24GHz Radar Sensors for IoT Applications
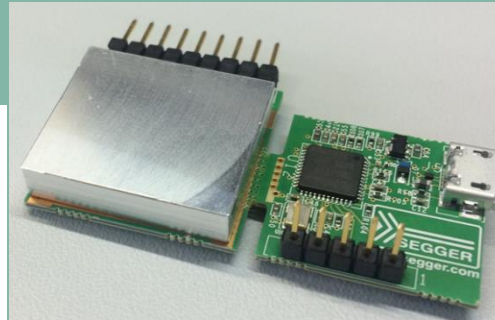
Abhiram Chakraborty
Millimeter-Wave Application Engineer
Infineon Technologies AG
Neubiberg – Germany

Outline

Outline

Infineon at a glance

Business Segments

- Industrial Power Control (IPC): 17%
- Automotive (ATV): 41%
- Power Management & Multimarket (PMM): 31%
- Chip Card & Security (CCS): 11%

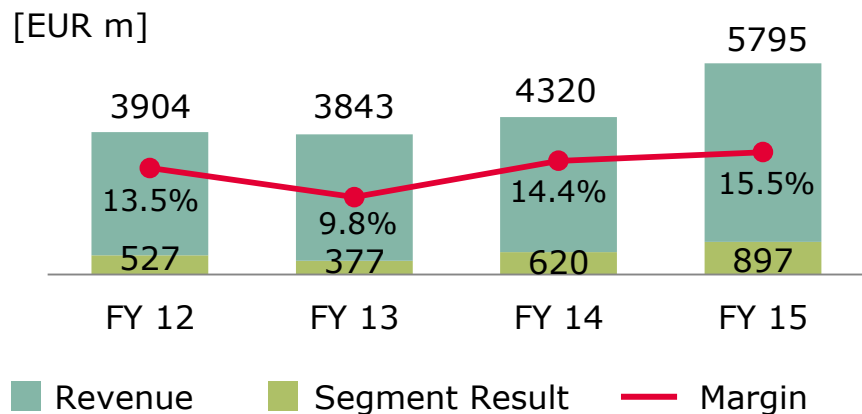Revenue FY 2015
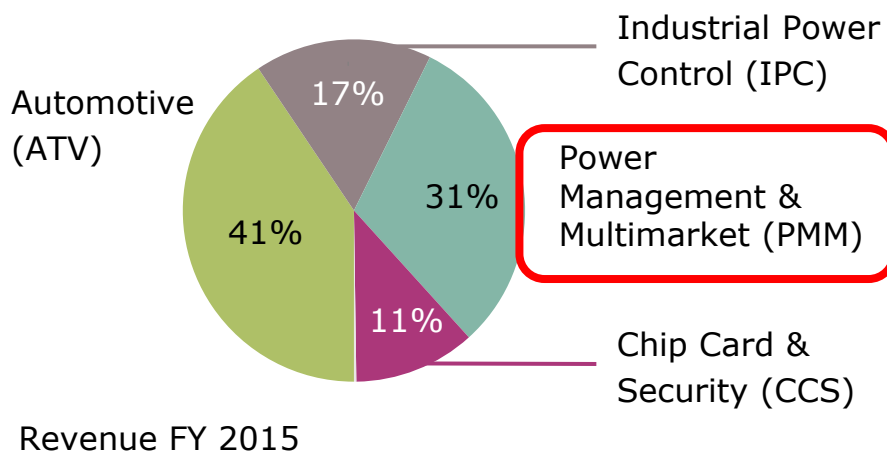
Employees

About **35,400** employees worldwide (as of Sep. 2015)

Europe
14,533 employees

Americas
3,682 employees

Asia/Pacific
17,209 employees

34 R&D locations
19 manufacturing locations

Financials

[EUR m]

	FY 12	FY 13	FY 14	FY 15
Revenue	3904	3843	4320	5795
Segment Result	527	377	620	897
Margin	13.5%	9.8%	14.4%	15.5%

■ Revenue ■ Segment Result — Margin
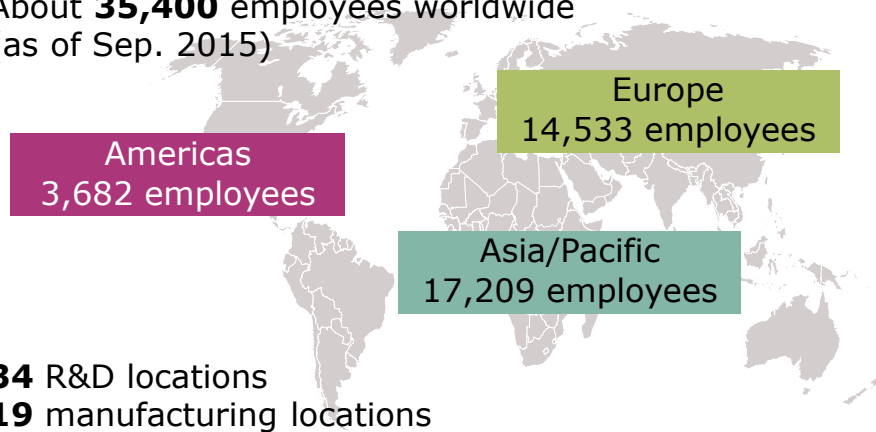
Market Position*

Automotive	Power	Smart card ICs
# 2	# 1	# 2
Strategy Analytics, April 2016	IHS Markit, July 2016	IHS Markit, July 2016

Power Management & Multimarket Segment – Achieving more, consuming less

Power Management			Radio Frequency & Sensing			High Reliability			
Computing	Lighting	Charger	Mobile devices	Cellular infrastructure	Sensing	Space	Aviation/ Defense	Medical ICD	Hi-Temp. /Heavy Industry

XDP™
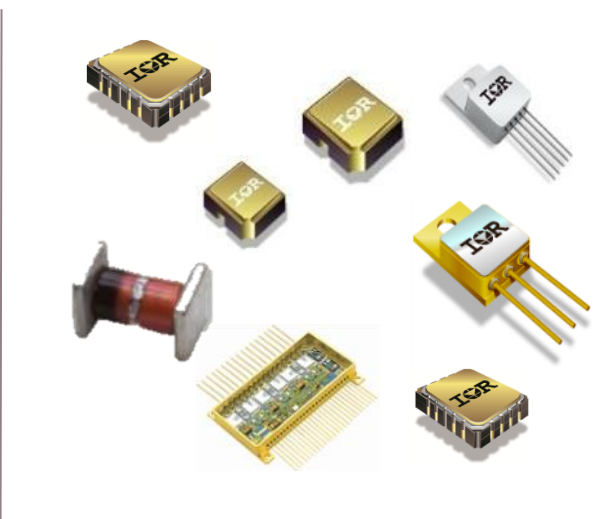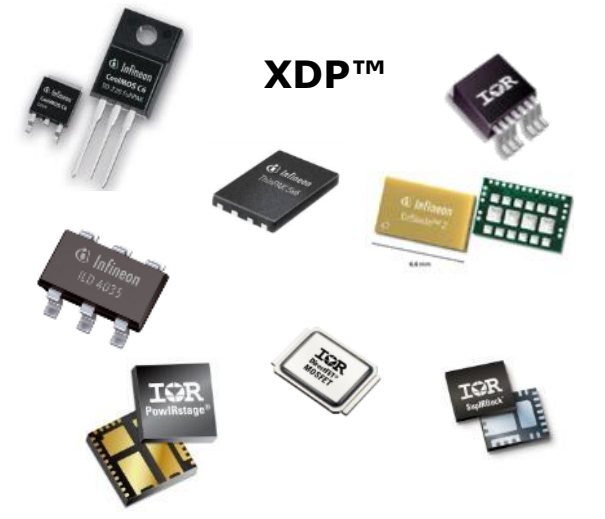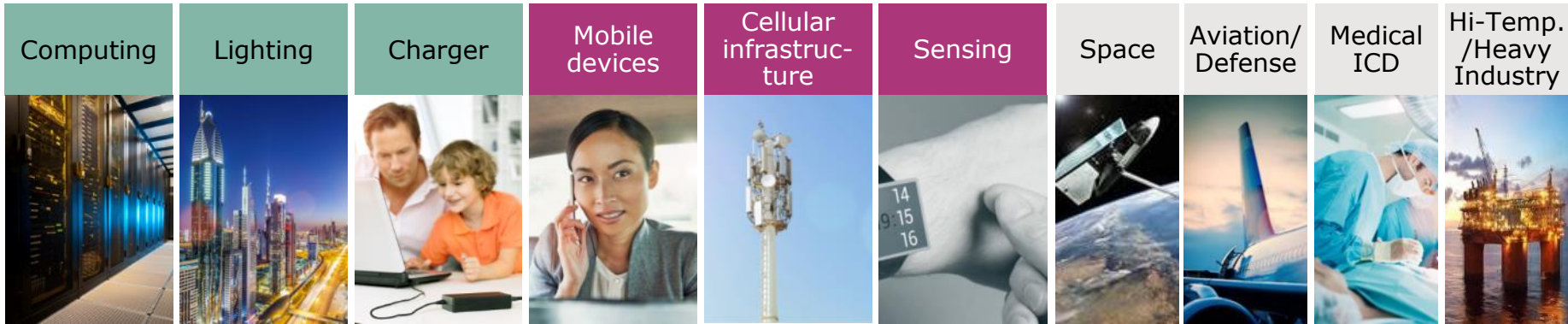
MOSFETs, Power ICs, RF switches, LNAs, Si-Mics, RF power, Radar ICs, Environmental Sensors

Application Segments for PMM

Power Conversion and RF Applications

- Solar & Energy Storage
- Cellular Infra-structure
- Computing DC-DC
- Class D Audio Amplifier
- Lighting
- SMPS
- Auto-motive
- Mobile Devices
- Battery
- Industrial

IFX is market leader in automotive radar with 43% MS*

Every 3rd smartphone contains an IFX SiMic
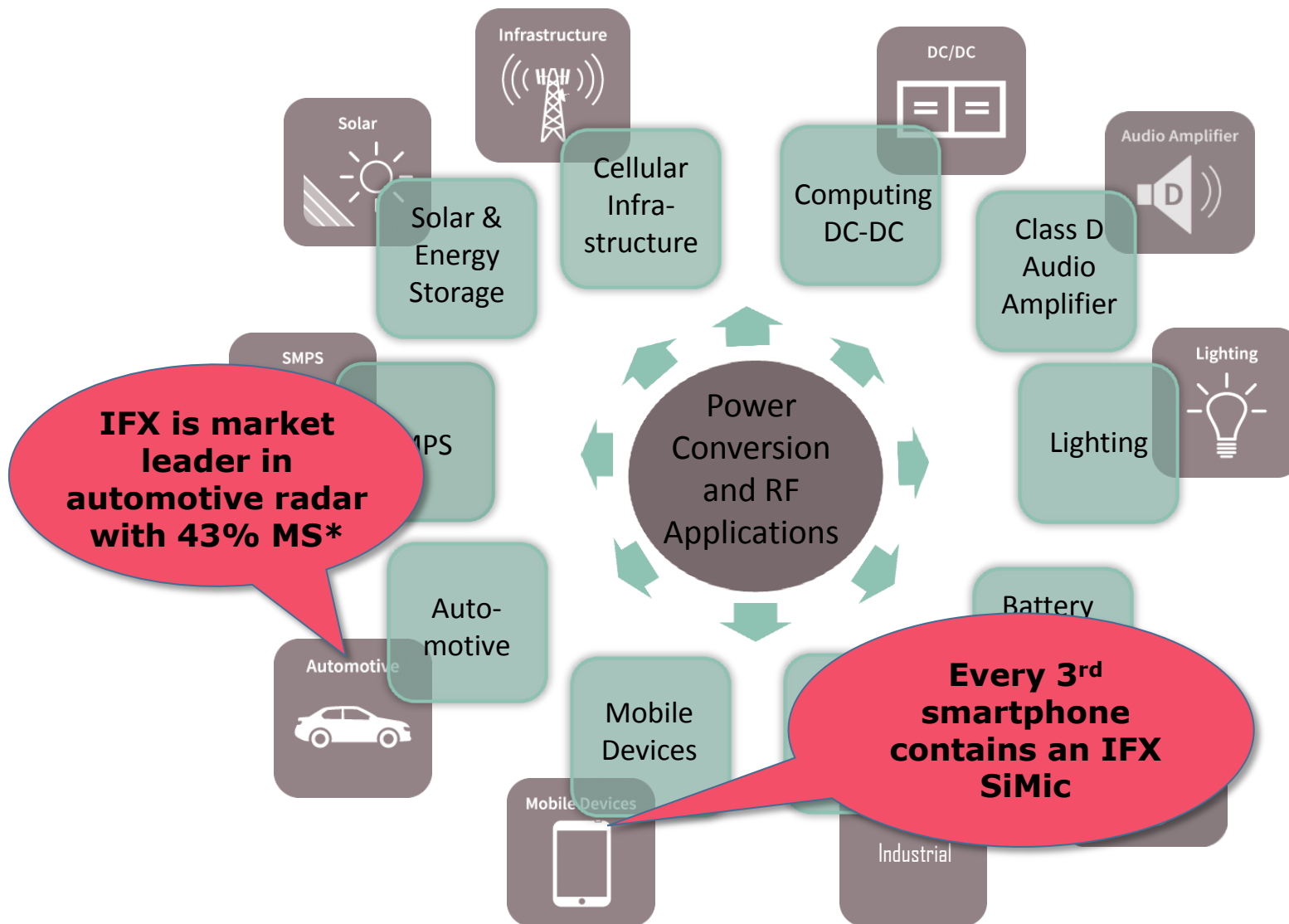
*Source: IHS Inc., "Advanced Driver Assistance Applications Sensor Market Database – H2 2015", February 2016

Power Management & Multimarket Segment – Achieving more, consuming less

Power Management			Radio Frequency & Sensing			High Reliability			
Computing	Lighting	Charger	Mobile devices	Cellular infrastructure	Sensing	Space	Aviation/ Defense	Medical ICD	Hi-Temp. /Heavy Industry

XDP™

MOSFETs, Power ICs, RF switches, LNAs, Si-Mics, RF power, Radar ICs, Environmental Sensors

Business Line "Radio Frequency & Sensors"

Radio Frequency & Sensors (RFS)

RF Mobile	mmW & Multi Source	Sensors	RF Power

Focus Application
> Mobile Devices

Products
> Switches
> LNAs
> Antenna Tuners

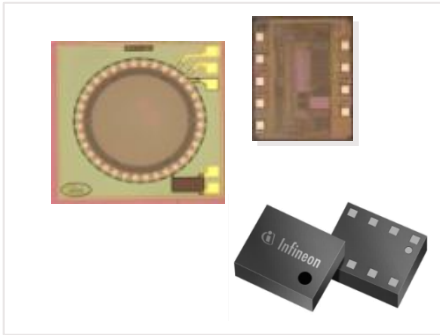**Focus Application**
> Mobile Devices, Automotive, Industrial

Products
> mmW Sensors
> mmW Communication
> TVS Diodes
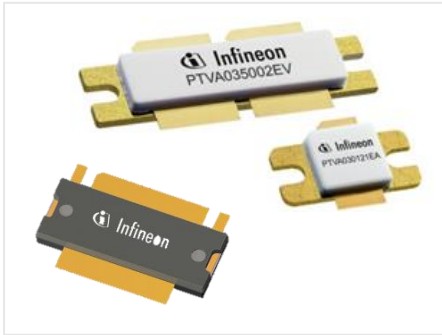> RF Diodes & Transistors
> AF Diodes & Transistors

Focus Application
> Mobile Devices

Products
> Silicon Microphones
> Consumer Pressure Sensors
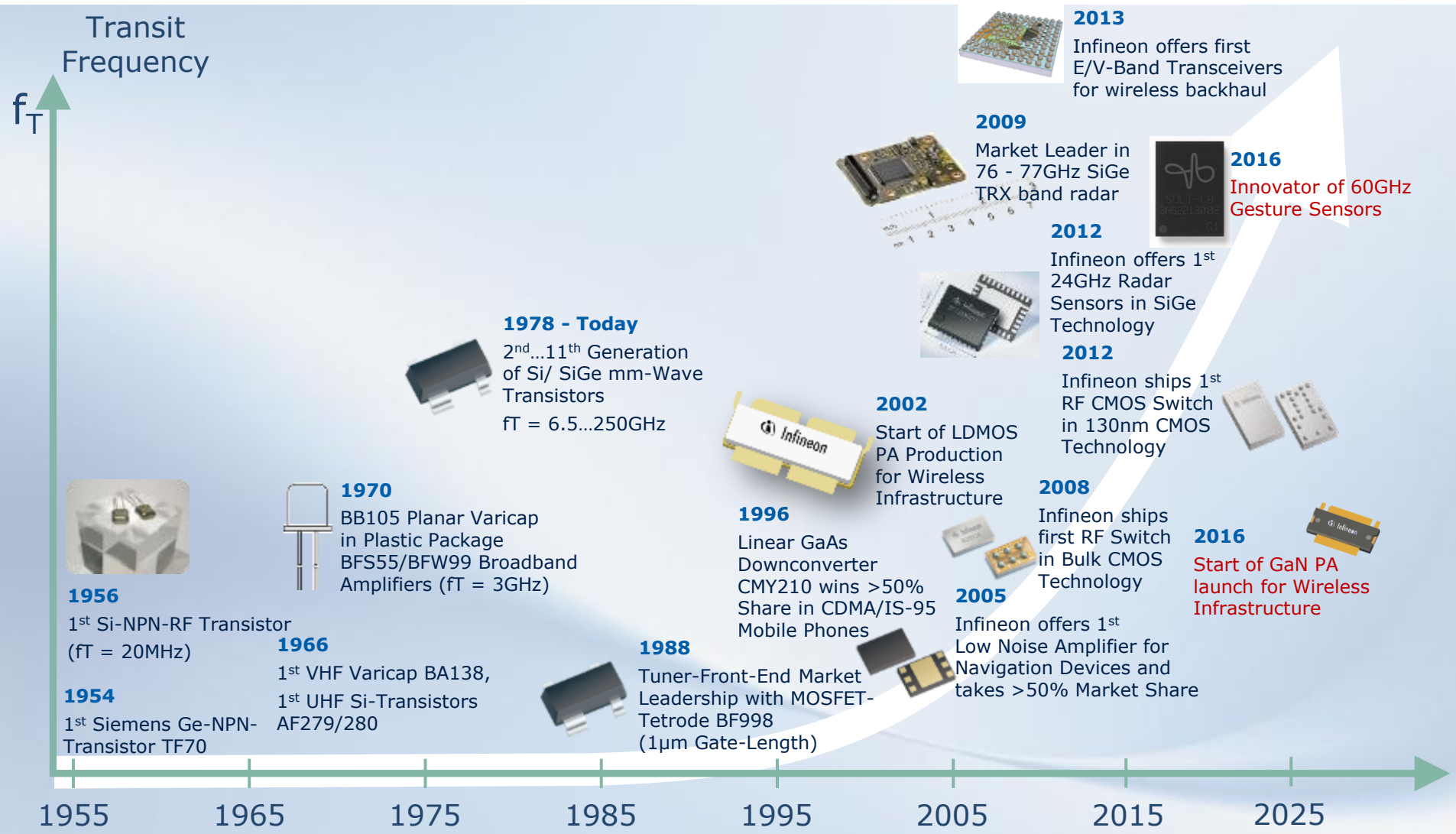> Opto Chips & ICs

Focus Application
> Cellular Infrastructure

Products
> RF Power Transistors
> Driver ICs

For more than 60 years Infineon Technologies has been setting market standards in all RF Segments

Transit Frequency

f_T

2013
Infineon offers first E/V-Band Transceivers for wireless backhaul

2009
Market Leader in 76 - 77GHz SiGe TRX band radar

2016
Innovator of 60GHz Gesture Sensors

2012
Infineon offers 1st 24GHz Radar Sensors in SiGe Technology

2012
Infineon ships 1st RF CMOS Switch in 130nm CMOS Technology

1978 - Today
2nd...11th Generation of Si/ SiGe mm-Wave Transistors
fT = 6.5...250GHz

2002
Start of LDMOS PA Production for Wireless Infrastructure

2008
Infineon ships first RF Switch in Bulk CMOS Technology

2016
Start of GaN PA launch for Wireless Infrastructure

1970
BB105 Planar Varicap in Plastic Package BFS55/BFW99 Broadband Amplifiers (fT = 3GHz)

1996
Linear GaAs Downconverter CMY210 wins >50% Share in CDMA/IS-95 Mobile Phones

2005
Infineon offers 1st Low Noise Amplifier for Navigation Devices and takes >50% Market Share

1956
1st Si-NPN-RF Transistor (fT = 20MHz)

1966
1st VHF Varicap BA138, 1st UHF Si-Transistors AF279/280

1988
Tuner-Front-End Market Leadership with MOSFET-Tetrode BF998 (1µm Gate-Length)

1954
1st Siemens Ge-NPN-Transistor TF70

1955   1965   1975   1985   1995   2005   2015   2025

Millimeter-Wave Portfolio @Infineon RFS

Millimeter-Wave @RFS

RADAR Transceivers

Gesture Recognition Transceivers

*Under development

Backhaul/5G Transceivers
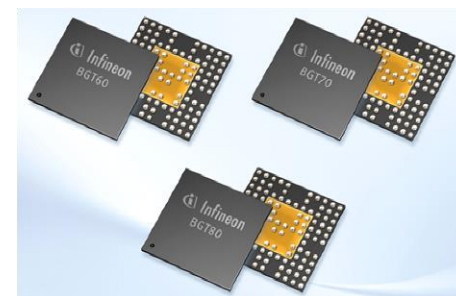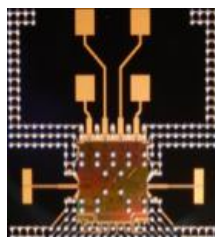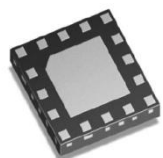
Overview of RADAR IC solutions from RFS

Millimeter-Wave
RADAR TRxICs

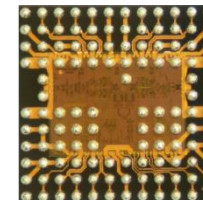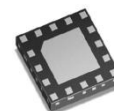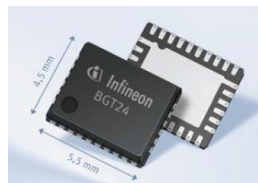**Automotive**

Industrial

24GHz Radar
(BGT24A Series)

24GHz Radar
(BGT24M/L Series)

60GHz Radar
(BGT61)

Outline

1. Infineon at a Glance

2. IoT Positioning at Infineon

3. 24GHz Radar Sensors for IoT Applications

4. Infineons 24GHz Products and System Offerings

5. RADAR Demonstration (Distance and Speed Measurement)

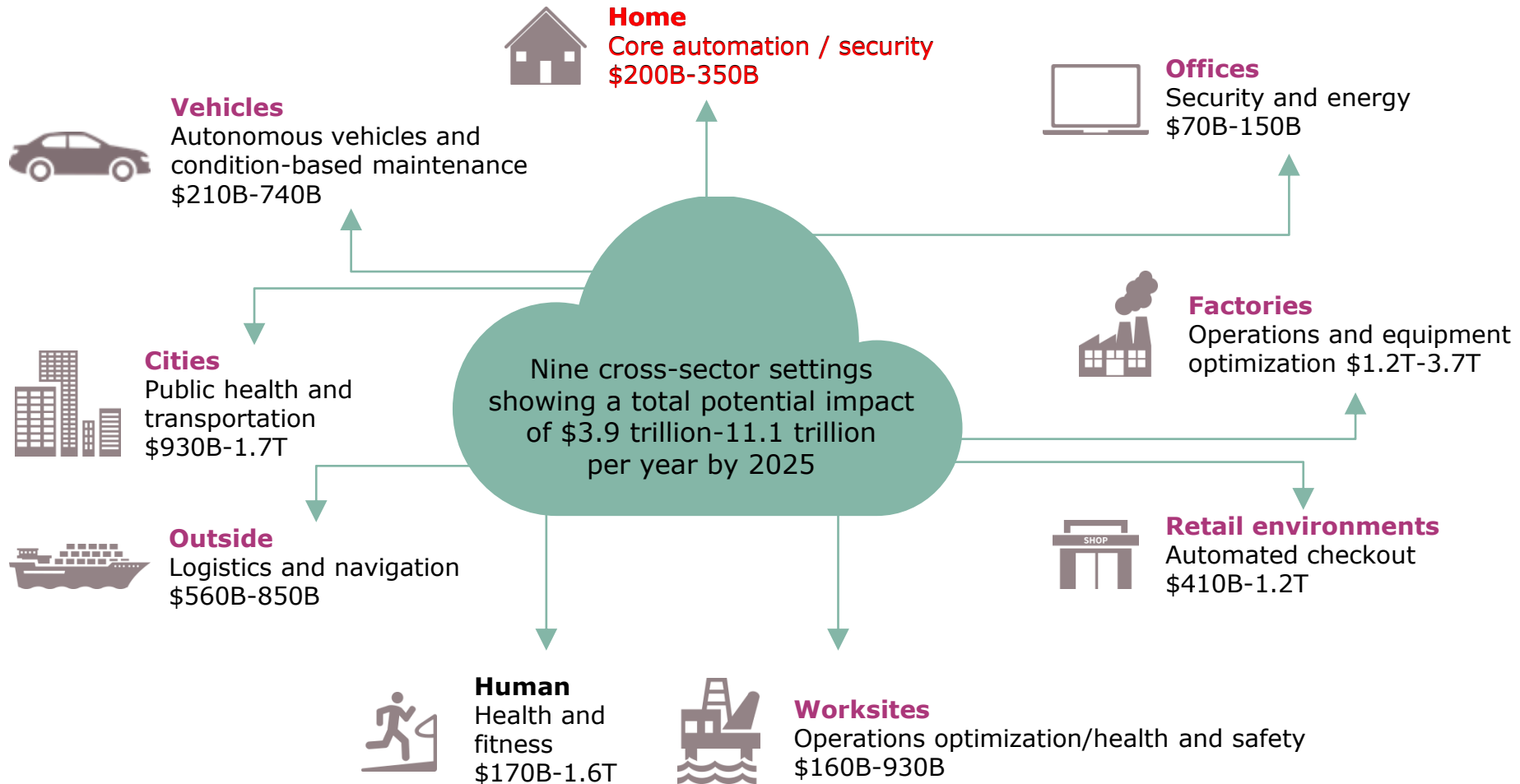# The Internet of Things is already reality, although still in its infancy

- Network of **cyber-physical objects with an IP adress** that contain embedded electronics to **sense, compute, actuate and communicate**
- Aim is to achieve **greater value and service** by exchanging data

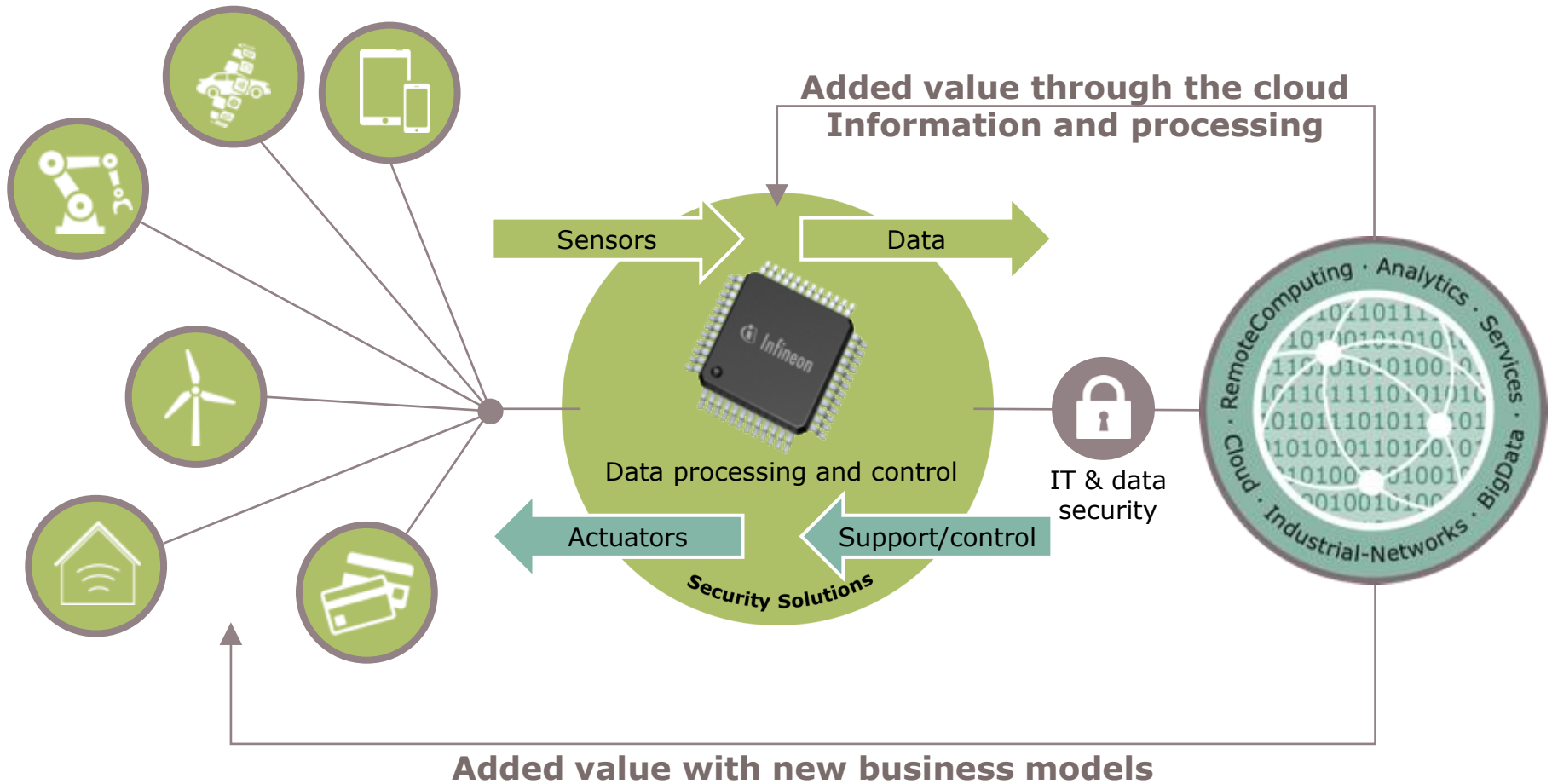**IoT installed base**
Connected devices, billions

Gartner ⬜ IDC 🟩 ABI 🟦

+15-20% p.a

	Gartner	IDC	ABI
2013	7	9	10
2020	26	28	30
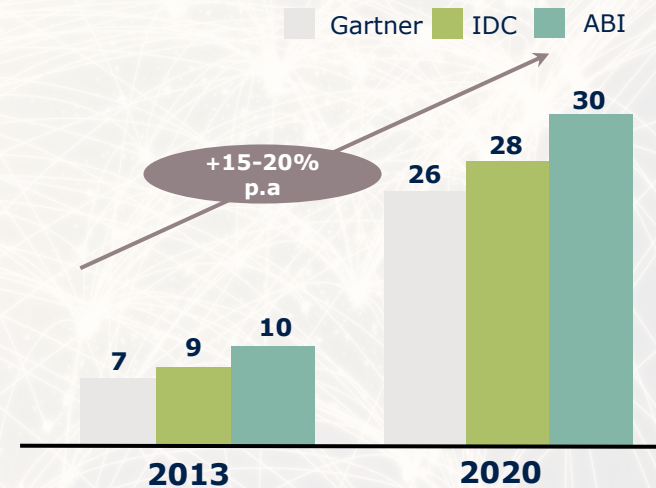
The IoT is expected to create significant value across industries

IoT will have a significant impact across multiple markets

Home
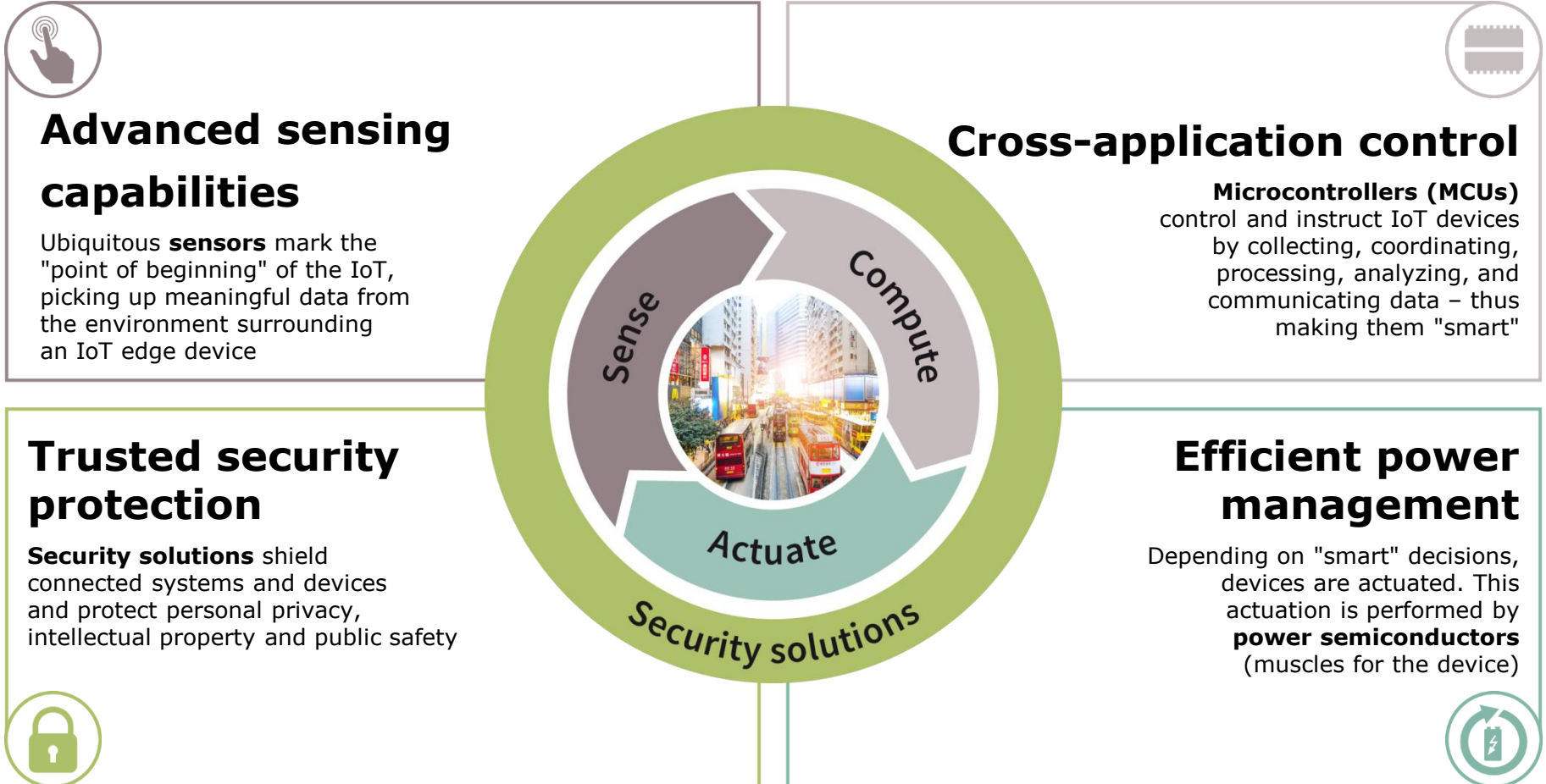Core automation / security
$200B-350B

Offices
Security and energy
$70B-150B

Vehicles
Autonomous vehicles and condition-based maintenance $210B-740B

Factories
Operations and equipment optimization $1.2T-3.7T

Nine cross-sector settings showing a total potential impact of $3.9 trillion-11.1 trillion per year by 2025

Cities
Public health and transportation $930B-1.7T

Outside
Logistics and navigation $560B-850B

Retail environments
Automated checkout $410B-1.2T

Human
Health and fitness $170B-1.6T

Worksites
Operations optimization/health and safety $160B-930B

Roughly 70% of total value outside consumer applications

Source: McKinsey & Company

Semiconductors are the crucial link between the real and digital worlds

Added value through the cloud
Information and processing

Sensors

Data

Data processing and control

IT & data security

Security Solutions

Actuators

Support/control

RemoteComputing · Analytics · Services · BigData · Industrial-Networks · Cloud

Added value with new business models

Infineon helps to create sustainable IoT success for its customers

Advanced sensing capabilities

Ubiquitous **sensors** mark the "point of beginning" of the IoT, picking up meaningful data from the environment surrounding an IoT edge device

Cross-application control

Microcontrollers (MCUs) control and instruct IoT devices by collecting, coordinating, processing, analyzing, and communicating data – thus making them "smart"

Sense

Compute

Actuate

Security solutions

Trusted security protection

Security solutions shield connected systems and devices and protect personal privacy, intellectual property and public safety

Efficient power management

Depending on "smart" decisions, devices are actuated. This actuation is performed by **power semiconductors** (muscles for the device)

Making IoT smart, secure and power-efficient

Infineon addresses a broad set of IoT market segments

Smart vehicles	Smart city & energy	Smart industry & business	Smart home & consumer devices
Smart cars › ADAS / autonom. driving › Connected car › Car security › (H)EV	**Energy & infrastructure** › Generation (renewables) › Advanced transmission & distribution / storage › Utilities, traffic, outdoors › Environmental sensors	**Factory automation** › Industrial automation › Industrial robotics	**Smart home** › Home automation incl. home appliances › Home energy management › Home security & safety › Lighting
CACV incl. Trucks & Busses › ADAS / autonom. driving › Secured connectivity › (H)EV	**Building automation** › Automation › Access control › Air conditioning › Elevators/escalators	**Medical equipment** › Health sensors › Diagnostics › Rehabilitation systems	**Smartphones, tablets & PCs**
Other forms of transport › Commercial aircraft › Connected trains › Ships (ferry & container) › Light electric vehicles	**Professional lighting** › Building lighting › Street lighting › etc.	**Other businesses** › e.g. Banking & securities, education, mining, retail and wholesale, transportation and logistics	**Consumer electronics & wearables** › Media players, smart glasses, smart watches › Well-being, assisted living

ICT

Communication networks

Data centers / server farms

Outline

1 Infineon at a Glance

2 IoT Positioning at Infineon

3 24GHz Radar Sensors for IoT Applications

4 Infineons 24GHz Products and System Offerings

5 RADAR Demonstration (Distance and Speed Measurement)

Introduction to radar

› **What is radar?**
  › "Radar" is an acronym for **Ra**dio **D**etection **A**nd **R**anging
  › Radar uses radio waves to detect **presence, direction, distance,** and **speed**
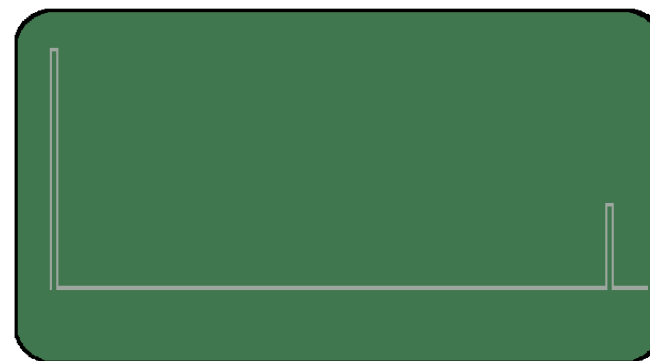
*Source: www.**radartutorial**.eu*

› **Why use radar over alternative motion sensing technology?**
  1. Radar provides several technical advantages over the alternative options
  2. With multiple software options available, Radar is more than just simple "Motion Sensing"
  3. Radar's superior penetration operates throughout any weather condition, day and night

Infineons BGT24LTR11 based 24GHz Radar Module

Radar in your Pocket!!
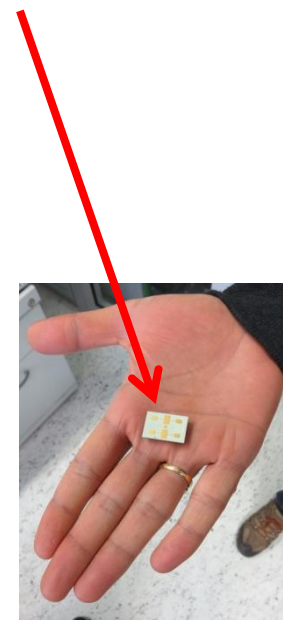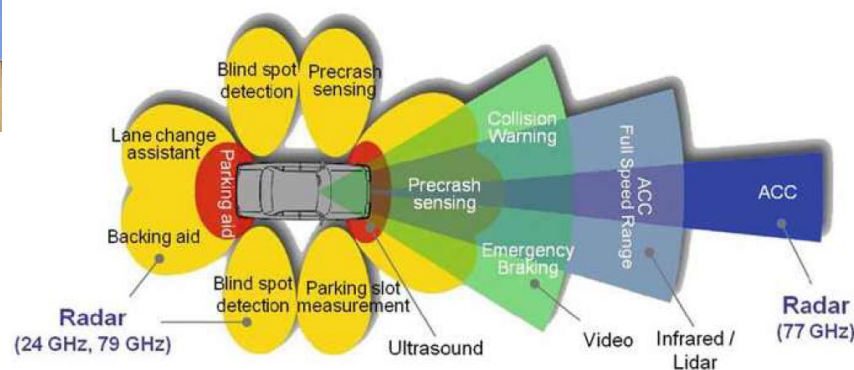
Information obtainable from a Typical 24 GHz sensor

Speed sensors
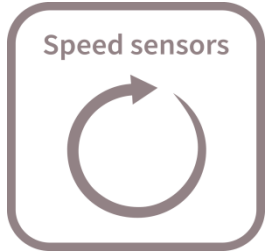
Speed/Velocity

› Derived from Doppler shift in frequency

(N, W, O, S compass)
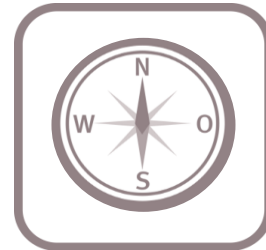
Range/Distance to target

› Derived from measurement of electromagnetic wave

Angle sensor
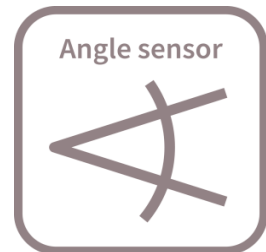
Angle/Direction to target

› Derived from phase difference at the antennas

Position sensor
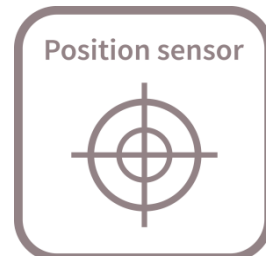
Position of Object

› Derived from FMCW

(Frequency-modulated continuous-wave radar)

Radar intelligent sensing concepts

Direction, proximity and speed detection

Target Positioning

Motion tracking

Ghost target suppression

Elimination of false alarms while not missing actual targets

Hidden mounting capability

Maintains operation through harsh weather conditions

Adaptable to different application requirements

24 GHz key markets & use cases

	Markets		
Lighting	Home & building automation		Multicopter
Street & Office Lighting	**Home Automation**	**Robotics**	**UAV / Multicopter**
› Presence and motion detection	› Presence and motion detection › Surveillance / Security › HVAC Control › Automatic Doors	› Collision Detection › Presence and motion detection › Sanitary › Lawnmower › Vacuum cleaner	› Collision detection and avoidance › Landing Sensor (Altimeter) › Height Control

Industry 4.0, IoT, and UAV applications

How a 24GHz Doppler Radar Works

Radar Transceiver

Transmit Wave

Reflect Wave

Microwave
Signal
Generator

Transmitter
Antenna

Mixer

Receiver
Antenna

Low Frequency
Output (IF) for
Processing

Doppler
effect
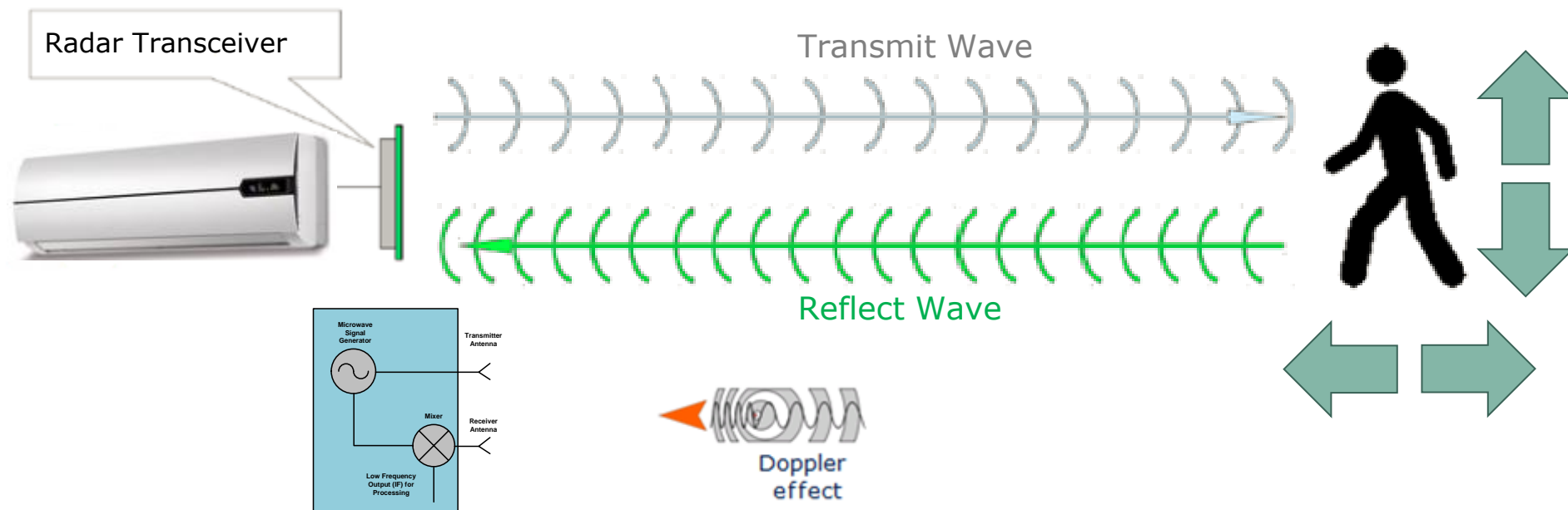
› The detection is by sending radio waves to the humanoid or object, and sense the change in the reflected signal

› This method can detect movements of objects

  – For example: speed, movement and direction of movement (Target Approaching or Moving Away)

› Apart from Doppler Radar, FMCW and FSK Radar can be used for highly precise target distance and position measurements

24GHz Radar Application Cloud for IoT
The Perfect Smart Home & Building
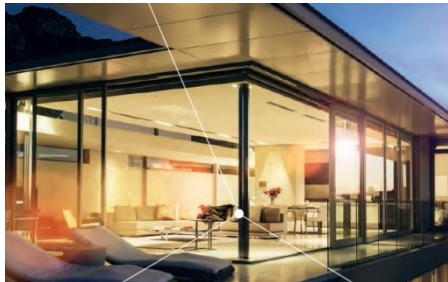
- ➢ **Smart and Energy Efficient Home and Office Lighting**
  - Movement and presence based light activation
- ➢ **Intelligent Door Openers**
  - Direction of movement based intelligence
- ➢ **Smart Security Sensors/Intrusion Detection**
  - Fusions systems with radar and camera for home and building security systems based on movement detection
- ➢ **Smart and Energy Efficient Air Conditioners**
  - People movement and presence detection based operation.
- ➢ **Smart Home Applicances**
  - Refrigerators, Robot cleaners etc operating based on movement and proximity detection
- ➢ **Smart Drones**
  - Collision Avoidance & Altimeter
- ➢ **Health Monitoring**
  - Patient monitoring systems

Information from all above Radar Sensor driven applications can be shared via a common hub over the Internet.

Outline

Infineons 24GHz Radar MMIC Offerings

BGT24MTR11	BGT24MR2	BGT24MTR12	BGT24LTR11
› **Transceiver 1Tx+1Rx/ IQ differential** › **VCO integrated, SPI** › **Power/temp sensor** › **RF$_{in}$ 24.0-26.0 GHz** › 500 mW @3.3 V › 4.5x5.5 mm -VQFN-32	› **Twin receiver 2Rx/ IQ differential** › **RF$_{in}$ 24.0-26.0 GHz** › 300 mW @3.3 V › 4.5x5.5 mm -VQFN-32	› **Transceiver 1Tx+2Rx / IQ differential** › **As TR11** › **700 mW @3.3 V** › **4.5x5.5 mm -VQFN-32**	› **Transceiver (1Tx+1Rx)** › Single-ended › BITE Tested › RF$_{in}$ 24.0 – 24.25 GHz › **150 mW @3.3 V** › **2.4 x 2.4 mm -TSNP-16**

Lower Power

Lower cost

Smallest footprint
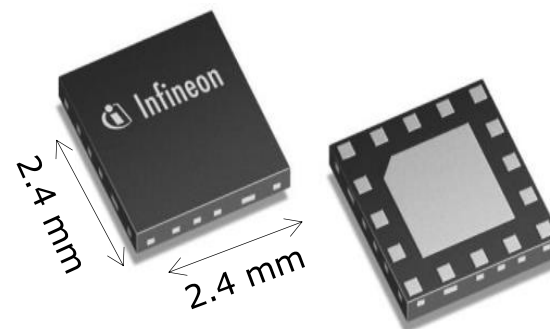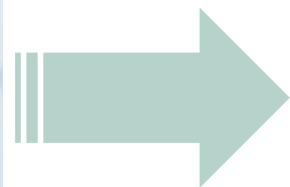
2015	**Availability**	Today

New

- *Ultra Low Power Consumption (Upto few uW under Duty Cycle mode)*

- *Ultra Small Form Factor (2.4mmx2.4mm)*
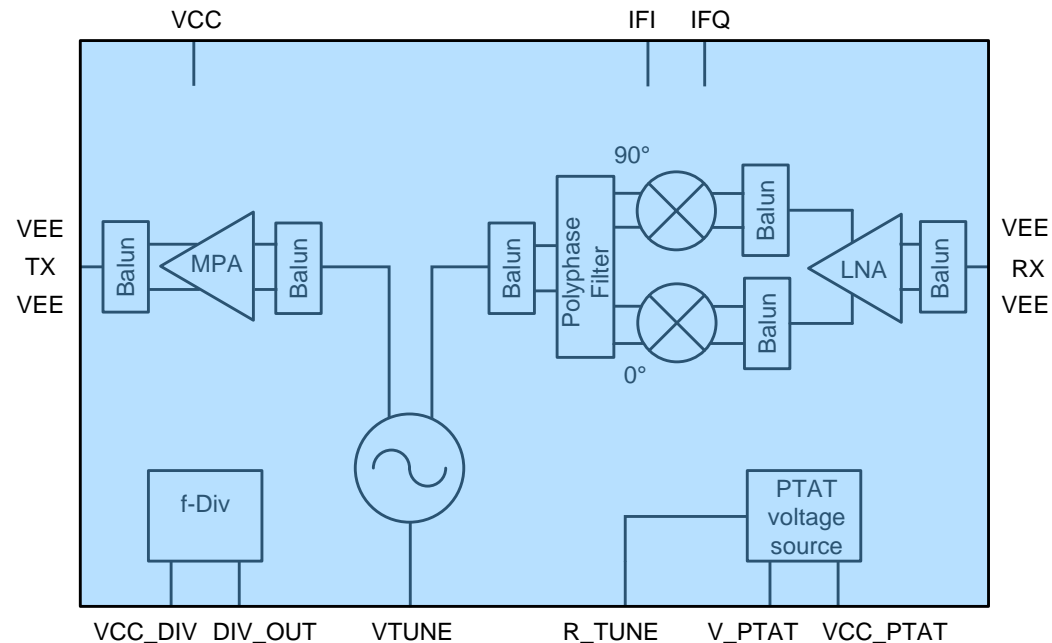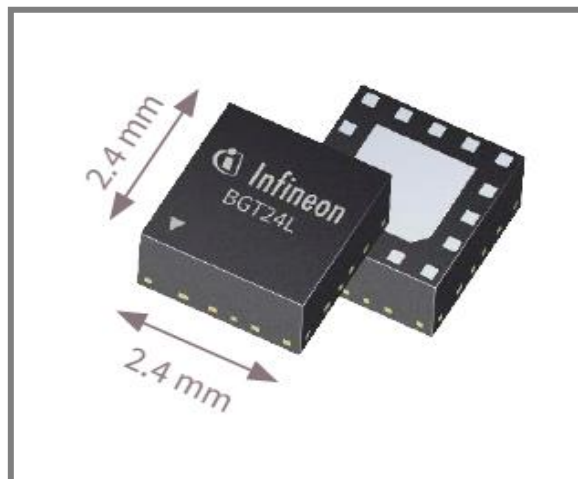
Block diagram
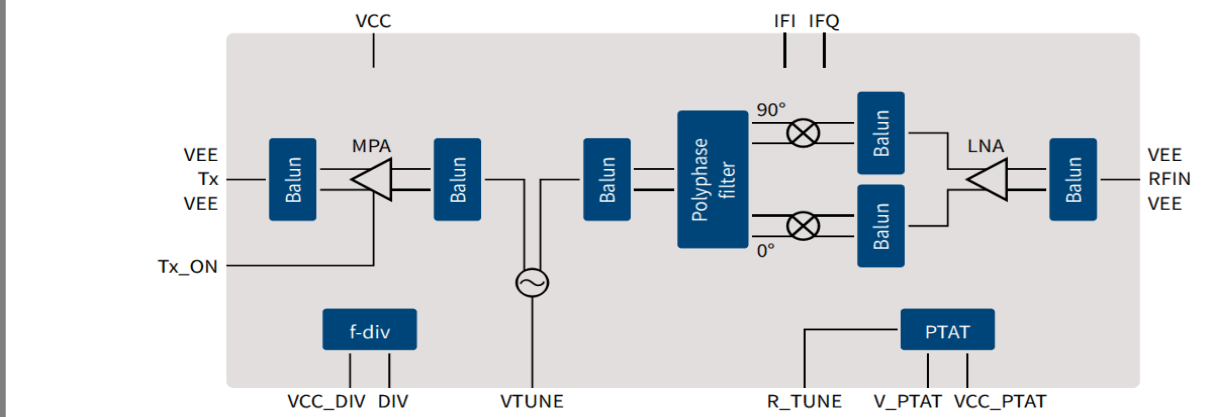
The VCO frequency is kept within the ISM band using the internal PTAT circuit, no external PLL or tuning circuitry required for frequency stabilization. The frequency band can be shifted using an external tuning resistor.
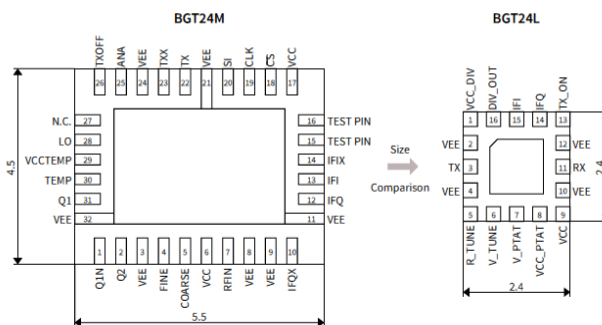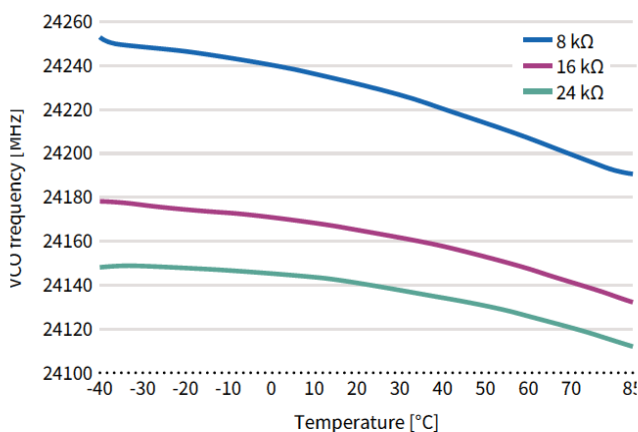
Easy to use design tools

> Chip evaluation board to perform basic measurements with the chip (EVAL_BGT24LTR11_BOARD)
> Demo kit to get a feel for motion detection using 24GHz radar sensing (SENSE2GOL)
> Complete datasheets and applications notes available to kick start your design

Ultra Low Power, Small Form Factor, MMIC with 1 Transmitter and 1 Receiver

› 24 GHz ISM band transceiver MMIC

› On chip temperature sensor

› Switchable prescaler with 1.5 GHz and 2.3 MHz output

› Fully integrated low phase noise VCO (typ -80dBc/Hz @100kHz offset)

› Modified Gilbert based homodyne quadrature receiver

› Single ended RF and IF terminal

› **Low noise figure NFSSB: 12 dB**

› **Output Power 6 dBm fixed**

› **Single supply voltage 3.3 V**

› **Ultra Low power consumption 150 mW**

› **Integrated Temperature Compensation Circuitry for ISM Band Operation**

› 200 GHz bipolar SiGe:C technology b7hf200

› Fully ESD protected device

› TSNP-16-1 leadless plastic package. (2.4*2.4 mm^2)

RF system board roadmap offerings

2014

RFB2412 (BGT24TR12 + XMC4400)

› 1 transmitter + 2 receivers
› Motion detection
› Doppler radar for speed monitoring
› **Software based FMCW for distance measurement of stationary objects - NEW**
› **Angle of arrival estimation - NEW**
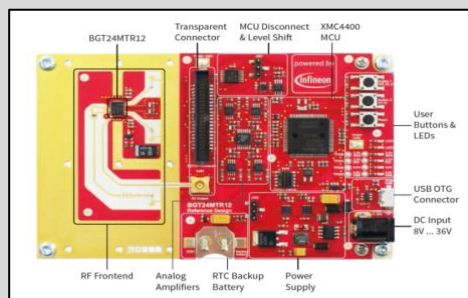
2015

Sense2GO2 (BGT24MTR11 + XMC4200)

› Starter kit for radar and Microcontroller development
› 1 transmitter and 1 receiver
› Motion detection and Doppler radar for speed
› Low power mode for enhanced battery life
› Industrial standard interfaces via CAN and IOLINK
› Software based FMCW under development
› **Increased Range to 15m**
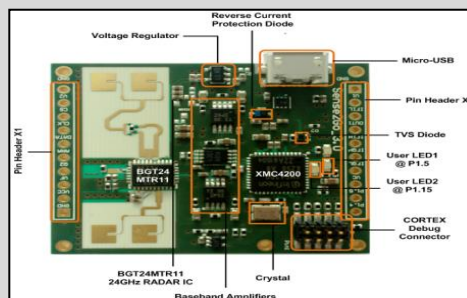
2016

Now Available

Sense2GOL (BGT24LTR11 + XMC1300)

› Starter kit for radar as well as IFX Microcontrollers
› Low end solution + development kit
› 1 transmitter and 1 receiver
› Motion detection and Doppler radar for speed
› Low power mode for enhanced battery life
› **Ultra small form factor (maybe… worlds smallest complete RADAR + MCU development kit)**
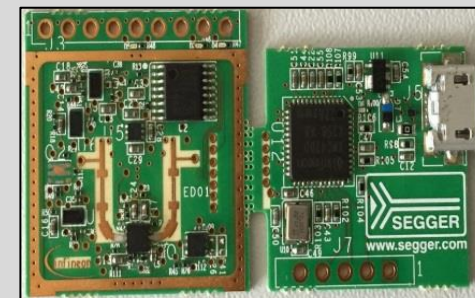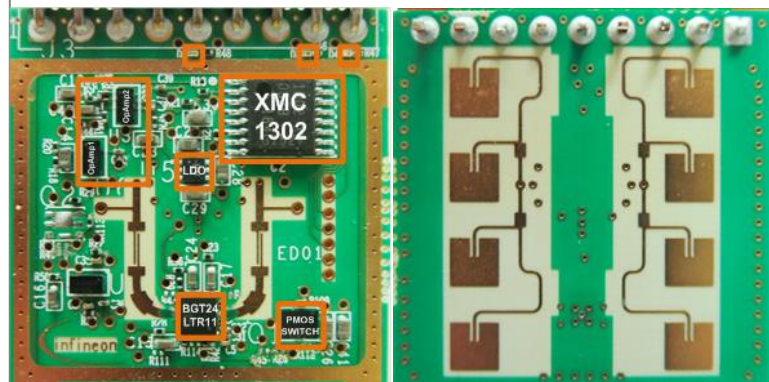
Sense2GoL demo board Overview

Worlds Smallest Fully Integrated Radar Module

25mm

25mm

50mm

RADAR MAIN PCB   Breakable- DEBUGGER PCB
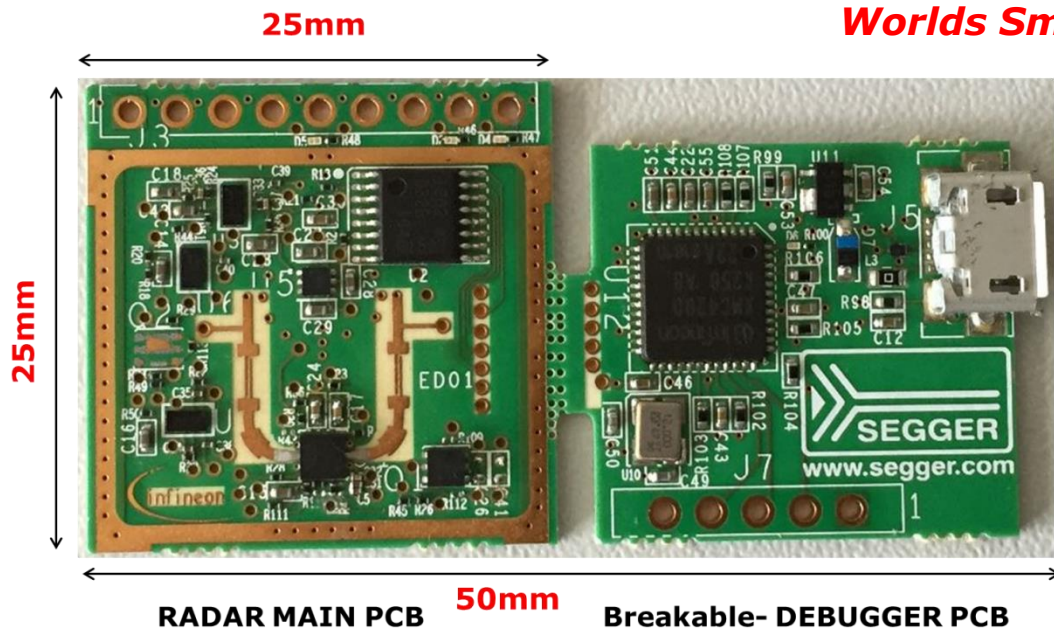
Kit contents

› User manual

› Firmware for Motion Detection

› SW GUI for Radar Signal Observation

› PCB Schematic and Gerber files

Key Features of the new Sense2GoL Demo Board

› **BGT24LTR11 – 24 GHz highly integrated low power MMIC**
› **XMC1302 ARM® Cortex™-M0 – 32 bit industrial Microcontroller**
› **Multiple Integrated patch antennas available (Default 1x4 with FOV = 28°x80°)**
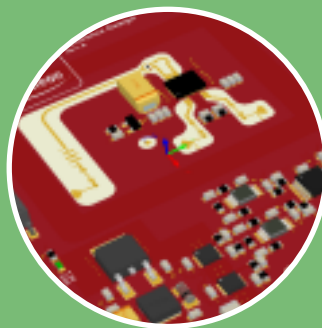› **Segger Debugger breakoff board for reprogramming**

BGT24LTR11 Demo Kit **SENSE2GO_L**
Ultra Low Power, Small Form Factor MMIC with
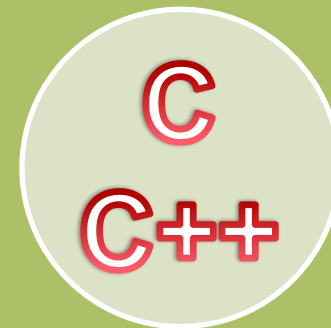32-bit ARM® Cortex® -M0 MCU XMC1302
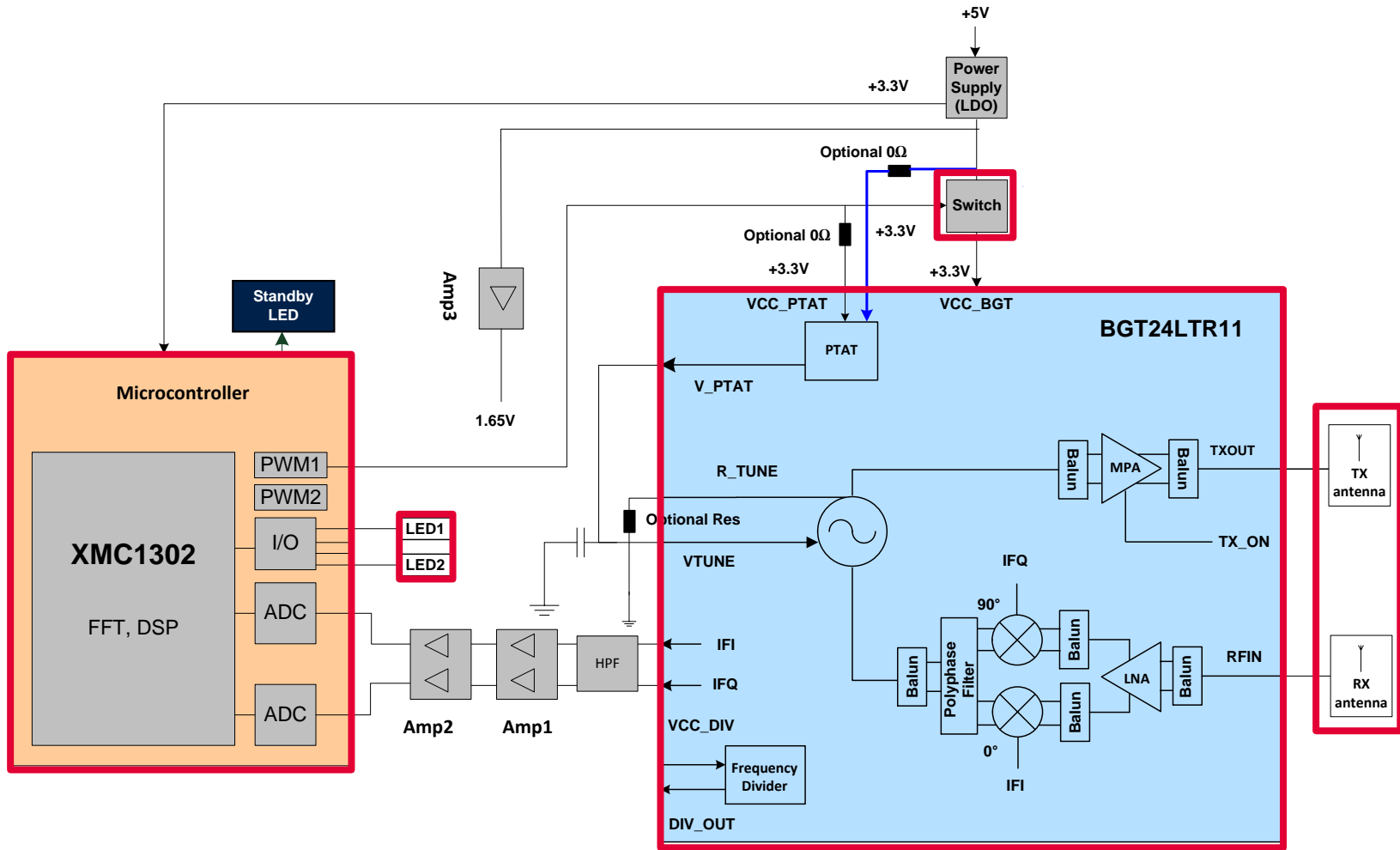
Radar System Design Requirements

Antenna Design

RF & BB PCB Design

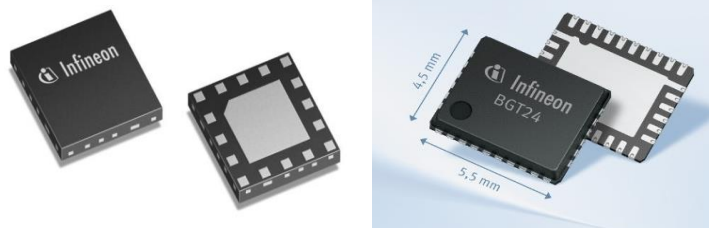**Signal Processing**

C
C++

Infineon helping you with Complete System Design

Infineons MMIC to Complete System offering

Features

› Radar-based motion detector operating in the 24 GHz ISM-Band
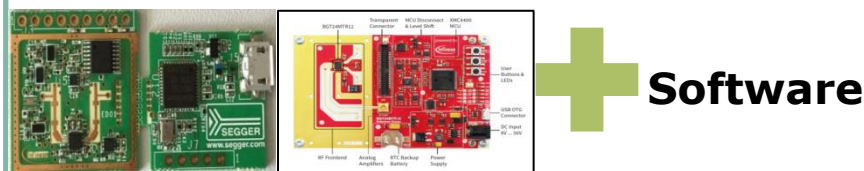› 4 MMIC Chips available

IFX MMIC

MMIC

Benefits

› Long range distance detection of moving objects up to 50 m
› Wide range speed detection up to more than ±100 km/h

Features

› 3 System Boards available
› All include 24GHz radar and XMC™ microcontroller
› Kit contains User manual, GUI, MATLAB compiler and Gerber files
› Requires Software

IFX Development Kit


+ Software

Demokit with SW, Reference design

Benefits

› Capability to detect motion, speed and direction of movement (approaching or retreating) , distance and Angle of Arrival based on hardware
› FW/SW for available for each radar mode

Features

› Complete module ,including radar MMIC, antenna options, MCU Signal processing options, and SW options (Doppler, FSK and FMCW versions available)

Partner Modules using IFX Chip
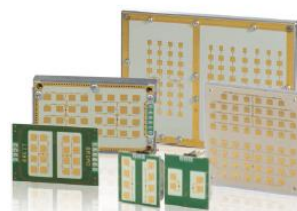
Module (RF module; RF module + MCU including SW)

Benefits

› Ease of design
› Turn-key solution for customers with limited radar/RF/SW know-how

Outline

1   Infineon at a Glance

2   IoT Positioning at Infineon

3   24GHz Radar Sensors for IoT Applications

4   Infineons 24GHz Products and System Offerings

5   RADAR Demonstration (Distance and Speed Measurement)

Welcome to Infineon's demos
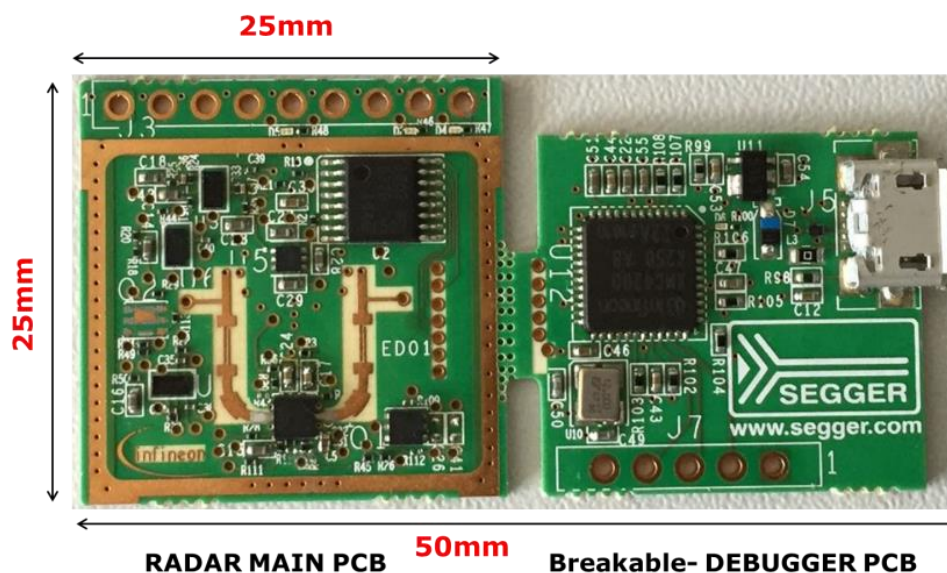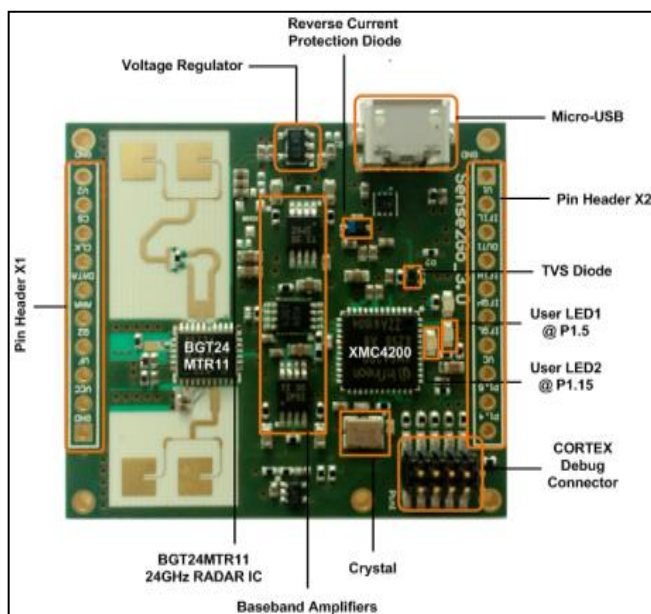
[Video](#)

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