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Project Coordinator

Dr. Martin Kunert
Robert Bosch GmbH
Daimler Strasse 6
71229 Leonberg
Phone +49 (0)711 811 37468
martin.kunert2@de.bosch.com

MOSARIM

SEVENTH FRAMEWORK PROGRAMME

Authors

Name	Company
Martin Kunert	Robert Bosch GmbH (RB)
Holger Meinel	Daimler AG (DAI)
Christoph Fischer	Daimler AG (DAI)
Malte Ahrholdt	Volvo Technology AB (VTEC)

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0.7	28.09.2010	Peer review version
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1.0	30.09.2010	Final Version

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1 Introduction

The aim of this report is to provide a reasonable forecast regarding the proliferation of automotive radar sensors up to the year 2020. But as with market penetration forecasts in general, the results contain a given uncertainty because not all influencing factors are known or some of the underlying factors may change over time. Based on the forecast number, the effect and impact of higher aggregated interference scenarios can be well determined by simulating the situation for the future years. The performance degradation or increased interference risk expected thereof can be estimated.
Based on the different vehicular radar frequency ranges already or soon in operation (24 GHz narrowband (NB) and ultra-wideband (UWB), 26 GHz ultra-wideband, 77 GHz long range radar (LRR) and 79 GHz short/midrange radar (SRR/MRR)) and by having in mind that the radar market strongly differs between passenger cars and heavy vehicles in total eight different forecast scenarios will be elaborated based on actual forecast study results and existing market volume estimations.
To avoid misinterpretation of the provided results, the automotive radar market penetration is given in absolute number of radar sensor units per year and not in e.g. the total sensor price or market volume in Euros.
The main focus is set for the European region with a small side glance to other countries where it may be interesting or useful.

In chapter 2, excerpts from different market studies conducted by Frost&Sullivan, ABI Research, TSR Ltd. and ITU Study Group 1 for passenger cars are given. Only the Frost&Sullivan study provided results for heavy vehicles.

In chapter 3, the main factors that may influence market penetration are described.

Finally, in chapter 4 the market penetration is forecasted in the timeframe from 2010 to 2020 for both passenger cars and heavy vehicles. Because many factors can influence the forecasted number of radar sensors within the different categories (see main influencing factors in chapter 3), an estimated minimum and maximum penetration rate is assumed, resulting in a kind of forecast corridor that increases in width (i.e. uncertainty) as time evolves.

Chapter 5 gives a conclusion on the market forecast and a caveat statement regarding the reliability and usability of the presented data.

2 Market studies and background information

As already mentioned in the introduction, the evaluation is conducted separately for both passenger cars and heavy vehicles (i.e. trucks and busses) due to their different behavior and attitude regarding radar system usage.

2.1 Passenger cars and light vehicles (vehicle category: M1, M2 and N1 [1])

To get an idea of what the market study values represent compared to the total annual production and the existing car fleet some indications from the OICA [2] and the ACEA [3] database are provided in the Table 2.1 below.

Country	Annual car production in 2009	Total car fleet in 2008
Germany	4.964.523	41.321.171
Europe	14.560.534	230.387.142
USA	2.246.470	159.754.000
China	10.383.831	16.060.000

Table 2.1: Annual production and total car fleet in some countries

As can be seen from Table 2.1 the annual car production in Germany is around 10% of the total car fleet in Germany. For Europe this ratio is around 6%, respectively. So even with a mandatory installation of radar sensors for all new cars it will take roughly about 10 years in Germany until the entire car fleet is equipped with radar sensors under best case assumptions. For Europe, the time will be even longer; in China, due to the still small car fleet and the fast growing rates, it may be significantly faster, as can be seen in Figure 2.1.

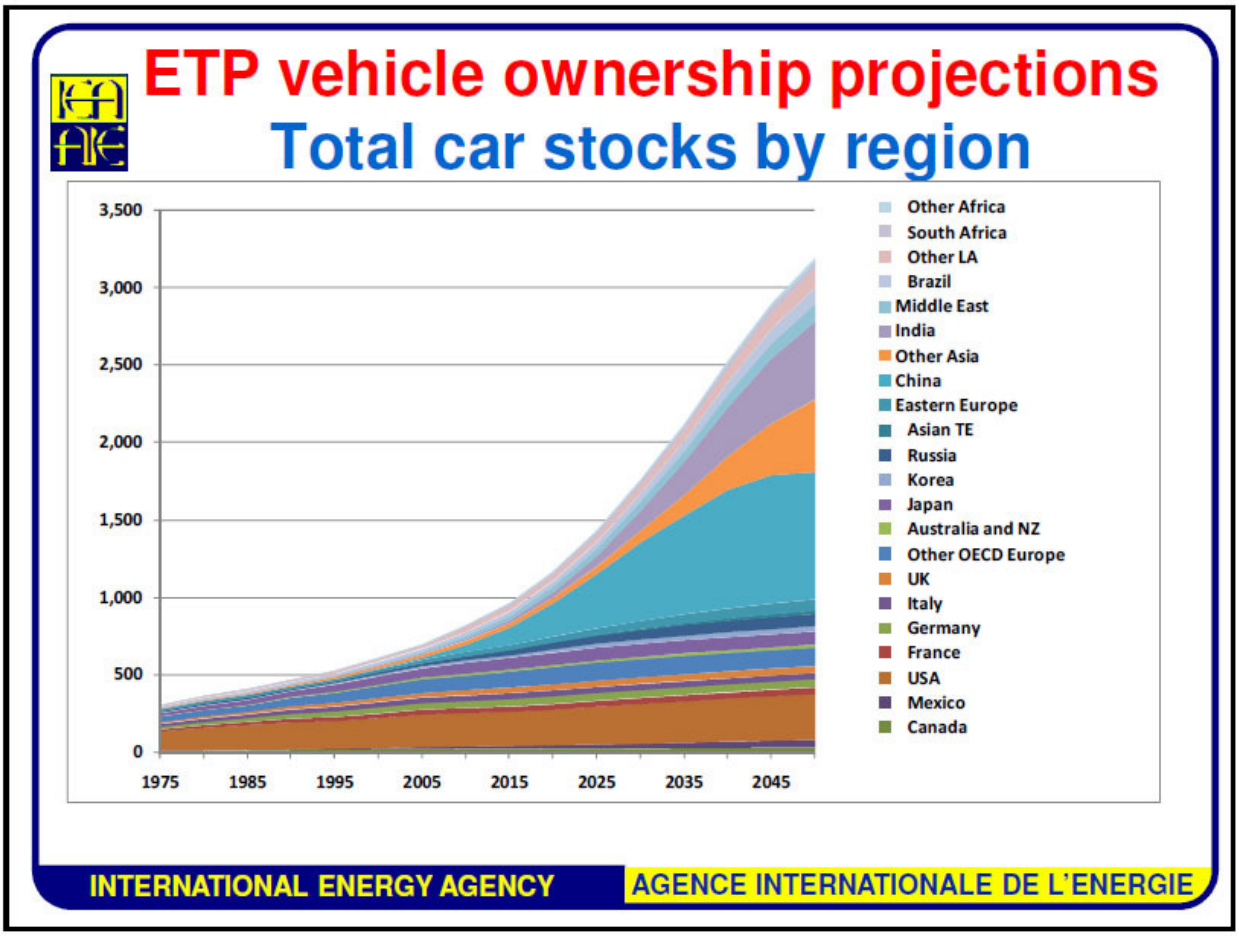

Figure 2.1: Total car stocks by region [4]

Compared to the worldwide passenger car production in 2009 of 57.200.000 units (in 2010 the production is expected to reach 65.000.000 units[5]), the number of new vehicles equipped with radar sensors today is still rather small (below 1% of total car production).
Figure 2.2 shows the general forecasts from three studies (Frost&Sullivan [6], ABI Research [7] and Techno Systems Research [8]) and also an averaged and extrapolated estimation up to the year 2030 for both the ratio of radar-equipped vehicles to the annual production and the percentage of radar-equipped vehicles regarding the whole vehicle fleet. Worldwide production and all kind of automotive vehicles are within this forecast's scope.

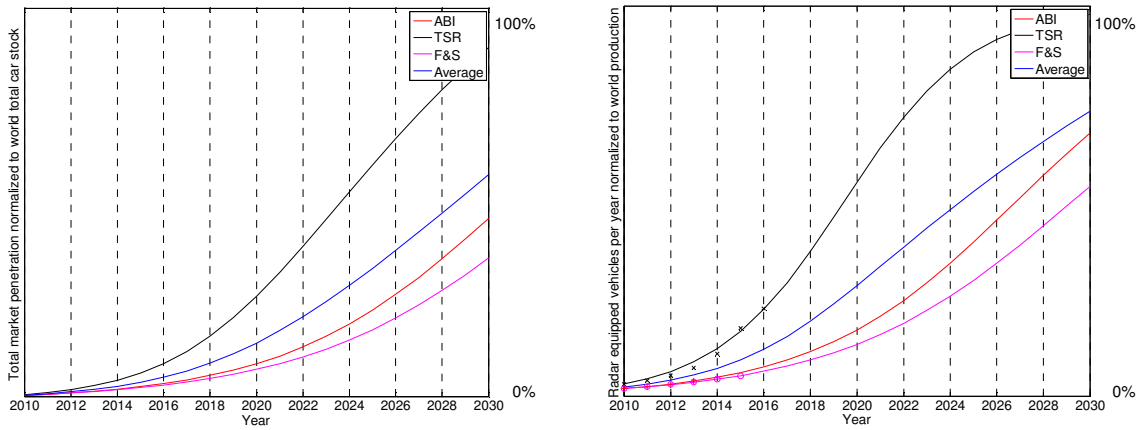

Figure 2.2: Averaged forecasts for market penetration and radar equipped vehicles based on the three studies from Frost&Sullivan (F&S), ABI Research (ABI) and Techno Systems Research (TSR)

In the following more details from these studies are given.

2.1.1 Frost&Sullivan forecast

In the Frost&Sullivan report "Opportunities in the automotive safety market" from 2005 [6] the market penetration for different sensing technologies is sketched. The penetration rate is given as percentage of all new produced vehicles. So, for Europe in 2015 about 728.000 units of 77 GHz LRRs (Long Range Radars) are estimated to be build into passenger cars (c.f. Figure 2.3 percentage with 2009 annual production number for cars from Table 2.1).

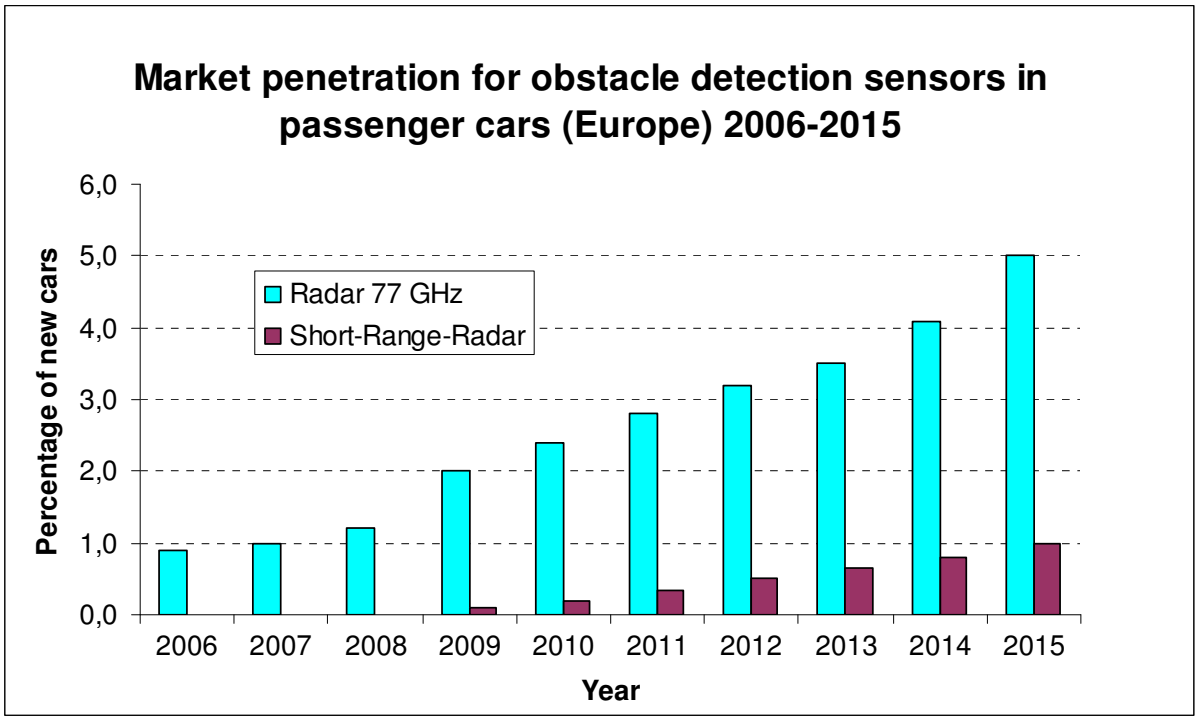

Figure 2.3: Sensor technology market penetration for passenger cars in Europe [6]

2.1.2 ABI-Research forecast

In the ABI Research report "Automotive Obstacle Detection Systems" from 2007 [7] the worldwide Radar-Based Obstacle Detection Sensor Shipments is sketched (see Figure 2.4).

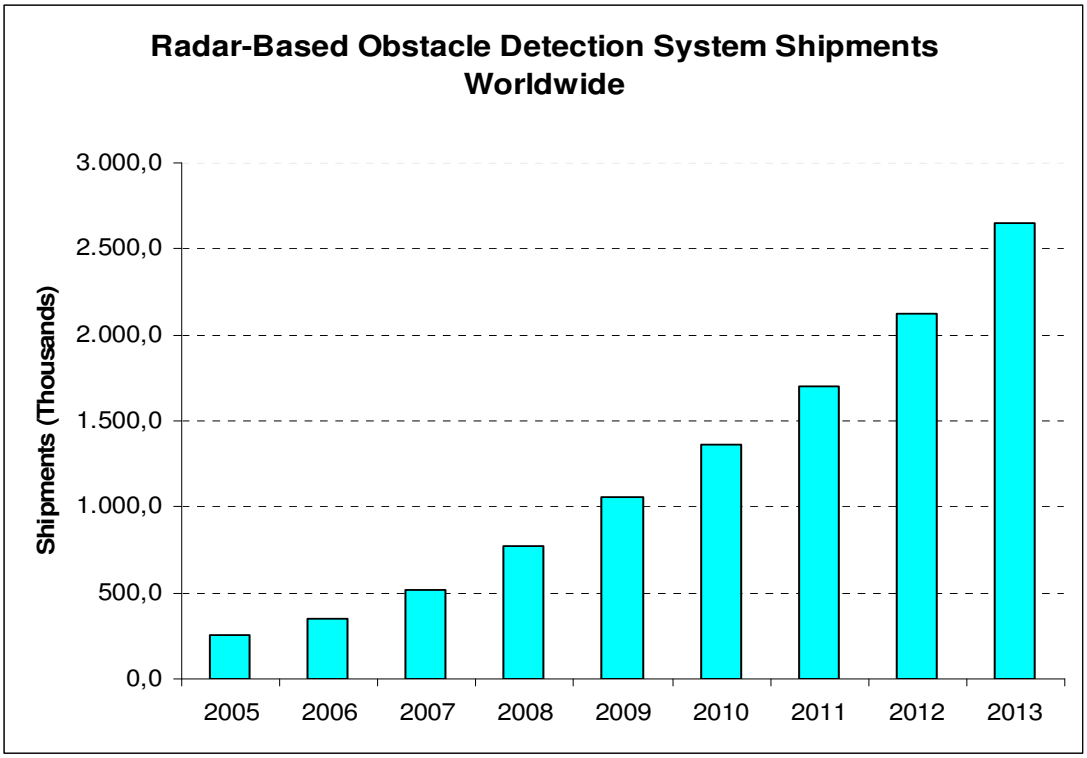

Figure 2.4: Radar-Based Obstacle Detection System Shipments worldwide [7]

2.1.3 Techno Systems Research Co., Ltd. forecast

In the Techno Systems Research Co. Ltd. "Market Analysis of Automotive Sensing System" study from 2010 [8] the worldwide shipments of Radar Sensors is sketched (see Figure 2.5).

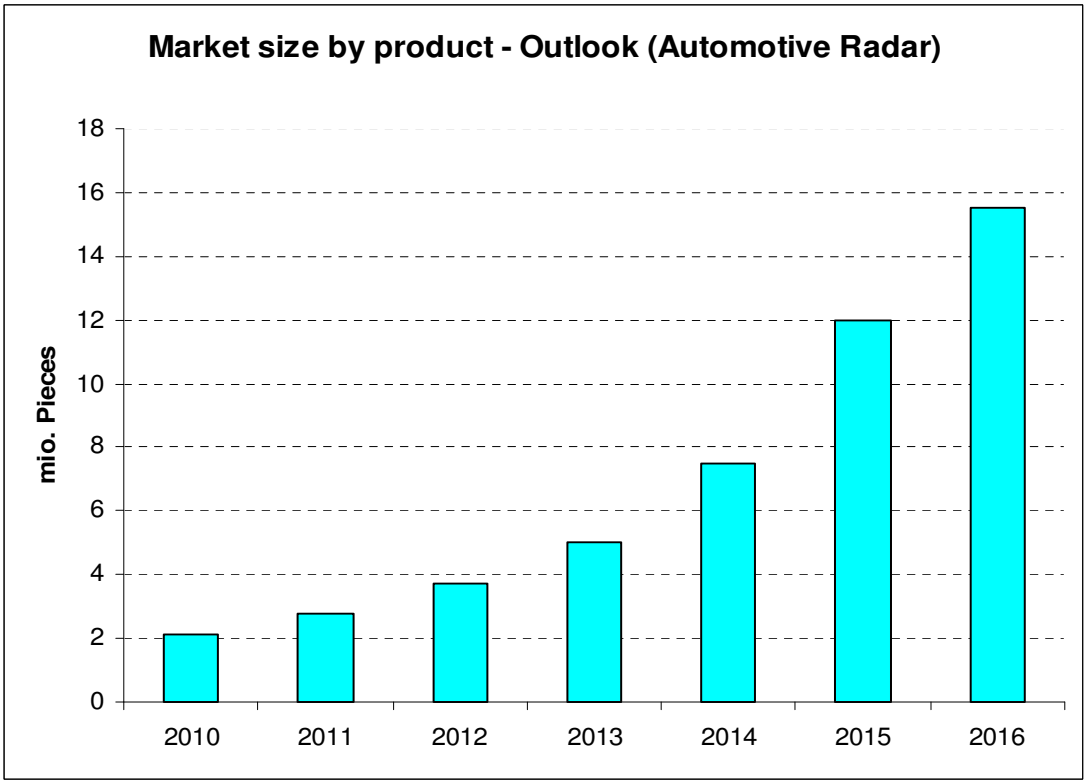

Figure 2.5: Market size for automotive radar sensors (worldwide) [8]

2.1.4 ITU SG1 forecast

Between 2001 and 2005 a special study group in ITU (Task Group 1/8) developed four ITU-R Recommendations regarding the coexistence of UWB devices with other incumbent frequency users and services. In the Recommendation ITU-R SM.1755 [9] a market penetration estimation for the three automotive radar frequency ranges 24 GHz UWB, 24 GHz narrowband and 79 GHz UWB is given (see Table 2.2). Depending on the time limited usage of the 24 GHz UWB regulation until 2013 the situation in Europe is considerably different compared to the USA. It is also assumed that there will be always a split in technology usage with respect to the same application or function, i.e. that no technology will be used for a given application with 100% penetration rate.

Technology penetration estimation for short-range sensors

Technology	Technology penetration (%)		
	Europe/2013	Europe/2030	USA/2030
24 GHz UWB SRR sensors	7	0	40
79 GHz UWB SRR sensors	1	55	0
Narrow-band SRR sensors (e.g. 24.00-24.25 GHz band)	20	10	10
Infrared and ultrasonic sensors	15	15	15
Camera based sensors	2	10	10
Vehicles with no short-range sensors	55	10	25

Table 2.2: Technology penetration for different sensors in Europe and USA until 2030 [9]

2.2 Heavy vehicles (vehicle category: N2 and N3 [1])

To get an idea what the market study values represent compared to the total annual heavy vehicle production and the existing commercial vehicle fleet, in Table 2.3 some indications from the OICA database [2] and from the Bureau of Transportation Statistics [10] are provided in Table 2.3.

Country	Annual commercial vehicle production in 2009	Total commercial vehicle fleet in 2008
Germany	245.334	2.900.000
Europe	1.671.310	8.300.000
USA	3.462.382	9.850.000
China	3.407.163	N/A

Table 2.3: Annual production and total commercial vehicle fleet of some countries [2], [10]

These figures are supported by information from EUROSTAT [11] extrapolating to a number of approx 1.500.000 to 1.800.000 annual vehicle registrations in classes N2 and N3 in EU27; the broad margin of extrapolation is due to the fact that recent data is not available for all countries.

For busses (vehicle classes M2 and M3), the number of vehicle registrations is approximately 35.000 to 55.000 per year in Europe.

2.2.1 Frost&Sullivan forecast

In the Frost&Sullivan report "Opportunities in the automotive safety market" from 2005 [6] the market penetration for different sensing technologies is sketched. The penetration rate is given as percentage of all new produced commercial vehicles. So, for Europe in 2015 about 235.000 units of 77 GHz LRRs (Long Range Radars) are estimated to be integrated in heavy vehicles (c.f. Figure 2.6 percentage with 2008 annual production number for commercial vehicles from Table 2.3).

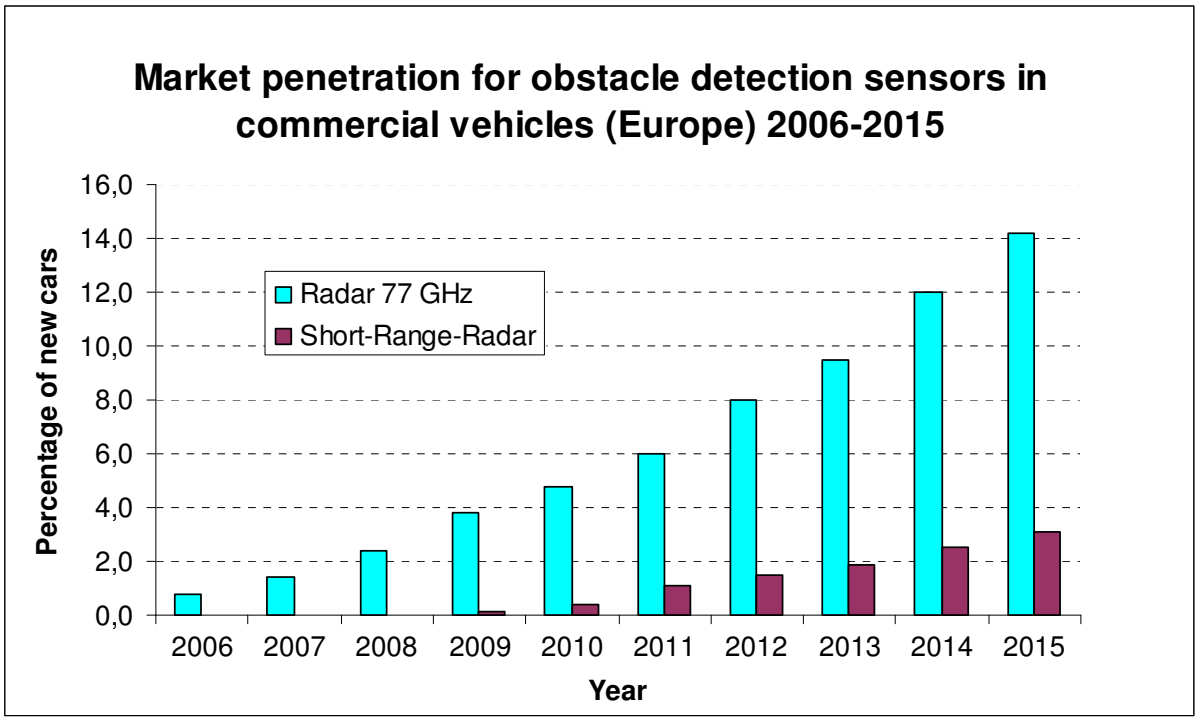

Figure 2.6: Sensor technology market penetration for commercial vehicles in Europe [6]

2.2.2 ABI-Research forecast

Within the ABI Research report "Automotive Obstacle Detection Systems" [7] no differentiation between passenger cars and heavy vehicles was made.

2.2.3 Techno Systems Research Co. Ltd. forecast

Within the TSR report "Market Analysis of Automotive Sensing System" [8] no differentiation between passenger cars and heavy vehicles was made.

2.2.4 ITU SG1 forecast

Within ITU SG1 [9] no differentiation between passenger cars and heavy vehicles was made.

3 Main factors influencing market penetration

There are several factors that may influence the proliferation and market penetration rates of new functions and systems. In the following sections the most relevant of them are shortly described and their possible impact on penetration rate is indicated.

3.1 Regulatory factors

Regulatory aspects are expected to be an influencing factor for market penetration of radar systems. In Europe for example, a not yet finalized UNECE regulation [12] is expected to mandatorily require Automatic Emergency Braking (AEBS) functionality for the vehicle classes M2, M3, N2 and N3. This regulation is expected to become effective November 2013 for new type approvals and November 2015 for all new vehicle registrations [13].

With the take rate of radar-based assistance systems currently being rather low for the effected vehicle classes, this is expected to increase significantly with these regulations taking effect. Although radar-based systems are not the only technical solution to implement an AEBS function, as of today it is the most common means, such that the majority of the effected vehicle classes are expected to be equipped with radar-based AEBS systems.
For EU27, this legal requirement will cover the annual production of about 40.000 vehicles for M2 and M3 class and about 1.500.000 vehicles for N2 and N3 class, as can be derived from an extrapolation of EUROSTAT [11] data.

The 24 GHz UWB radar band is subject to time-limited frequency regulations in Europe [14]. Currently, a sun-set date of 2013 for installation of 24 GHz UWB radar sensors in new vehicles is stipulated. The sun-set date for 24 GHz UWB sensors is however currently under a technical review and might be adjusted. This regulatory impact will lead to a sharp decrease in the number of installed 24 GHz UWB radar sensors. In the long term, the 24 GHz UWB sensor technology is planned to be replaced by 79 GHz radar sensors.

In conclusion, the impact on the radar penetration rate by regulatory factors can be very high (up to the maximum possible penetration rate if mandatory usage is stipulated).

3.2 Key-Event-driven factors

One well-known key-event that significantly influenced the proliferation of a new assistance function was the failure of the Mercedes A-class vehicle in the Scandinavian elk-test. As a result, Daimler decided to equip all A-class cars with an ESC system and for competition reasons all other OEMs with vehicles in the same segment class followed. This resulted in an almost 100% take-rate for all new cars in Europe. The elk-test effect is well visible in the graph of Figure 3.1.

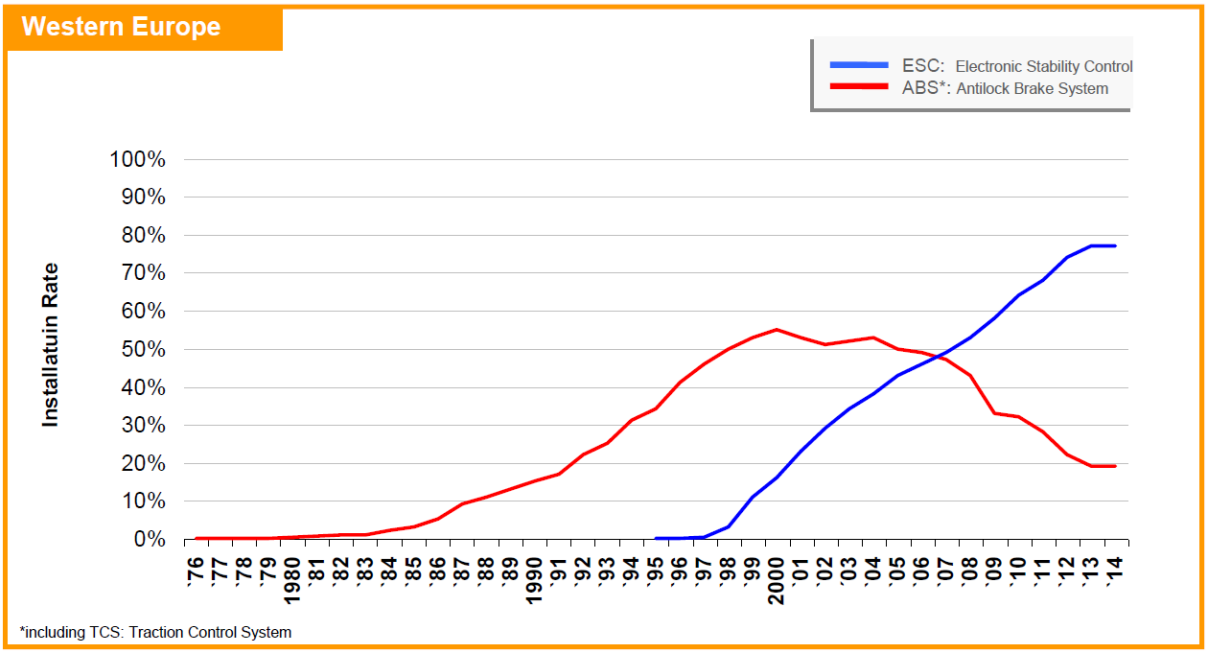

Figure 3.1: ESC market penetration in Western Europe – effect of elk-test [15]

Immediately after the elk-test failed in October 1997 the penetration rate of ESC systems constantly increased by ca. 6% p.a. - Taking the figures of Table 2.1 for Europe as a basis, this corresponds to a very high take-rate for all new produced passenger cars. In the same time the installation rate of classical ABS decreased accordingly because ABS functionality is included in any ESC system. Without the consequences resulting from the failed elk-test the market penetration of ESC would have been much slower, especially in the first years.

The occurrence of such a key-event in the future could in a similar way also strongly influence the penetration number for radar sensors.

3.3 Technology-dependent factors

Short-Range-Radar (SRR) based driver assistance systems were originally developed using the frequency range in K-Band (18 – 26.5 GHz); 24.05 to 24.25 GHz for narrowband - and 22.0 to 26.65 GHz for UWB applications, respectively. This first frequency choice was commercially driven and mainly based on the RF component costs and availability. Depending on the frequency regulations for Europe (see chapter 3.1 [14]) a sun-set date for the installation of 24 GHz UWB radar sensors in new vehicles becomes effective in July 2013. Consequently new sensors in E-Band (76-120 GHz) have to be installed from that point in time onwards; 76 to 77 GHz for narrowband - and 77 to 81 GHz for broadband applications, respectively. The usage of SiGe (Silicon-Germanium) semiconductors that is in focus of new technology development today and actually sponsored by the German Ministry of Education and Research (BMBF) within the RoCC-Project will be the solution for the future. The 79 GHz approach provides several advantages like smaller sensor size and thus lighter weight, while the disadvantages, like still higher RF component costs (more complex mounting or packaging) or higher signal attenuation (i.e. by bumper radome) compared to 24 GHz seem to be solved in the long run. Further advantages are increased sensitivity and speed accuracy, as well as higher angular resolution in azimuth and elevation. Due to the cost effective SiGe technology automatic sensor calibration, being not yet available today, comes into reach.

Furthermore the now available SiGe technology can also be taken for 77 GHz Long-Range-Radar (LRR) sensors for ACC employment.
The impact on the radar penetration rate by technology-dependent factors is moderate as innovation speed is mainly driven by market needs (i.e. the famous chicken-egg dilemma).

3.4 Commercial issues and cost-benefit

Radar-based driver assistance functions have entered the market from the premium car segment, now stepping down towards the medium and compact car segment. In Europe, with the Mazda 3 a first compact car with radar-based lane change assistance is available. In the US first cars in the segment below 15.000 € are equipped with UWB SRR. This increased the volume of radar units as well as the technology advances and yielded a reduction of the price per unit. In return this will increase the number of radar-based system sold annually.
The study of [8] foresees the unit price of radar systems to drop from 200 USD in 2009 to 100 USD in 2016, whereas prices of vision systems are expected to remain approximately constant, thus benefiting an increased spread of radar systems.
The impact on the radar penetration rate by commercial issues and cost-benefit is evaluated to be still moderate because only higher volumes result in a later on cost reduction.

3.5 Country-specific conditions and factors

The somewhat complicated and especially for UWB applications market penetration hampering frequency allocation situation in Europe has been described above in chapter 3.1.
In countries like the US and Japan a different frequency approach was chosen in K-Band: here the 26 GHz Band was allocated for UWB employment without any time limitation.
The frequency allocation issue in Korea or China is not yet settled. Especially the choice of China might have an important impact on the unit numbers to be sold in future, as can be seen from Figure 2.1 (mainly the Chinese car fleet will be growing by two-digit growth in the next decades). Furthermore, the Chinese decision might have a distinct influence on the other BRIC-States.
Finally country-specific technology competence, skills, needs, protective tariffs or market trends may impact the selection or proliferation of the used sensor technology (e.g. in the United States Fixed Service backbone links are mainly wired and thus the 26 GHz frequency band for wireless point-to-point connections is less used as in Europe and Asia, giving the possibility for other devices like UWB SRRs to make use of this frequency resource).

The impact on the radar penetration rate by country-specific conditions and factors is currently seen to be medium and may diminish over time as globalization advances.

4 Forecast of radar unit proliferation for 24 GHz (Narrow-band and UWB), 77 GHz and 79 GHz in Europe

4.1 24 GHz narrowband systems in Europe

4.1.1 Passenger cars forecast

In 2009, around 300.000 new 24 GHz Narrow Band radar units have been installed in passenger cars in Europe. Based on these values and with a minimum/maximum market penetration rate of 4% / 20% the forecast in radar units p.a. is sketched in Figure 4.1.

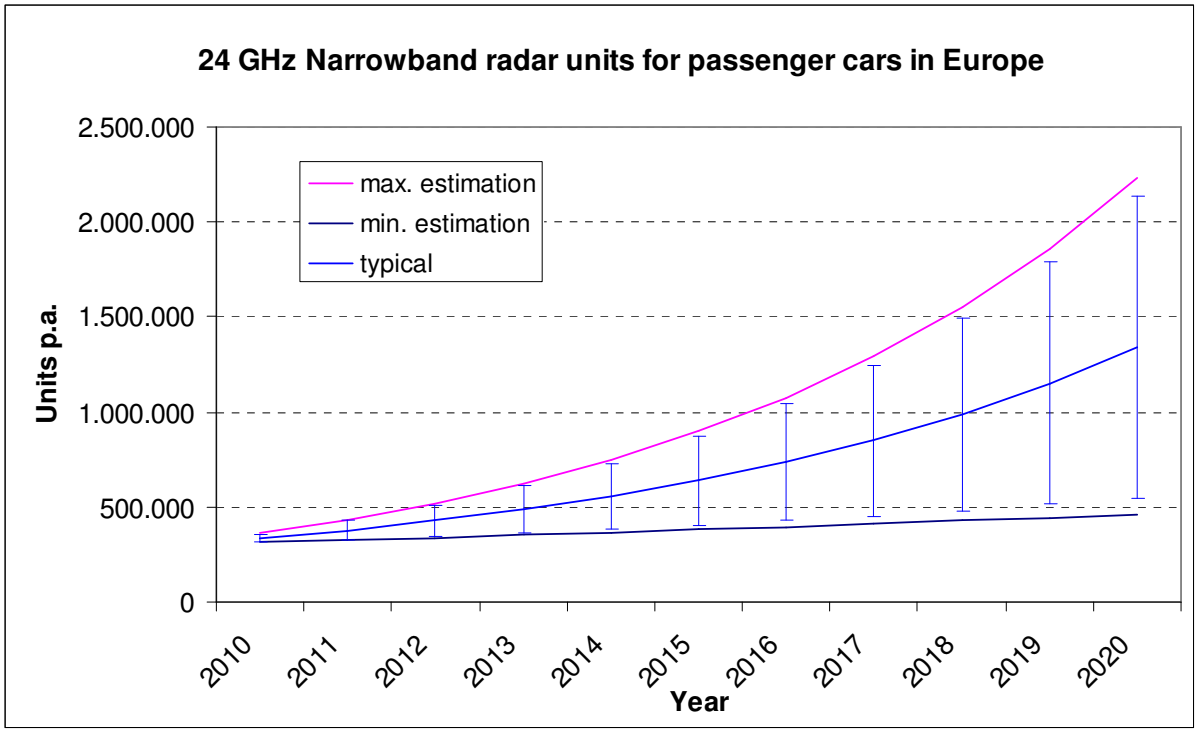

Figure 4.1: 24 GHz narrowband annual production unit forecast for passenger cars in Europe

4.1.2 Heavy vehicle forecast

In 2009 no installation number of 24 GHz Narrowband radar units in heavy vehicles in Europe is reported. Even if any unreported installation might have happened, the number is negligible compared to that for the passenger cars. Due to the lack of any reliable information regarding installation rates and trend no forecast chart is provided for this category type.

4.2 24 GHz Ultra-wideband systems

4.2.1 Passenger cars forecast

In 2009 around 60.000 new 24 GHz UWB radar units have been installed in passenger cars in Europe. Based on these values and with a minimum/maximum market penetration rate of 4% / 20% the forecast in radar units p.a. is sketched in Figure 4.2.

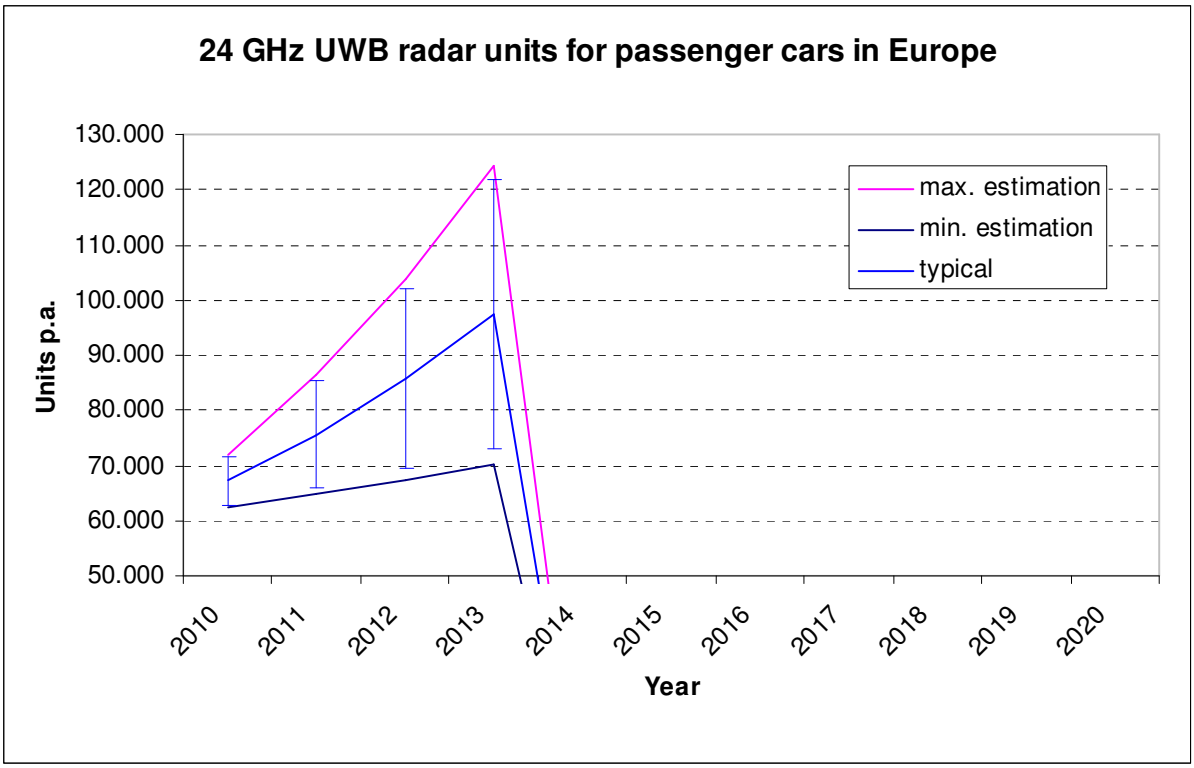

Figure 4.2: 24 GHz UWB annual production unit forecast for passenger cars in Europe

Note: Due to the European Commission's sunset date that prohibits any new 24 GHz UWB devices to be installed on vehicles in EU27 after June 30th, 2013 there is no further forecast possible as the installed units p.a. drops to zero after that date.

4.2.2 Heavy vehicle forecast

In 2009 around 5.000 new 24 GHz UWB radar units have been installed in heavy vehicles in Europe. Based on these values and with a minimum/maximum market penetration rate of 4% / 20% the forecast in radar units p.a. is sketched in Figure 4.3.

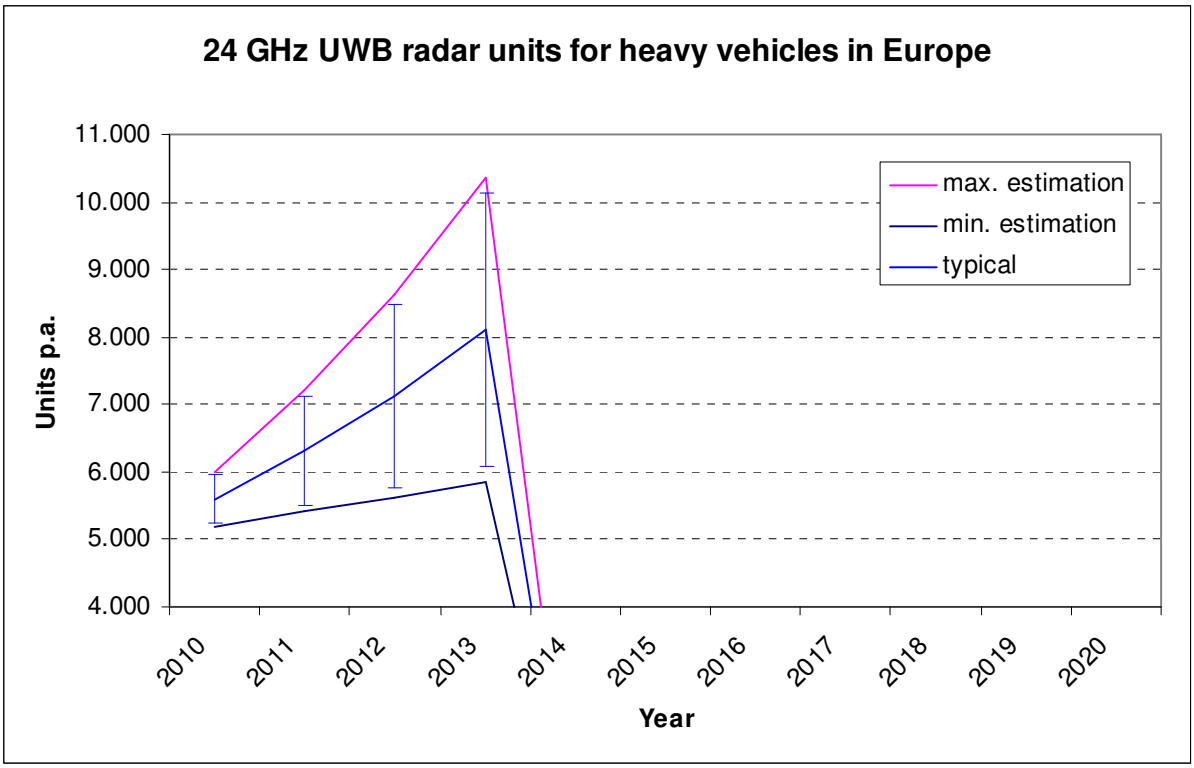

Figure 4.3: 24 GHz UWB annual production unit forecast for heavy vehicles in Europe

Note: Due to the European Commission's sunset date that prohibits any new 24 GHz UWB devices to be installed on vehicles in EU27 after June 30th, 2013 there is no further forecast possible as the number of installed units p.a. drops to zero after that date.

4.3 77 GHz Long-Range Radar Systems

4.3.1 Passenger cars forecast

In 2009 around 200.000 new 77 GHz radar units have been installed in passenger cars in Europe. Based on these values and with a minimum/maximum market penetration rate of 4% / 20% the forecast in radar units p.a. is sketched in Figure 4.4.

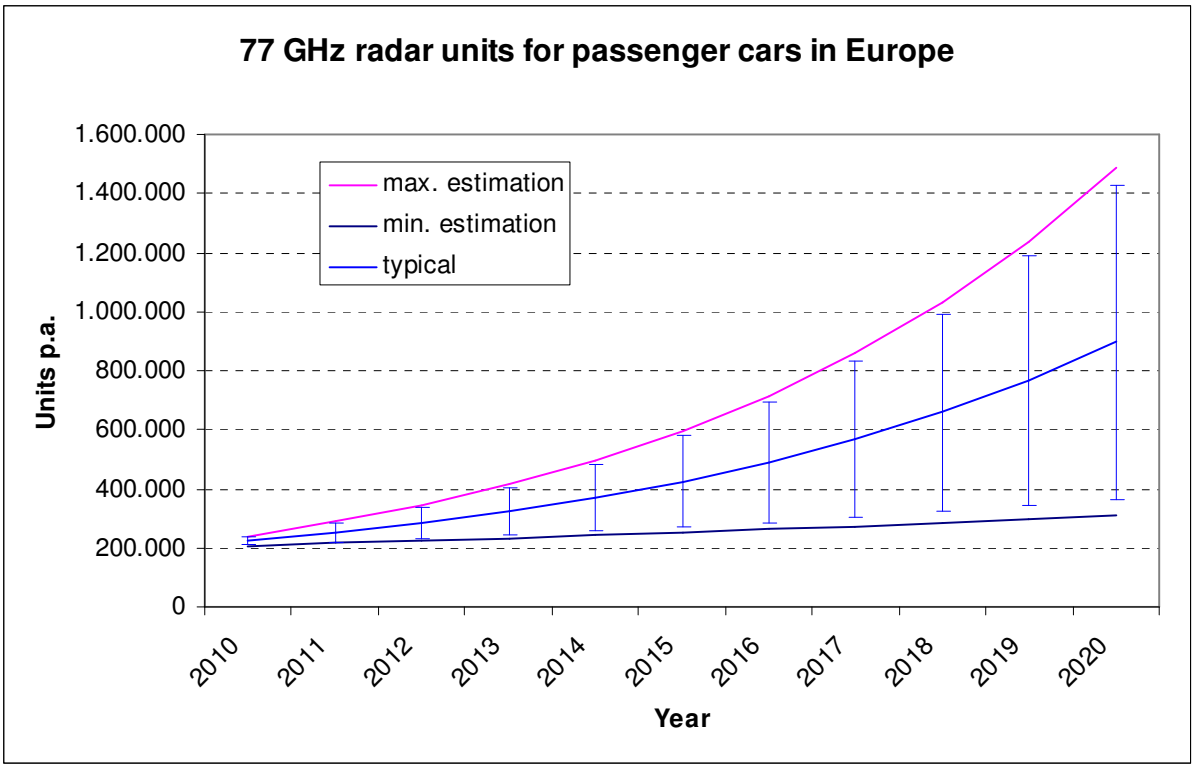

Figure 4.4: 77 GHz radar annual production unit forecast for passenger cars in Europe

4.3.2 Heavy vehicle forecast

In 2009 around 15.000 new 77 GHz radar units have been installed in heavy vehicles in Europe. Based on these values and with a minimum/maximum market penetration rate of 4% / 20% the forecast in radar units p.a. is sketched in Figure 4.5.

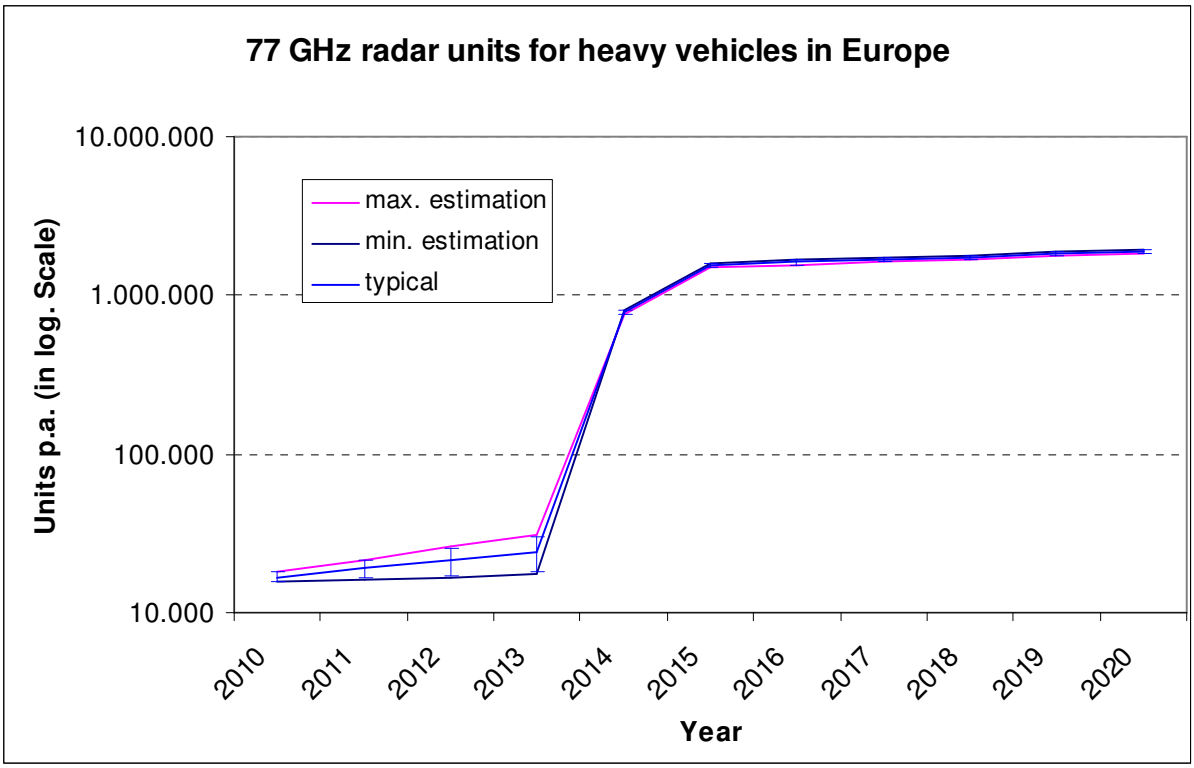

Figure 4.5: 77 GHz radar annual production unit forecast for heavy vehicles in Europe

Note: The mandatory implementation of AEBS for commercial vehicles (see chapter 3.1) will increase the take-rate from a few percent in 2013 to full installation in 2015. It is assumed that the already used 77 GHz technology will be also used when the AEBS function becomes mandatory. After 2015 an annual growth rate of 3% is further applied. Other sensor technologies or radar systems using different frequencies may take over parts of the 77 GHz market.

4.4 79 GHz Short&Mid-Range Radar Systems

4.4.1 Passenger cars forecast

First 79GHz radar sensors may replace the closing 24 GHz UWB market (see chapter 3.1) in the 2013 timeframe. It is assumed that a major part or even all of the existing 24 GHz UWB annual production can be taken over by 79 GHz devices. Based on these values and with a minimum/maximum market penetration rate of 4% / 20% the forecast in radar units p.a. is sketched in Figure 4.6.

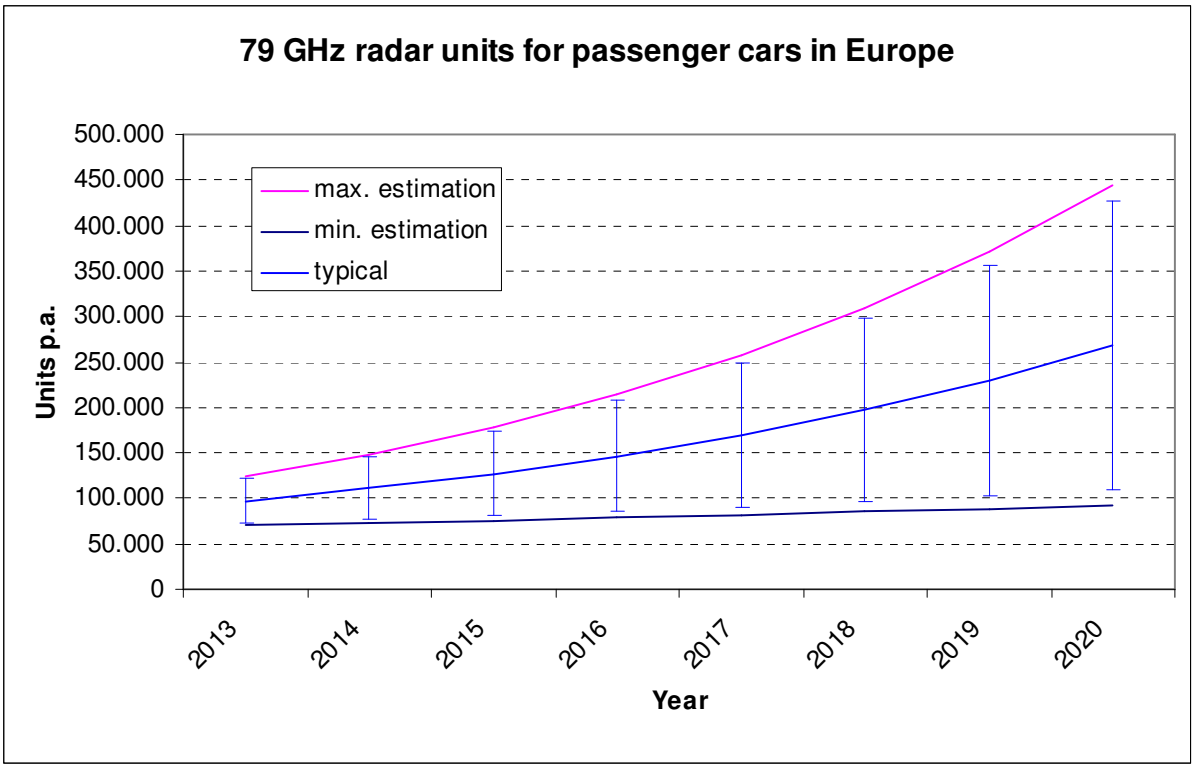

Figure 4.6: 79 GHz radar annual production unit forecast for passenger cars in Europe

Note: The estimations are based on a one to one takeover of the forecasted 24 GHz UWB unit numbers that will be produced in 2013 for the last time due to the sunset date. Possible additional market shares from other radar bands (e.g. 24 GHz Narrowband or 77 GHz) are not taken into account and may influence the forecast on a large scale. Finally, the shift of the sunset date to a later time may also significantly change this forecast.

4.4.2 Heavy vehicle forecast

First 79GHz devices may replace the closing 24 GHz UWB market (see chapter 3.1) in the 2013 timeframe. It is assumed that a major part or even all of the existing 24 GHz UWB annual production can be taken over by 79 GHz devices. Based on these values and with a minimum/maximum market penetration rate of 4% / 20% the forecast in radar units p.a. is sketched in Figure 4.7.

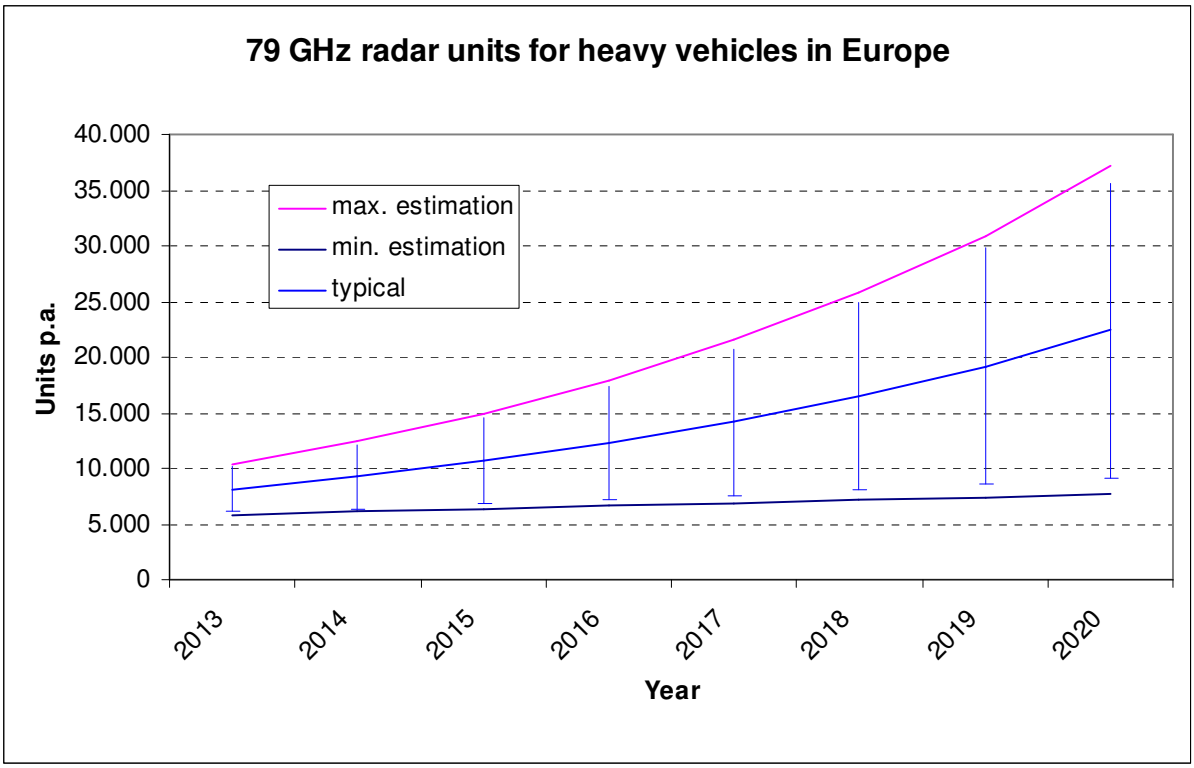

Figure 4.7: 79 GHz radar annual production unit forecast for heavy vehicles in Europe

Note: The estimations are based on a one to one takeover of the forecasted 24 GHz UWB unit numbers that will be produced in 2013 for the last time due to the sunset date. Possible additional market shares from other radar bands (e.g. 24 GHz Narrowband or 77 GHz) are not taken into account and may influence the forecast on a large scale. Finally, the shift of the sunset date to a later time may also significantly change this forecast.

5 Conclusion

A forecast of the European market until 2020 is conducted based on the available numbers of radar units that were installed in passenger cars and heavy vehicles in 2009. The forecasts are extracted from available data of already existing studies and possible evolution scenarios (with worst case, typical and best case assumptions).

The obtained results are subject to unpredictable influences. Especially regulatory aspects like mandatory use or technology-hypes like new environmental sensing methods can drastically change the numbers of radar units that will be put on the market.

One stabilizing factor that supports the radar proliferation is the robustness in detection performance and the very weak installation requirements (can be placed almost anywhere invisible behind the vehicle's outer surface). Because of already existing different radar frequency operation ranges, a 100% market penetration of one unique radar type (e.g. 24 GHz narrowband) is not expected. Market share saturation will happen when the used technology has reached its maximum application range capability, which depends on the total amount of available technical solutions for a given application and the respective take-rates.

The obtained results and forecast scenarios can be used in other MOSARIM tasks to consider sensor density probabilities in the future.

General Caveat:

Please consider the following cautionary statement:

All investigations, forecasts and estimations in this report are carefully prepared and conducted. No liability regarding the presented numbers and figures can be granted. This report contains forward-looking statements that are based on current expectations, estimates and projections about global business and industry and reflects certain assumptions based upon information available as of the date of this report. These forward-looking statements are not guarantees of future performance and are subject to certain risks and uncertainties which could cause actual results to differ materially from those projected. You should not place undue reliance on this report. There is no obligation to republish revised forecasts to reflect events or circumstances after the date hereof or to reflect the occurrence of unanticipated events.
Using the results of this study for any commercial or business purpose is strictly prohibited.

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[13] Addendum AEBS, Uniform Provisions concerning the Approval of Motor Vehicles with regard to the Advanced Emergency Braking System, Draft.

[14] 2005/50/EC Commission Decision of 17 January 2005 on the harmonisation of the 24 GHz range radio spectrum band for the time-limited use by automotive short-range radar equipment in the Community

[15] eSafety Forum - ELSA (European Large Scale bridging Action) in Transport, 2nd European Workshop, April 28th, 2010

7 Acronyms and Abbreviations

ABS	Antilock Brake System
anfac	Asociación Española de Fabricantes de automóviles y Camiones
AEBS	Automatic Emergency Braking System
BRIC	Brasilia, Russia, India and China
ELSA	European Large Scale bridging Action
ESC	Electronic Stability Control
EU27	The 27 European Member States
IEA	International Energy Agency
ITU	International Telecommunication Union
LRR	Long Range Radar
N.B.	Narrow Band
OEM	Original Equipment Manufacturer
OICA	Organisation Internationale des Constructeurs d'Automobiles
RF	Radio Frequency
RoCC	Radar on Chip for Cars
SRR	Short Range Radar
UNECE	United Nations Economic Commission for Europe
UWB	Ultra Wide-Band