資料4-3

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The Future in Motion

Worldwide Standardization in Radar

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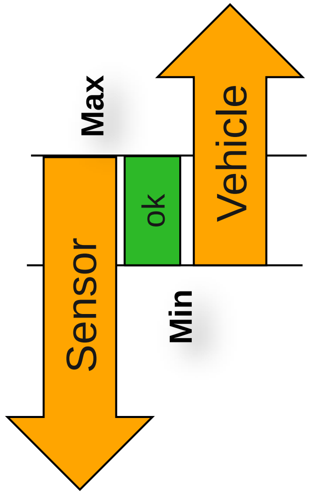
2022年2月16日

Evolution of Frequency Ranges for Automotive Radar Worldwide Allocations

Frequency band / range		List of typical Use-cases	Key parameters
76–77 GHz		Adaptive cruise control Front cross traffic alert Blind-spot detection, lane change assistance, rear cross traffic alert, pre-crash rear, exit assistance.	**High Performance**
24 GHz (ISM) 24.05 – 24.25 GHz		Distance warning, Blind-spot detection, lane change assistance, rear cross traffic alert, pre-crash rear, exit assistance	Basic performance, Low cost
24 GHz (UWB) 24.25– 26.65 GHz		Stop-and-go, Blind-spot detection, lane change assistance, rear cross traffic alert, pre-crash rear, exit assistance	Market entry for automotive radar Phased out in Europe/US by 2022

New dimension in Radar Regulations
Vehicle and sensor level

Level	Scope	Requirement	Basis of Regulation
Vehicle	**Driver Functions**	Acceptance criteria for driving functions, Sensor aging, Environmental degradation	ISO standards, UN ECE, NCAP **=> Minimum Performance required (Min Limit)**
Sensor	**Radio Spectrum regulation**	Power, Frequency, Bandwidth, Spurious, Interference	National Radio Laws and technical standards **=> Limits the Performance (Max Limit)**



1. **Vehicle and Sensor: both requirements to be fulfilled**
2. **Spectrum requirements limits performance of driving functions**
3. **Examples for radar performance criteria in ISO standardization**
   a) Motor bike detection in 55m [UNECE_ACSF_ESF*]
   b) Aging of sensor detection range: 20% max over lifetime
   c) Environmental degradation of sensor detection range: 20% max (weather)

***)** Working Group on Automatically Commanded Steering Functions / Emergency Steering Functions

Worldwide Radar Frequency Regulation in 76-77 GHz

Country / Region	Limit	Other info
China	Peak: 55 dBm	Released New regulation in Dec-2021 Automotive Radar in 76 - 79 GHz band
Europe	Average: 50 dBm Peak: 55 dBm	High power limits
Japan	10 dBm conducted burst power all Tx	Burst power all Tx Maximum antenna gain limit is 40 dBi
South Korea	20 mW conducted (Average: 50 dBm, Peak: 55 dBm)	Changed in Radio Law in Aug-2019 Increase Antenna TX power 10mW -> 20mW (single Tx) Apply limits to individual Tx antenna
USA / Canada	Average: 50 dBm Peak: 55 dBm	Released New standards in 2017/2018 High power limits 76-77 GHz and 77-81 GHz bands merged

Driving functions - ISO and UN ECE regulations Selected examples

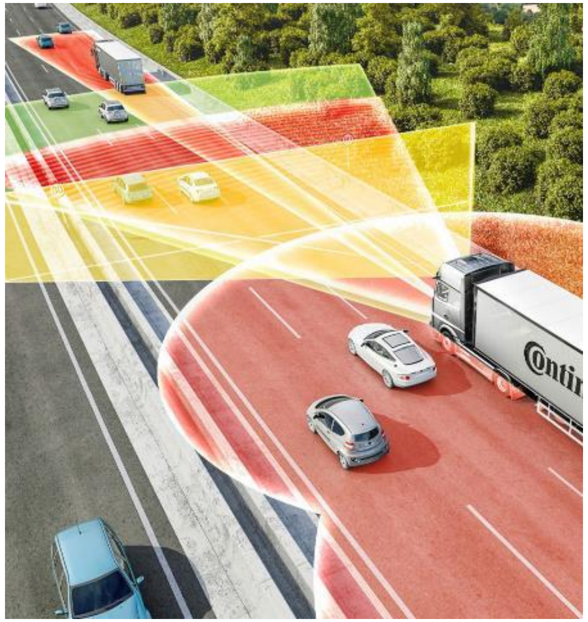
Low speed following system	› **ISO 22178:2009** › Control vehicle speed adaptively to a forward vehicle by using information like ranging and motion
Forward vehicle collision mitigation systems	› **ISO 22839:2013** › To be able to reduce the severity of forward vehicle collisions that cannot be avoided
Advance Emergency Braking System (AEBS)	› **UN ECE/TRANS/WP.29/GRVA/2019/5** › Uniform provisions concerning the approval of motor vehicles about the Advanced Emergency Braking System (AEBS)

- Driving functions are baseline for automated driving
- Driving functions challange radar performance
- Driving functions according to ISO standards require worldwide radar harmonisation in frequency regulation

Vehicular radar technology
Evolution and benchmarks in radio technology

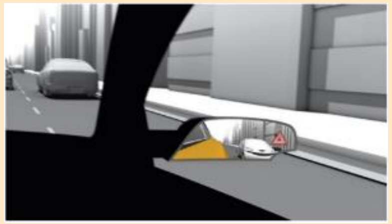
MIMO antenna technology is required	› **High number of Tx / Rx antennas on sensor level** Example: 3 / 4 / 8 / 10 Tx [Transmit] › **High resolution in azimuth and elevation**
Minimum radiated power for high performance radars	› **EIPR target in range of 30 – 40 dBm** › **Detection Range following radar equation** › Target detection range: 160 m to 250 m, depending on object type
Antenna design focus on broad view	› **Typical gain 10 – 20 dBi,** › **higher antenna gain is not beneficial** › 35 - 40 dBi in Japan radar regulation will not capitalize in higher performance
Chipsets with multi-Tx outputs (for MIMO)	› **Output power typ. 10 mW – 15 mW for individual Tx** › Aggregation of power by multi-Chip integration › 10 Tx Antennas = 10*15 mW = 150 mW Output power

Multi Tx high radar will have higher conducted output power exceeding 10mW limit



Transmit Power / Physical detection range relationship Comparing different sensor functions

*Source: ETSI TR 103 593 V1.1.1 Table 5

Radar type	Sensor Function	Bandwidth requirement	Radio power requirement [Average e.i.r.p]	Detection range
Short range	Blind spot detection 	800 MHz	26 dBm	Child at 20 m Pedestrian at 23 m Bicycle at 31 m
Mid range	Lane change assist, Front and rear traffic alert 	450 MHz	**35 dBm**	Child at **44 m** Pedestrian **at 58 m** Bicycle at **69 m** Motorcycle at **94 m** **Vehicle** at **166 m**
Long range	Adaptive cruise control Emergency Brake 	250 MHz	**40 dBm**	Motorcycle at **166 m** **Vehicle** at **296 m**

Under current regulations, Radar sensors cannot meet future requirements for the detection range of objects

Radar detection range for MIMO sensor design
Conducted output power versus Radiated power [example]

Conducted power TRP
calculation for 10 Tx antennas
[assume 25mW (14dBm) output per antenna]

- **EU / US: No limit**
  24 dBm = 250 mW = 10 Tx * 25 mW (= 14 dBm)
- **Japan: Limited to 10 mW + 50% production tolerance**
  12 dBm = 15 mW

Radiated power EIRP
= Conducted antenna power + Antenna Gain
[assume antenna gain =13 dBi]

- **EU / US: Average power**
  37 dBm EIRP = 24 dBm + 13 dBi
- **Japan: Burst power test method (3dB reduction)**
  22 dBm EIRP = 12 dBm + 13 dBi – 3 dB

Detection Range Comparison
EU/ US and Japan

	RCS [sqm]	22 dBm	37 dBm
Child	0.1	22 m	53 m
Bicycle	0.3	29 m	69 m
Motor Bike	1	39 m	93 m
Vehicle	10	70 m	166 m

Based on radar equation:

$$Range = \sqrt[4]{\frac{P_r \sigma c^2 G_r^2}{(4\pi)^3 f_O^2 P_{min}}}$$

Summary
Importance of worldwide standardization in radar

- ISO / UN ECE standards will drive performance in radar technology
- Driving function requirements challenges frequency regulation
- For global automotive market:
Worldwide alignment in frequency regulation and band allocation needed
- New radar technology and chip set technology towards higher number of antennas needed for high performance radars
- Japan regulation in methods and limits should be reconsidered based on new radar technology and upcoming driving function rules