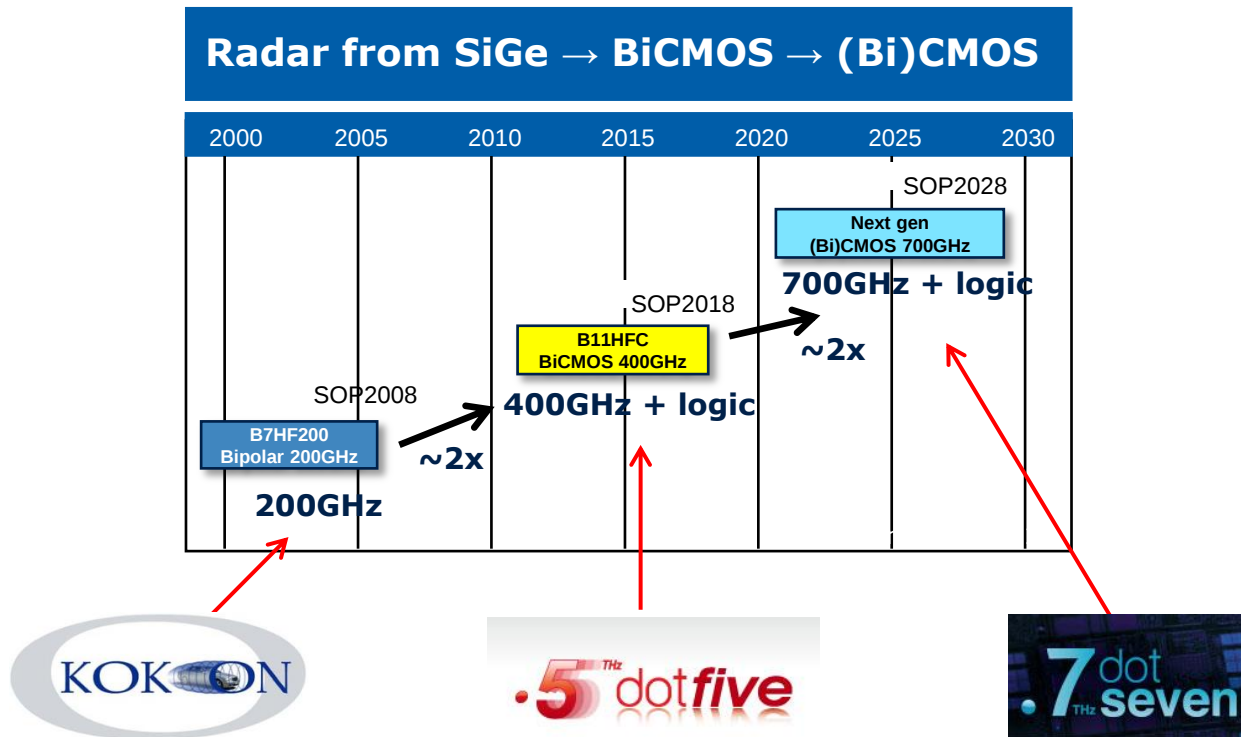
- B7HF200 is qualified for automotive applications and in production since 2009
- C11N is qualified for automotive applications and in production since 2004

B11HFC Technology = 400GHz Bipolar plus CMOS



- Higher RF integration + higher $f_{\max}$
 - More TX & Rx channels / chip
 - 400GHz $f_{\max}$ → lower power consumption
- Higher logic content
 - Integrated frequency control and stabilization
 - Self test / self calibration
 - Monitoring and functional safety functions during operation
 - IF preprocessing / digital interfaces
- Significantly easier volume assembly with eWLB package
 - First 77GHz package on the market
 - Less expensive PCB (no cavity)
 - Assembly on standard SMD lines

Progress Enabled by Funding Projects

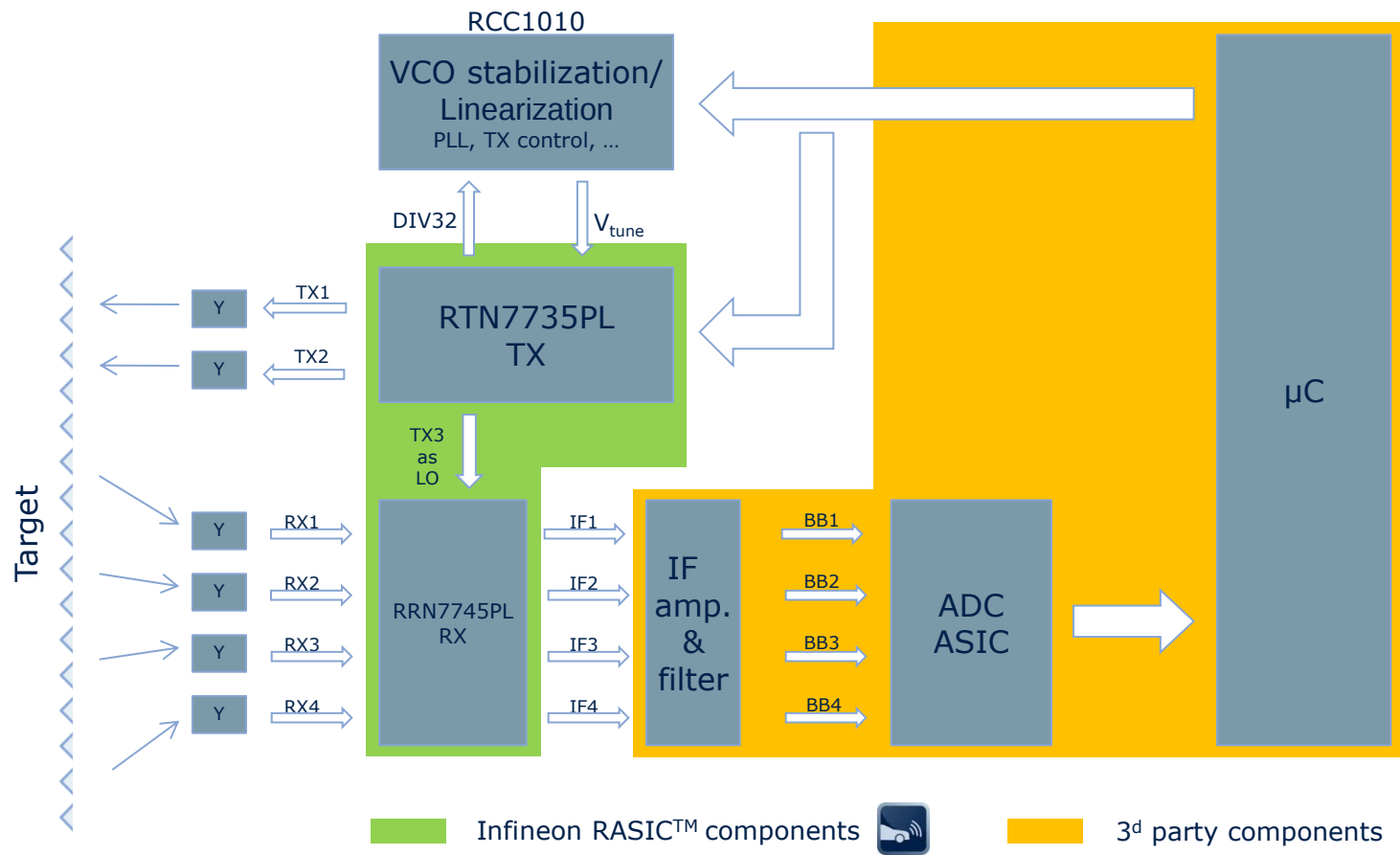




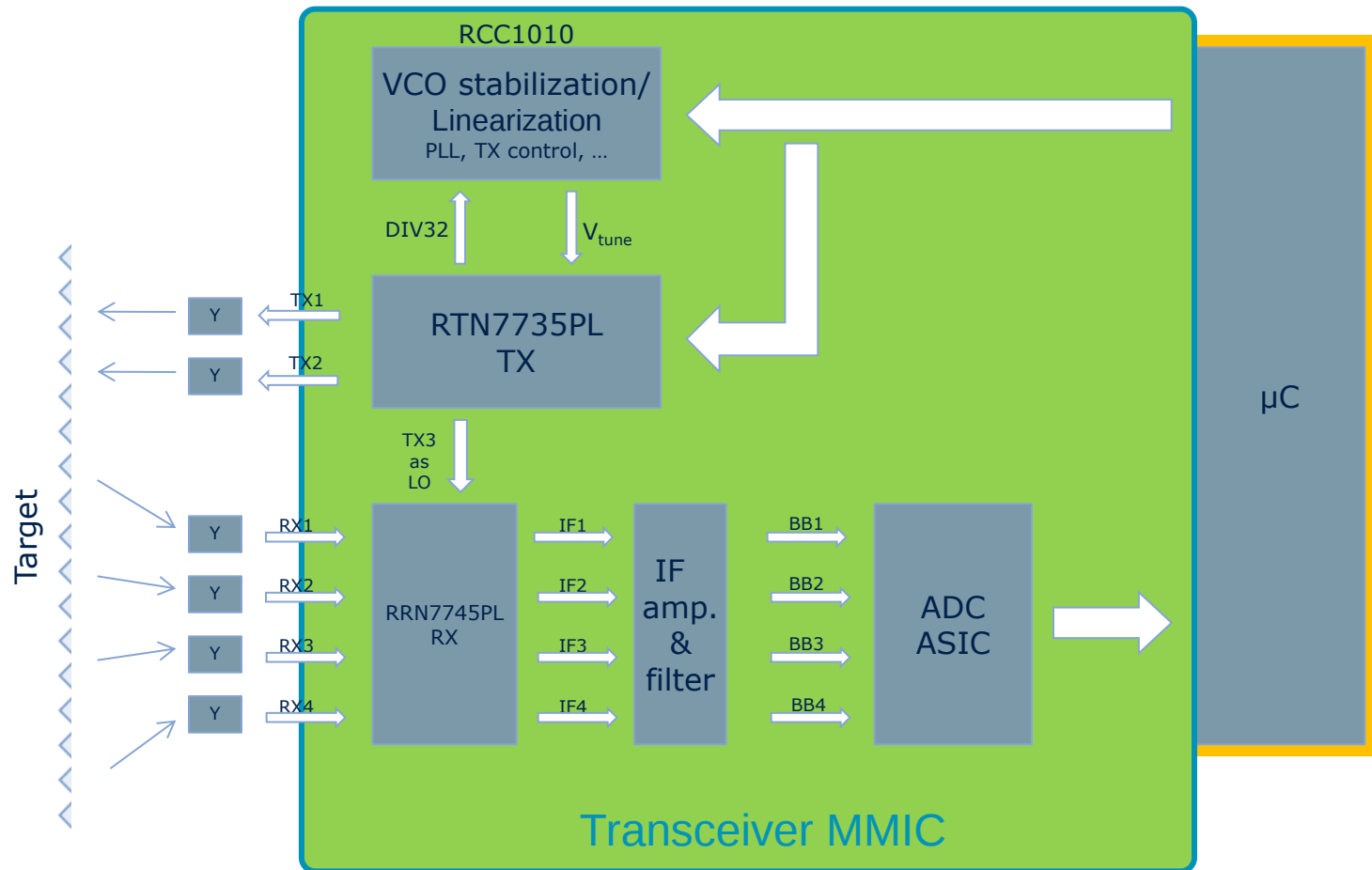
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Typical 77GHz Radar System Partitioning



77GHz BiCMOS Radar System Partitioning

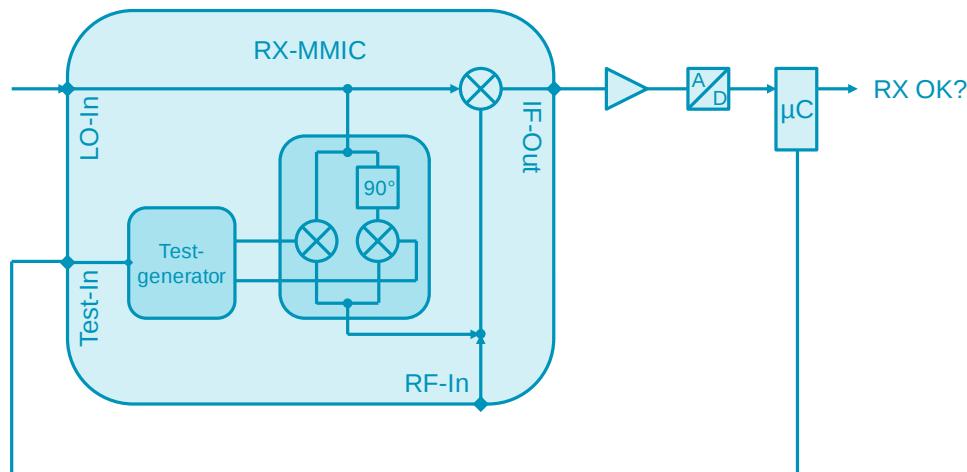




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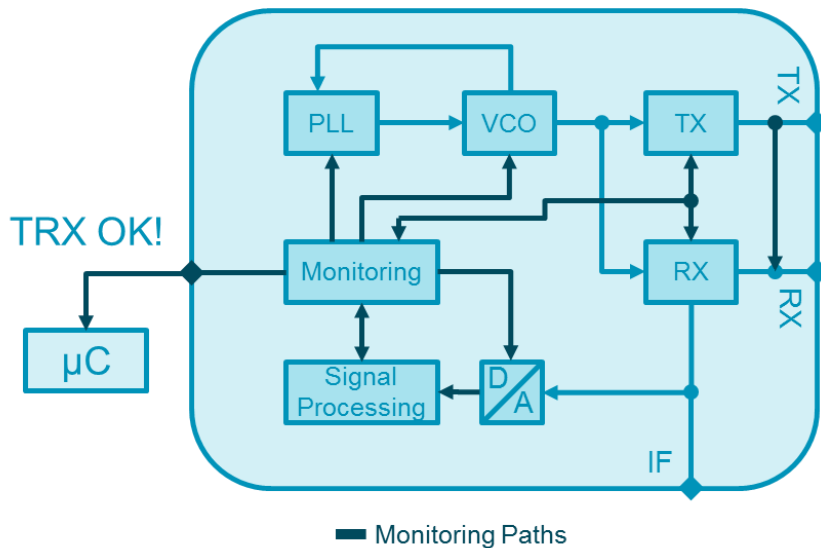
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- **Functional Safety**
- Conclusion

Functional Monitoring Today



- Today functional monitoring is supported by integrated monitoring blocks
 - Receiver test signal generators
 - TX/PA output level monitors
 - TX frequency counters
 - ...
- Monitoring cycles have to be initiated by the system controller
- Components are monitored individually but not in their interaction
- Assessment of the monitoring signals and evaluation of system health has to be done by the system signal processing

Functional Monitoring for BiCMOS Based Systems



- By introducing suitable signal path the complete TRX chain can be monitored
- Sequencing is done internally → also monitoring cycles are done autonomously
- Thru integrated signal processing the health check for the TRX subsystem is done MMIC-internally and signaled to the system controller



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Conclusion

- Automotive radar (and other assistance) systems can significantly contribute to road safety
 - Public pressure (NCAP) will drive the market
- For the next years BiCMOS will be the optimum technology from technical and economical point of view
 - Nevertheless pure CMOS might get the technology in upcoming years
- Automotive radar MMICs are still niche products
 - Technology progress and market penetration greatly profit from funding projects
- Higher integration levels will be required to reduce bill of material and manufacturing cost
- Compliance with automotive functional safety standards is obligatory
 - Higher integration levels also allow extended functional monitoring features



Acknowledgement

- This work is part of the:
 - DOTSEVEN project supported by the European Commission through the Seventh Framework Program for Research and Technological Development