Grant Agreement number 244335

ARTIC

Antenna Research and Technology for the Intelligent Car

Funding Scheme: Coordination Action

Deliverable D1.1
Smart car antenna needs review

Due date of deliverable: 30 September 2008
Actual submission date: 15 May 2009
Revision 2: 1 February 2010

Start date of project: 1/4/2008 Duration: 30 months

Organisation name of lead contractor for this deliverable: RUAG Aerospace AB

Revision 2

Project co-funded by the European Commission within the Seventh Framework Programme		
Dissemination Level		
PU	Public	
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

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Document Number: ARTIC-D1-1

Workpackage: 1

Estimated Person Months:

Dissemination level (PU,PP,RE,CO):

Nature (R, P, D, O):

Version: 2

Total Number of Pages: 44

File name:

Editors:

Participants:

Abstract

This document gives the deliverable D1.1 giving the needs for car antennas.

It covers all communication and sensor needs. Special effort is given to car radars, to small antennas including MIMO, to wideband antennas including satellite communication and to cooperative vehicular systems.

Detailed requirements can not be given due to the fast evolvements in this area, but system concepts and requirements, frequency ranges and , types and localization of antennas are discussed.

Keyword List

Document Evolution

Revision	Date	Reason of change
Rev. 1.0 Draft A		Draft Edition
Rev. 1.0	2009-05-15	First Edition
Rev 2	2010-02-01	Update due to EC comments

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1. Introduction

This report is the deliverable D1.1, assembling the requirements on the different antenna types used for the automotive industry. The requirements are not fixed, since this whole area is rapidly developing. It is, however, very important to look at the antenna requirements early, since the antenna performance is vital in the choice of system configurations.

Much of the information concerns the standards, like allowed frequency bands, and system concepts.

Chapter 2 gives an overview of the antenna needs and important consideration to be taken into account.

Chapter 3 is mainly concerned with sensors, the most important rf sensors being the car radars.

Chapter 4 deals with small antennas for communications including MIMO technique.

Chapter 5 gives a broad view for wideband requirements, including sensors and satellite communication.

Chapter 6 concentrates on cooperative systems and their requirements.

The picture is quite complex, as can be expected in an emerging area. It is very important to agree on system concepts and standards. The automotive industry will need to secure the required frequencies, so far they have been weak compared to the mobile phone operators. On the other hand, these two industry groups should work closely together to solve the future car communication needs.

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2. Overview

2.1 Services to be provided

The design and placement of vehicle integrated antennas is becoming more and more difficult with the number of increasing services. As most of these services require multiple antennas for diversity or MIMO, the number of antennas for each service has to be multiplied by 2 to 4. Services that have to be taken into account are shown in Figure 2-1 below.

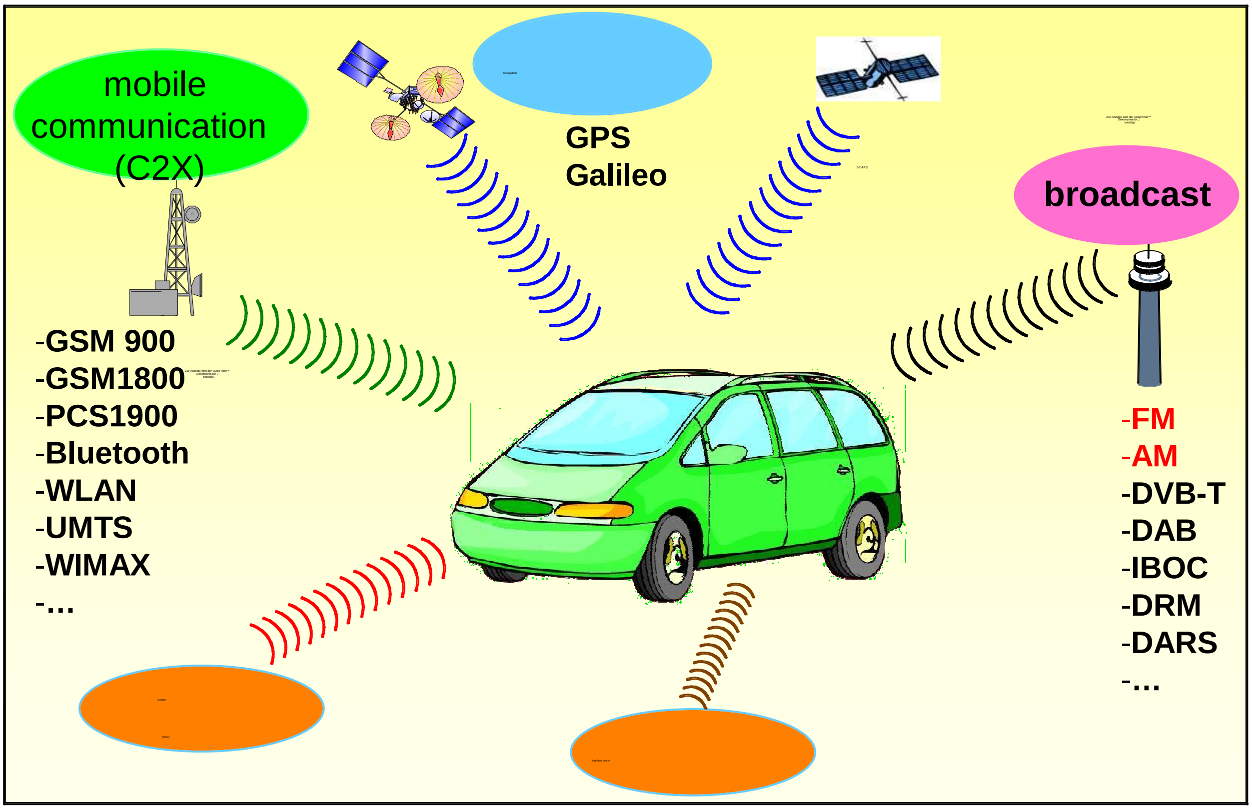

Figure 2-1 Services for automotive broadcast and communications

The frequencies for the above services are spread from several MHz to 6 GHz. This is shown in the next Figure The services are separated for Data Services, Communications and Broadcast. For Broadcast services still analogue and digital have to be distinguished. It is easily understood that the number of services can vary between 10 and 20. If MIMO or diversity have to be applied the number of antennas my range from 20 to 60. It obvious that this has to be handled extremely efficient, otherwise cost, car design and quality will suffer.

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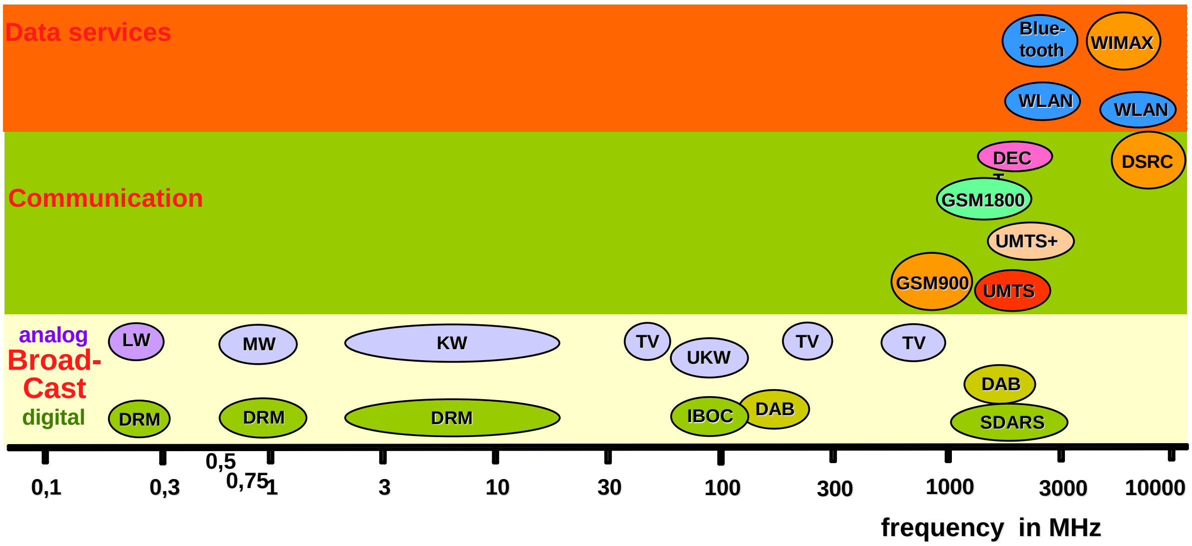

Figure 2-2 Frequency domain distribution of automotive services for Data, Communications and Broadcast

Internationally the specific frequencies for the different above listed services may vary in addition. This causes a sever stress for the design and placement of automotive antennas. Especially the upcoming C2X services require a specific attention, as they include Advanced Driver Assistance Systems (ADAS). Their specific applications are shown in the following Figure

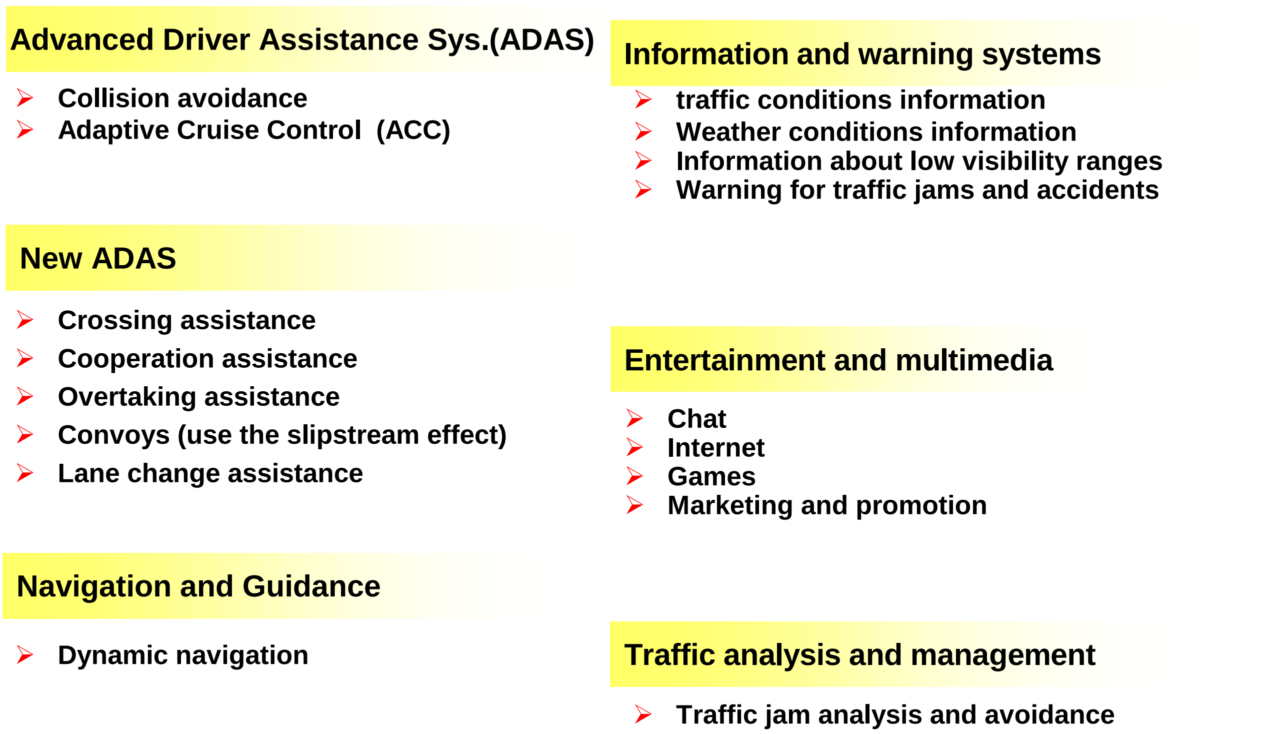

Figure 2-3 C2X communications applications

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2.2 Considerations for the Design of Automotive Antennas

For the design of automotive antennas a number of criteria have to be considered. The most relevant are listed below.

- service to be covered
- frequency range
- antenna characteristic (coverage azimuth and elevation)
- antenna gain
- antenna efficiency
- type of antenna
- Diversity required
- MIMO required
- correlation of multiple antennas
- material to be used
- broadband combination with other services
- placement on vehicle
- car design aspects (most influential, visibility, size, colour, radome …)
- cost (R&D, production, integration, service …)
- sensitivity to environments influence (temperature water, snow, dust ..)
- Tx/Rx frontend integration
- RF/IF cabling
- power supply

Table 2-1 List of antenna design considerations

In the following several, relevant criteria and considerations are discussed in more detail.

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2.2.1 Favourite placement of antennas on vehicles

The different services and frequency ranges have been discussed already above. Next a qualification of the different possibilities for placement of antennas is made. For this a typical car is used and the places are according to their suitability coloured from 1 (best) to 6 (worst). For some special services this classification does not apply, f.e. parking aid, or automotive Radar.

The selection criteria for antenna placement are more detailed below:

Single antennas:

- sufficient antenna hight
- hemispherical coverage
- ground plane/balun
- no vehicle interfering signals
- polarisation purity (SDARS)

Multiple antenna systems:

- decoupling
- pattern diversity
- polarisation diversity
- spatial diversity

Multi-band antennas:

- decoupling of the bands

Table 2-2 Selection criteria for antenna placement

Taking all the above into account the following placement hierarchy results:

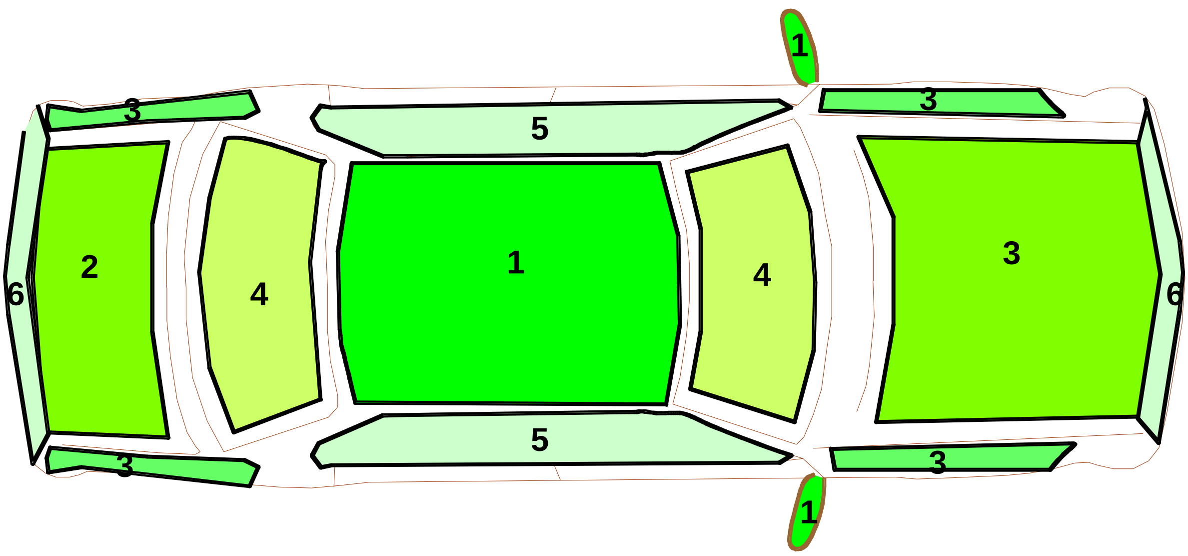

Figure 2-4 Placement hierarchy for automotive antennas

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For cabrio type vehicles this placement has to replace by the one shown in the following Figure

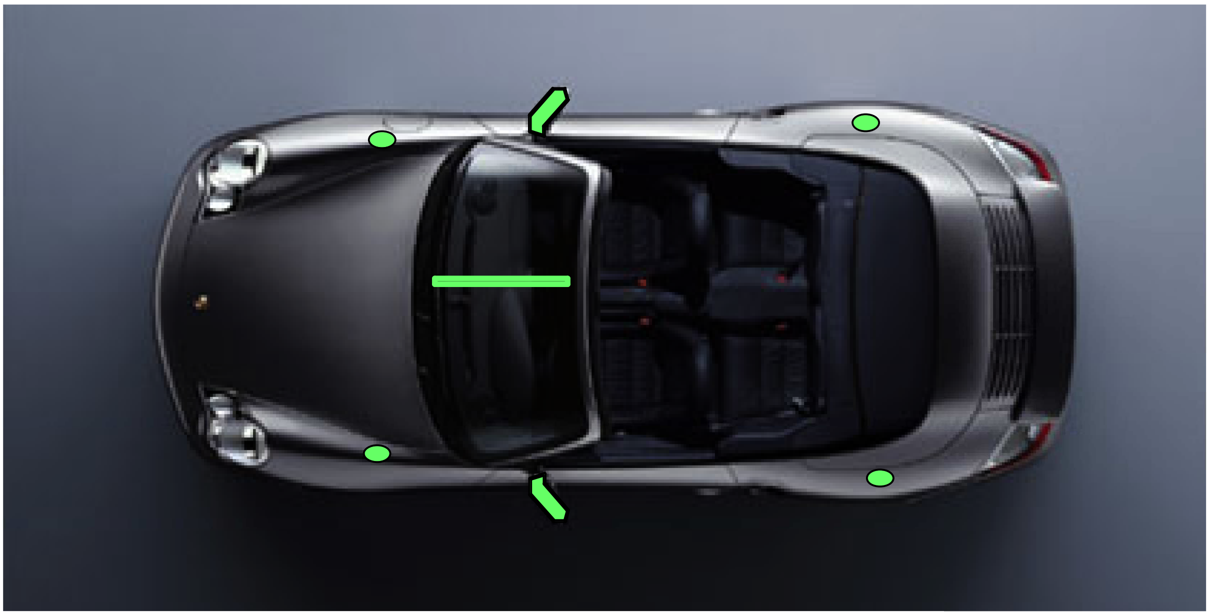

Figure 2-5 Antenna placement possibilities for cabrios

It can easily be understood, that cabrios cause some severe problems for the antenna integration. Just the opposite is true for SUVs. These vehicles have usually a rooftop spoiler which is well suited for antenna integration, see next Figure

Figure 2-6 Antenna integration in SUVs

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2.2.2 Possibilities for Antenna Module Integration

For this discussion two typical areas are considered, the rooftop antenna and car internal communications.

Service \ Antenna Integration	Roof-top Antenna (e.g. ECE R 26) in MHz	Internal Communication
GPS/Galileo	1575/1176-1590	
Mob.-Phone	810-910; 1710-2170;	
SDARS	2320-2345	
DSRC[1,2]	5875-5925	
Long-Range Services (Heating, Car Check)		
RKE		
PASE		
TPMS		
WLAN	2400-2485; 5150-5850	
DAB	225, 1450	
Bluetooth		
WIMAX	2495-2690	

Table 2-3 Services and frequency bands for integration in one antenna on rooftop (coloured brown) and internal communications (coloured blue)

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2.2.3 Automotive Antennas for Satellite Services

Satellite services require normally only one antenna, best rooftop, as the signal are received from the upper hemisphere. The problems that arise for the design of antennas for satellite reception are:

- design
- size
- characteristics

While the design aspects are to be discussed with the car designer, the antenna characteristics are for some services required for the Quality of Service. Typical requirement are shown below.

Crit. / Service	Center Frequency	bandwidth($\|S_{11}\|$< -10 dB & Zenith AR<3dB)	Polarisation	Antenna-gain	Regulation
GPS	1575,4 MHz	2 MHz	RHCP	>2 dBi	none
Galileo					???
SDARS	2332 MHz	25 MHz	LHCP	>2 dBi	yes

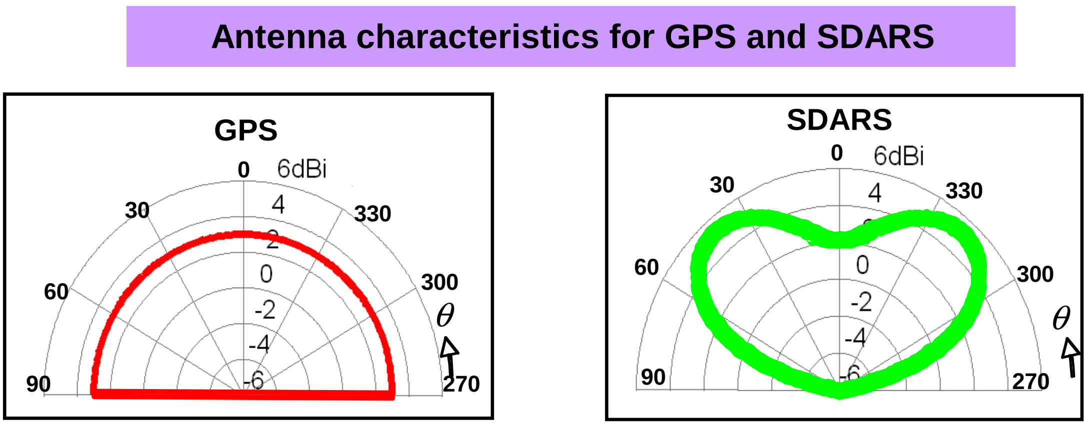

Figure 2-7 Considerations for antennas for satellite services

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3. Expert Group 1: Millimetre wave antennas

3.1 Regulatory aspects for millimetre wave automotive radar sensors in Europe

EU authorities have launched a program to reduce fatal road accidents by 50% by 2010, with focus on driver assistance and on-board safety systems for accident reduction, including automotive radar. For this purpose, the European Telecommunication Standard Institute ETSI has identified the 79 GHz range as the most suitable band for long term and permanent development of automotive radars [1] (EN 301 091). However, the current technology is not mature enough to implement cost-efficient radar front-ends in the millimetre wave range. Therefore, the European Commission has approved the temporary allocation of the 24 GHz band in January 2005, to allow for the faster implementation and usage of automotive radar [2]. However, this band is interfering with other applications and it is seen only as a transitional solution until 2013, when the technology for 79 GHz is thought to be mature enough for cost-efficient implementation of radar sensors in cars [3]. The market penetration of the 24 GHz radars should not exceed 7%.

The temporary use of 24-GHz with a transition to 79-GHz is called "packaged solution" (Figure 3-1) to make an early contribution to the enhancement of road safety possible and to give the time for the development of the 79-GHz technology.

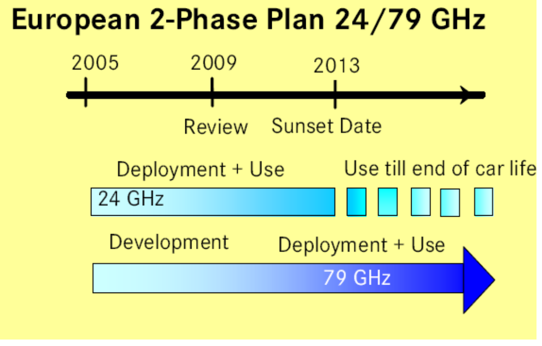

Figure 3-1. "Package solution" for automotive short range radar in Europe

On the 17th of January 2005, the EC approved the decision to allocate the 24 GHz frequency band for automotive short-range radar (*e*-Safety initiative). According to this decision:

- The frequency band of 21.625-26.625 GHz is allocated for the temporary use of UWB automotive short range radar (SRR) from 1 July 2005 until 30. June 2013. In parallel, research and development programmes must be conducted with the objective to introduce equipments operating in the 79-GHz band.

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- From mid of 2013, new cars have to be equipped with SRR sensors which operate in the frequency range between 77-81 GHz (79-GHz band). The 79-GHz frequency band was designated for the use of automotive short range radars in the ECC decision (ECC/DEC/(04)03) from 19 March 2004. The main regulations are the following:
  - 79 GHz frequency range (77-81 GHz) is designated for SRR equipments on a non-interference and non-protected basis with a maximum mean power density of -3 dBm/MHz e.i.r.p. associated with a peak limit of 55 dBm e.i.r.p.,
  - the maximum mean power density outside a vehicle resulting from the operation of one SRR equipment shall not exceed -9 dBm/MHz e.i.r.p.,
  - the 79 GHz frequency range (77-81 GHz) should be made available as soon as possible and not later than January 2005.

3.2 24 GHz automotive radars: needs

SRR automotive radars operating at 24 GHz require an operating range of up to 30 meters and are used for a number of applications to enhance the active and passive safety for all kind of road users (Figure 3-2):

- Passive safety:
  - ACC support,
  - Obstacle avoidance,
  - Collision warning,
  - Lane change assistant,
  - Lane departure warning,
  - Blind spot detection and monitoring,
  - Parking aid (forward and reverse),
  - Airbag arming.

- Active safety:
  - Stop and follow,
  - Stop and go,
  - Autonomous braking,
  - Firing of restraint systems and pedestrian protection.

In addition, combination of long range radars (LRR) and SRR will provide valuable data for advanced driver assistance systems (ADAS) (Figure 3-3).

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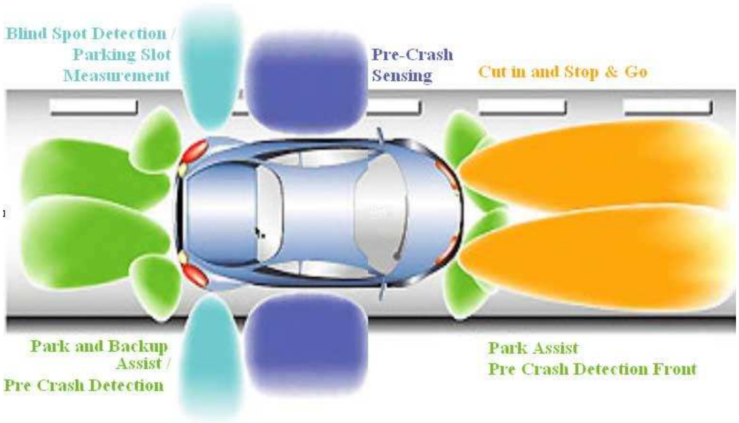

Figure 3-2. SR radars – Needs.

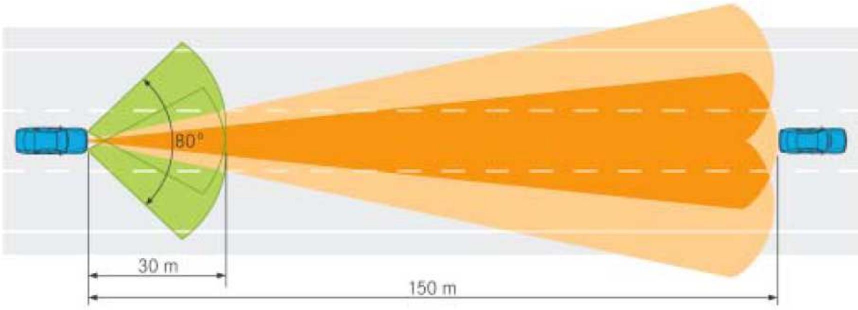

Figure 3-3. Combination of LRR and SRR for advanced safety features.

The 24 GHz SRR is a combination of two functions:

- A high resolution distance measurement to provide speed information of an approaching object using Doppler radar. This necessitates a narrow band +20 dBm peak signal with a mean power level of 0 dBm. All wanted emissions associated with the necessary bandwidth are inside the SRD (short range device) band (24.05 to 24.25 GHz), as stated in CEPT Recommendation 70-03.
- A wide band radar to provide information of the position of objects with a high resolution of approximately 10-15 cm and requires an average spectral power density of -41.3 dBm/MHz or -103.3 dBm/Hz, spread approximately ± 2.5 GHz centred on the SRD band at 24 GHz. Emissions outside of this mask are at least a further 20 dB down i.e. -50 or -110 dBm respectively.

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3.3 77/79 GHz automotive radars: needs

3.3.1 Cost analysis of the current solutions available on the market

The first 79 GHz adaptive cruise control (ACC) radars were introduced in 1999 to Mercedes-Benz premium cars of S-class [8] as a *comfort* function that decrease the vehicle speed if a car ahead is becoming too close, keep the preset safe distance and restore the preset speed in case of overtaking. Today the same function is available in BMW 3-series for **€850** [9].

The first combination of 77 GHz LR radar and 24 GHz SR radar was introduced in 2005 again by Mercedes-Benz in S-class providing better monitoring of the traffic situation: the LR radar scans a distance up to 150 m with an angle of 9° (more than three lanes) and SR radar observes immediate surroundings up to 30 m with an angle of 80° [10]. In emergency situation the Pre-Safe© system, gathering information from the radars, adjusts seat to a safer positions, tightens seat belts, closes windows to provide better support for the curtain air bags and makes the brake response faster. Today's price of this radar assisted cruise control system (sold under the label Distronic Plus) is **€3000** [11]. However, this technology is still not mature enough to be considered as a full collision mitigation system because even on a broadcasted performance demonstration this system did not prevented a double rear-end collision [12].

Another example of automotive radar available on the market is a combination of ACC and Blind Spot Info System, which detects vehicles in the blind spot zone, optional in Volvo S-80 for the price **€1900** [13]. TRWA has developed a 79 GHz ACC Doppler radar based on GaAs MMIC in 2002, which was introduced in Volvo and Man trucks. Its second generation system AC-20 is supplied also for Volkswagen Passat and Phaeton, and is sold as Automatic Distance Control option [14]. Besides standard ACC task the features of this multi-functional radar system are (according to car manufacturers' requirements): follow to stop, assisted stop and go, distance warning, collision warning and collision mitigation. The size of the radar is 98×98×63 mm^3, range 1 – 200 m, speed resolution 0.09 kph, and field of view 11° [15].

3.3.2 Limitations of the current generation of automotive radars and future needs

According to the previous sections, the main future needs for millimetre wave automotive radars are the following:

1. Enhancement of the performance of LR radars, and cost reduction,
2. Development of multi-function radars with LR and SR capabilities (examples: follow-to-stop, stop & go, operation in complex environments, etc.),
3. Development of tunable LR and SR radars with enlarged field of view (FoV),
4. Raw data interfaces and data fusion,
5. Cooperative sensors,
6. Reduced cost for mass market production.

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The transition from 24-GHz to 79-GHz causes an increase in frequency and a reduction of wavelength by the factor 3.3. The smaller wavelength λ enables one to reduce the antenna size and spacing ($\sim\lambda$) and lower effective antenna area ($\sim\lambda^2$). The higher frequency range also yields increased atmospheric and bumper losses. With higher frequencies semiconductor power output decreases, parasitic effects are more stringent, and packaging and testing are more difficult. The development plan towards the introduction of 79 -GHz SRR sensors is illustrated in Figure 3-5.

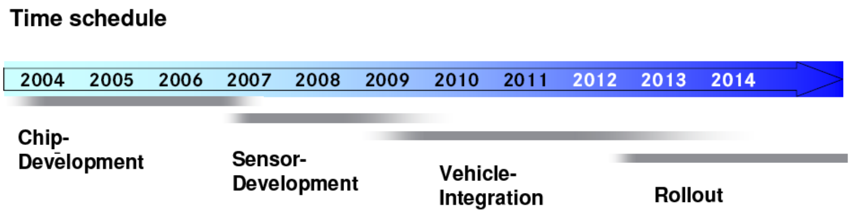

Figure 3-4. Time schedule for the development and rollout of 79 GHz SRR sensors.

The essential needs of future 79-GHz radar sensor systems are the following:

- Low chip and component costs,
- Low assembly costs,
- Improved performance,
- Reduced power consumption,
- Improved electrostatic discharge (ESD)/electromagnetic interference (EMI),
- High update rates.

The typical specifications for 79-GHz SRR systems are:

- Central frequency 79 GHz,
- Bandwidth 4000 MHz (the achievable range resolution is around 3.75cm),
- Maximum field of view +/- 80°,
- Range 30 m,
- Range Accuracy +/- 5 cm,
- Bearing accuracy +/- 5°,
- Typical antenna gain: 13 dBi.

Mechanically scanning antennas that can be used in millimetre wave automotive radars were realised in the mid-nineties [4][5] and are still used for their development [6]. Despite of relatively good performance, mechanically steerable systems are very bulky and expensive; they also might suffer from lack of reliability in moving and jolting vehicles. In addition, this approach alone is not compatible with the design of multi-function and tuneable radars. Due to the high speeds in traffic situations, complete azimuth beam sweep should be performed in milliseconds, which is impossible for *low-cost* mechanical scanning antennas.

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This explains why compact *electronic beam steering devices are necessary* to achieve these goals. Electronic beam steering implemented, e.g. in phase array antennas, has been used successfully for years in military and space application. But these systems remain prohibitively expensive for automotive applications. In order to be commercially attractive for automotive industry, **high performance multi-functional radar should cost under €200** [7].

3.4 References in chapter 3

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[12] http://www.leftlanenews.com/mercedes-tv-demo-turns-into-3-car-pile-up.html

[13] http://www.vbs.volvocars.co.uk/nbs20/24_default.asp?model=S80n

[14] http://www.volkswagen.co.uk/new_cars/phaeton/options

[15] http://www.adaptive-cruise-control.com/medias/5/1172588419.pdf

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3.5 Conclusions

Current SRR sensors operate at 24 GHz. This gives the opportunity to develop vehicle applications for object detection in the vicinity of a car, making a new generation of automotive safety systems possible.

Future safety and comfort applications for vehicles will benefit from higher sensor performance at smaller size. Pushed by significant progress in Silicon based MMIC technologies and low cost packaging capabilities, the 79 GHz SRR sensors are in the process of becoming cost-competitive and affordable. Nevertheless, the SARA consortium (http://www.sara-group.org/official_information/specific_decisions_for_different_countries/eu.ivp) acknowledges that the 79 GHz frequency range is seen as the long-term solution for SRR.

The European frequency regulation currently requires SRR to migrate from 24 GHz to 79 GHz spectrum in the year 2013. The system integration and validation of 79 GHz technology may not be available in time for a seamless transition. A phase of car integration and extensive car tests will require additional several years in order to ensure that all safety aspects are correctly implemented. The technology to be used in a car line must be fixed around 5 years before start of production. This implies that the 79 GHz sensors must have been mature in 2008, which is not the case. The car manufacturers need sufficient time for vehicle integration including development of bumper materials and paintings as well as extensive tests for safety applications. The net result is that independent of the availability of these radar technologies at 79 GHz today it is still recognized that there is a possibility that there may be a gap in the availability of SRR in new cars being placed on the European market after the 24GHz band is no longer available for use in 2013.

It is also important for the 79 GHz SRR market growth that availability of a worldwide harmonised frequency allocation is possible. Europe should encourage other markets such as North America and Japan to adopt the same band as the European allocation. In this case Economies of scale would bring costs down, which in turn should expand opportunities for 79 GHz SRR becoming an affordable technology as a mid- and long term solution worldwide with the broad benefits for road safety in Europe that this will bring.

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4. Expert group 2: Small antennas

4.1 Fields of application

The use of small antennas has also to be considered when implementing automotive systems. They are used both in human-machine interfaces, as well as in a number of other applications, such as listed bellow, and displayed in **Errore. L'origine riferimento non è stata trovata.**.

1. Multistandard Gateway
2. Transceiver-System+Antenna
3. Sensors and Bus Systems
4. C2C communication (IEEE 802.11p)
5. C2I communication (IEEE 802.11a/b/g)
6. C2I satellite communication (DVB-S) and navigation (GPS, GALILEO)
7. C2I short range connectivity (ISM Applications, Bluetooth, Zigbee)
8. C2I mobile communication (GSM/UMTS/HSxPA/LTE, WiMAX), Broadcast (UKW/TMC/TMCpro, DVB-T/DVB-H)

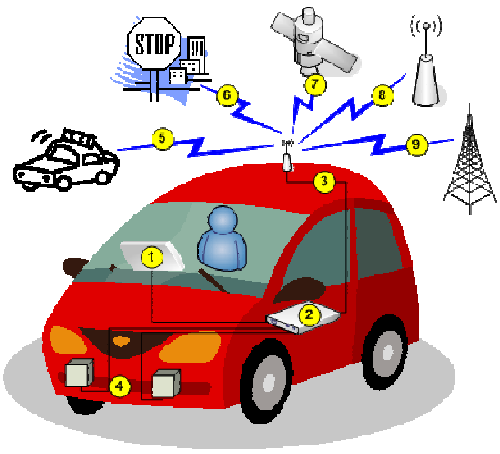

Figure 4-1: Human Machine Interface and Applications

A graphical representation of the future of the interaction of a smart car with its surroundings is shown in Figure 4-. To implement this scenario, multiple communications devices and standards have to be implemented in the vehicle.

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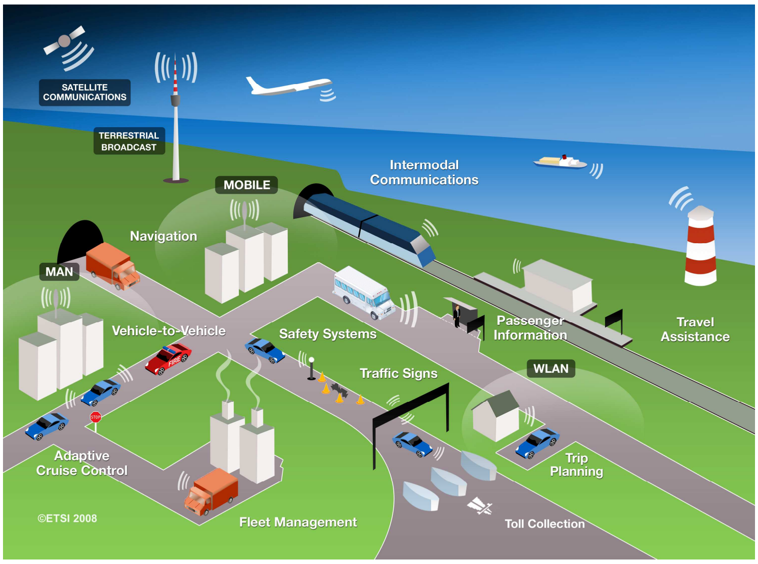

Figure 4-2: Future automotive scenarios (source: ETSI)

The main fields of application that require the design of small automotive antennas include:

- Broadcast
    - Long-medium wave/FM radio
    - DAB terrestrial-satellite
    - Satellite TV
- Navigation
    - GPS/Galileo
- Communications
    - Cellular (GSM/DCS/PCS/UMTS, etc.)
    - TETRA (public access mobile radio)
    - Future mm-wave systems (V2V, V2I)
- Transponders
    - Tolling for road charging
    - Asset tracking
- Other
    - Windscreen rain sensors
    - Keyless entry
    - Wireless burglar alarms
    - Tire pressure monitoring
    - Etc.

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Moreover, the ITS (intelligent transport system), which is to be under way by the EC funded specific support action COMeSafety, gives new requests for small antennas. The main applications are:

- Active Road Safety
  - Driving Assistance - Co-operative Awareness
  - Driving Assistance – Road Hazard Warning
- Co-operative Traffic Efficiency
  - Traffic management based on DNM/CAM (two different types of messages)
  - Speed management
  - Co-operative navigation
- Co-operative Local Services
  - Location based services , e.g. POIs
- Global Internet Services for Communities
  - Fleet & freight management
  - Insurance & financial services
  - ITS station life cycle management

The antenna requirements for each of these categories will be summarised in §1.4.

4.2 Networks types

When designing « small » antennas for a smart car, different network configurations have to be considered. These are listed in Table 4-.

Table 4-1: Types of networks considered for different applications.

Network areas	Telecomm.	Health	Transport	Environm.
BAN	X	X		
PAN	X	X		
LAN	X		X	X
WAN	X	X	X	X
Satellite	X		X	X
Sensors	X	X	X	X

Each network type has its specific characteristics, not only in terms of coverage and data rate, but also regarding its applications and the necessity of applying for a license or using the services of a network provider. Table 4-2, for example, displays a comparison between the characteristics of three of the standards that can be used in automotive applications.

Table 4-2: Comparison between three different communications standards.

Parameter	**3G (UMTS)**	**IEEE 802.11 (WLAN)**	**IEEE 02.16-2004(WiMAX)**
Frequency band	1.92-2.17 GHz	2.4-2.483 GHz 5.15-5.35 GHz (Indoor) 5.47-5.725 GHz (Outdoor)	No worldwide. WiMAX Forum: 3 profiles in the licensed band (2.3 GHz, 2.5 GHz,

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			3.5 GHz) unlicensed band: 5.x GHz
Coverage	500-900 m (cell-radius)	10-300 m	7-10 km (NLOS)
Data rate	Up to 384 kb/s 7.2 Mb/s (HSxPA) Download up to 100 Mb/s, Upload up to 50 Mb/s (LTE)	Up to 54 kb/s 108 Mb/s (IEEE 802.11n)	Up to 75 Mb/s (20 MHz bandwidth)
Mobility	Mobile (Roaming, vehicle speed)	Limited portability	Limited portability/Mobile options
License	Licensed	Unlicensed	Licensed

To choose the standards that are best fitted for a certain application, data rates and coverage should be considered. Figure 4-3 shows graphically the relationship between both parameters for different standards that can be used in automotive applications.

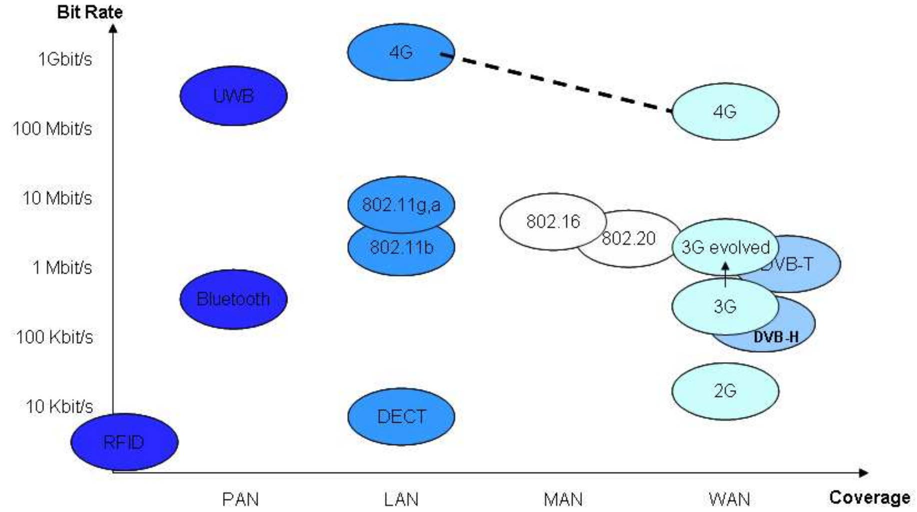

Figure 4-3: Different wireless and cellular communications standards

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4.3 Frequency bands and characteristics

Table 4-1lists the frequency bands assigned to some of the main wireless and cellular standards worldwide. In some cases, these standards may overlap. Yet, in the case of automotive antennas differs from those of mobile handsets: cars are typically designed for specific markets, so that the equipment may differ from one geographical region to the other. This in turn means that different antennas may be needed.

Table 4-3: Frequency bands of different wireless and cellular standards

<table>
<tr><th colspan="2">Standard</th><th>TX</th><th>RX</th></tr>
<tr><td colspan="2">AMPS/D-AMPS</td><td>824-849</td><td>869-894</td></tr>
<tr><td colspan="2">GT 800</td><td>806-821</td><td>851-866</td></tr>
<tr><td colspan="2">GSM 400</td><td>450.4-457.6</td><td>460.4-467.6</td></tr>
<tr><td colspan="2">GSM 850</td><td>824-849</td><td>488.8-496</td></tr>
<tr><td colspan="2">E-GSM (GSM 900)</td><td>880-915</td><td>925-960</td></tr>
<tr><td colspan="2">DCS (GSM 1800)</td><td>1710-1785</td><td>1805-1880</td></tr>
<tr><td colspan="2">PCS (GSM 1900)</td><td>1850-1910</td><td>1930-1990</td></tr>
<tr><td colspan="2">UMTS FDD</td><td>1920-1980</td><td>2110-2170</td></tr>
<tr><td colspan="2">UMTS TDD</td><td>1900-1920</td><td>2010-2025</td></tr>
<tr><td colspan="2">Bluetooth</td><td colspan="2">2400-2483.5</td></tr>
<tr><td colspan="2">WLAN</td><td colspan="2">2400-2500</td></tr>
<tr><td colspan="2">GPS</td><td></td><td>1575.42</td></tr>
<tr><td colspan="2">HIPERLAN/1 - /2</td><td colspan="2">5150-5350 (Indoor)
5470-5725 (Outdoor)</td></tr>
<tr><td rowspan="2">Wi-Fi</td><td>IEEE 8002.11a/h</td><td colspan="2">5150-5250 (Indoor)
5250-5350 (Outdoor)
5725-5825 (CSMA/CA)</td></tr>
<tr><td>IEEE 8002.11b/g</td><td colspan="2">2400-2483.5</td></tr>
<tr><td colspan="2">IEEE 8002.11.n (ITS)</td><td colspan="2">5875 – 5905</td></tr>
</table>

In addition to those standards, short distance links can be implemented using the ISM frequencies listed in Table 4-2

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Table 4-4: ISM bands available for short links

Lower limit	Upper limit	Comments
6.765 MHz	6.795 MHz	
13.553 MHz	13.567 MHz	
26.957 MHz	27.283 MHz	
40.66 MHz	40.70 MHz	
433.05 MHz	434.79 MHz	only Region 1 (Europa, Africa etc.)
868 MHz	870 MHz	only Region 1 (Europa, Africa etc.)
902 MHz	928 MHz	only Region 2 (North and South America)
2.400 GHz	2.500 GHz	
5.725 GHz	5.875 GHz	
24 GHz	24.25 GHz	
61 GHz	61.5 GHz	
122 GHz	123 GHz	
244 GHz	246 GHz	

4.4 Antenna requirements

The main antenna requirements for different scenarios will be analysed in this section.

4.4.1 Communications

Communications possibilities in the automotive environment include the use of both licensed and unlicensed bands, as well as cellular and wireless solutions. Table 4-5 shows the characteristics of some of the mains standards that are included in this category.

Table 4-5: Characteristics of different communications standards

Name	Range	Data rate
DECT (macht das Sinn)	50 m (indoor)	2 Mb/s
UMTS	10 km	384 kb/s 2 Mb/s 3.6 kb/s 7.2 Mb/s (HSxPA) 100 Mb/s, (LTE, download) 50 Mb/s (LTE, upload)
GSM	Up to 35 km	9.6 kb/s
GPRS	Up to 35 km	170 kb/s
IEEE 802.16 (WiMAX)	10 km	1-100 Mb/s

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Antennas for cellular applications should display at least an omnidirectional antenna, as in Figure 4-4. This is however difficult to obtain, due to the size of the groundplane, and the presence of metallic elements in its surroundings, so that a number of sidelobes are prone to appear. Normally, the radiation pattern of a monopole is taken as a reference.

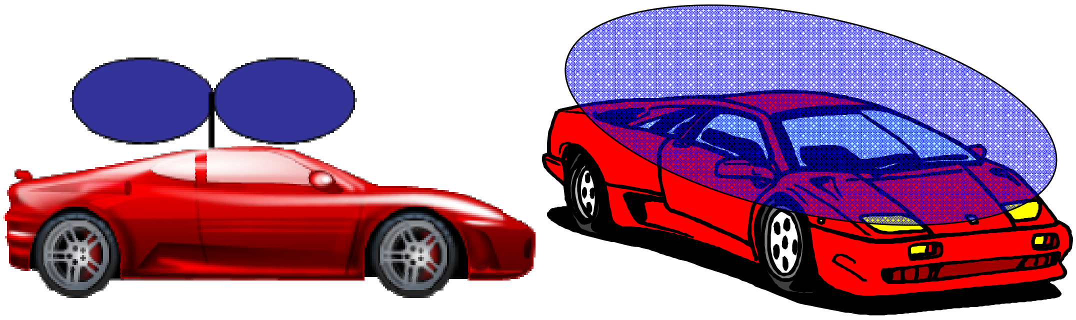

Figure 4-4: Desired radiation pattern of a car-roof antenna.

In order for the user to be able to use different communications standards, multiband antennas or wideband as well as multi-antenna systems are needed. An example of such is presented in Figure 4-5. One of the challenges is the requirement for antennas to be the smallest size possible, so that they can be integrated in the car without effect on its aerodynamics and its aesthetical design.

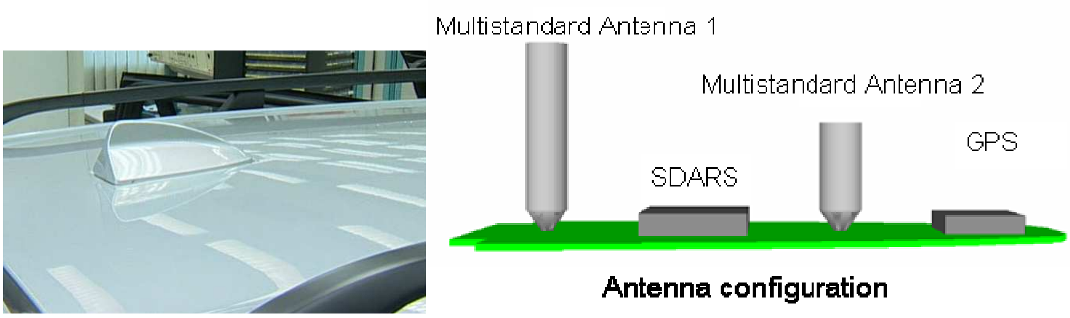

Figure 4-5: Multistandard roof-top antenna

For the antennas used for mobile vehicular applications, important specifications also include:

- Efficiency. High efficiency translates into better signal reception, which reduces the number of dropped connections and improves the system's ability to support fast data transfer rates. Yet, sometimes a compromise has to be accepted, and depending on the application efficiency can be sacrificed to improve other system characteristics.
- Return loss: There is a great deal of variation in the return loss of antennas, so that a threshold value cannot be clearly defined. Many antennas have a return loss of 6 dB when operating under normal conditions.
- Selectivity and isolation: These aspects are particularly important if the system is equipped with multiple antennas.

In the past, design activity seemed to be concentrated in single bands moving higher in frequency. Now, by contrast, there is a growing interest in occupying lower frequency bands, such as the one around 700 MHz considered for LTE. This in turn translates into the need for larger antennas that have to be integrated.

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By combining several antenna modules, intelligent systems with MIMO capabilities can be implemented. This is the case of the configuration presented in Figure 4-6.

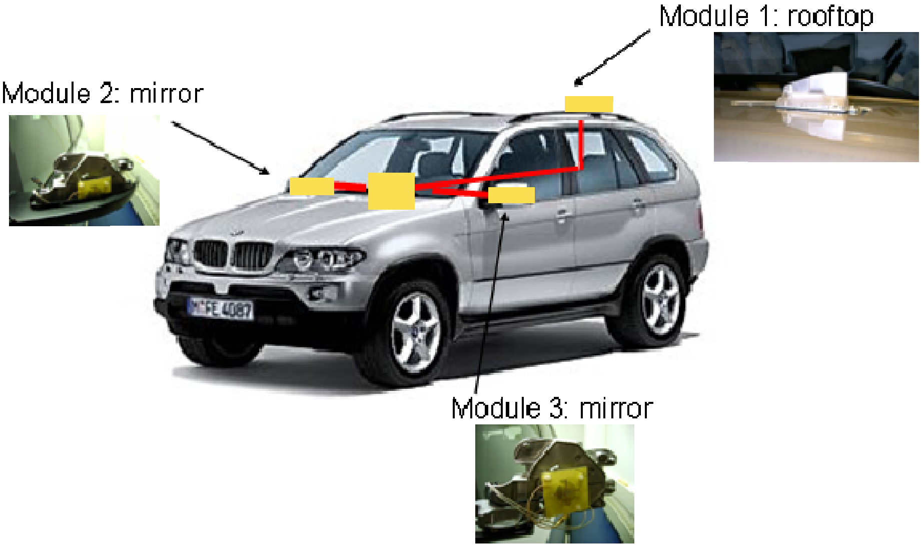

Figure 4-6: Combined intelligent system of several antenna modules

Many wireless data protocols require receive diversity or multiple-in multiple-out (MIMO) architectures. For example, the current LTE standard states that LTE should implement MIMO antennas and a number of advanced signal processing techniques to achieve the maximum data rate. The same MIMO strategies are envisaged for WiMAX applications. In these configurations, achieving high isolation and low mutual coupling between the antenna elements becomes particularly important.

- Communication systems that adapt to fading
- MIMO system (Multiple Input Multiple Output):
    - multiple ports on Tx & Rx
    - different channels: signals distributed in an optimum manner
- MIMO antennas and terminals: special testing instrumentation
- Quality of a MIMO system in a fading multipath environment: maximum available capacity in bits/sec/Hz
- Antennas for MIMO systems degrade the capacity due to:
    - low radiation efficiency
    - correlation between received signals

MIMO technologies can increase the data rate with respect to traditional Single Input, Single output systems (SISO) through the use of spatial diversity, which can be useful to overcome fading problems in multipath environments. A MIMO system uses multiple ports in both the transmitter and the receiver, so that the signal travels through different channels and is thus transmitted in an optimal manner, as shown in see Figure 4-7.

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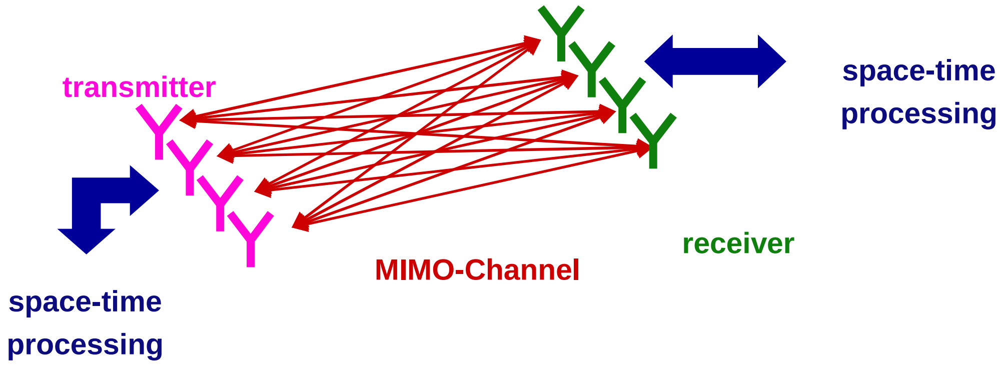

Figure 4-7: MIMO communications system

Typical antenna specifications for MIMO include:

- **Number of independent antennas:** a reasonable improvement of the achievable data rates can already be obtained with a 2x2 MIMO configuration, since it brings a reasonable data rate benefit.
- **Radiation Efficiency:** the efficiency should be as high as possible. It will greatly depend on the size of the antenna and the platform in which it is integrated. Multiple antennas operating within the same frequency band or in bands that are close to the band of interest will add the factor of mutual coupling, which can greatly diminish the efficiency.
- **Gain Balance Ratio:** some studies suggest that this should approach 1 (maximum achievable). That means that all antennas should have similar gain to maximise the benefits of MIMO. Yet this is not necessary in all configurations, and has to be approached on a case to case basis.
- **Correlation Coefficient:** the lower this parameter, the better MIMO performance can be achieved. Ideally, the correlation coefficient should be 0, which means that the different signals are completely uncorrelated.

Important developments in automotive applications take place in the domain of car-to-car (C2C, V2V) and car to infrastructure (C2I, V2R) communications (COMeSafty ITS).

The frequency band around 5.9 GHz has been allocated by CEPT/ECC for such applications, whereas the European Commission is expected to allocate the 5.875-5.905 band for safety related applications. Typical C2C applications include accident and congestion warning, blind spot warning, lane change assistance. C2I applications cover information on road works areas, speed limits or intersections (see Figure 4-8 and Figure 4-9).

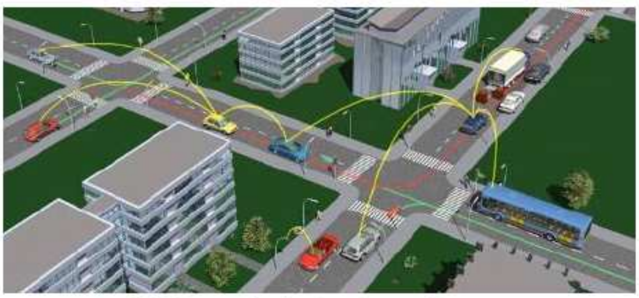

Figure 4-8: C2C communications in an urban environment (Source: Daimler)

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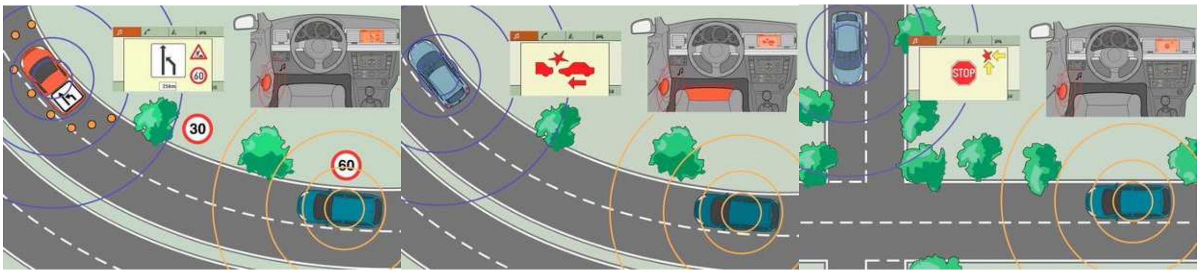

Figure 4-9: C2C and C2I communications in various traffic situations (Source: FOCUS Auto)

C2C and C2I technologies are based on the IEEE 802.11p standard, that is, WLAN technology. The choice is driven by the fact that this standard enables time critical safety applications while displaying very low data transmission delay. The communications are also independent from infrastructure, and make use of unlicensed frequencies.

The requirements for C2C communications include low system costs, reliable data transfer even at relatively high velocities and with multipath environments (Ad-Hoc networks, different traffic situations). To achieve this, MIMO systems may be necessary, although the standards only impose the use of diversity strategies. The challenges reside in adapting the characteristics of WLAN systems to realistic radio environments, with multipath propagation, moving targets and variable environments.

4.4.2 Broadcast

Receiving devices for radio broadcast systems have been present in cars for a long time. The technology of antennas for FM and AM reception now mature, with highly integrated solutions in addition to the classical rod antennas. Yet, in the last years , new standards such as Digital Video Braodcast (DVT), Digital Audio Broadcast (DAB) and Digital Radio Mondiale (DRM) have appeared, that impose new constrains to the antenna design. The characteristics of these three standards are presented in Table 4-6.

Table 4-6: Characteristic of various broadcast services

Name	Range	Data rate
DVB-T	40-60 km	30 Mb/s
DAB	60 km	1.5 Mb/s
DRM	>1000 km	72 kb/s

In the case of terrestrial applications, the desired pattern is still omnidirectional. Yet in the case of satellite-based services, the radiation pattern should be almost hemispherical, as shown in Figure 4-10. In that case, the complexity of the solutions will depend on system requirements. They can include small arrays with switched elements, mechanically steerable antennas, hybrid systems (mechanical steering in azimuth, electronic steering in elevation) or fully electronic steering.

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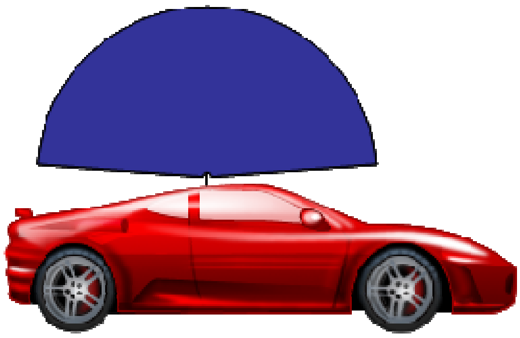

Figure 4-10: Roof-top antenna with almost hemispherical coverage

In the case of DRM, the challenge resides in integrating the antennas, as the very low frequency of the band (below 30 MHz), which allows for very-long-distance signal propagation, implies the use of large antenna elements.

4.4.3 Navigation

Navigation systems are also part of most middle to high end cars. Today, this means almost exclusively GPS receivers, but in the future different Global Navigation Satellite Systems may be implemented in a single vehicle. A list of GNSS systems and their characteristics is given in Table 4-7:

Table 4-7: GNSS characteristics

System	Owner	Carrier frequencies (GHz)	Coverage
GPS	USA	1.575 (L1) 1.2227 (L2) 1.176 (L5)	Global
GLONASS	Russia	1.6 1.2	Global
Galileo	Europe	1.176 (E5a) 1.207 (E5b) 1.278 (E6) 1.575 (E2-L1-E1)	Global
Beidou	China	1.4	Asia

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The requirements GNSS Antennas are:

- Simple structure, low cost
- Frequency coverage: may include more than a frequency band or more than one system. The options can be:
  - increased bandwidth
  - multiband operation
- Gain pattern
  - ideally, hemispherical
  - real antennas: gain roll-off of 10 to 20 dB from boresight to the horizon.
- Circular polarization to avoid fading from:
  - he changing relative orientation of the antennas as the satellites orbit the Earth
  - the effects of Faraday rotation caused by the ionosphere.
- Multipath suppression to avoid degradation of positioning accuracy
- Phase centre stability: for accuracy in positioning and timing
- Compatible with future requirements

4.4.4 Transponders

Transponders on board from vehicles use typically unlicensed frequency bands, as listed in Table 4-8. The devices are most often placed in the windshield, and the antennas have to display almost omnidirectional characteristics. Due to the characteristics of the transponders and the business model, the antennas have to keep low production costs.

Table 4-8: Characteristics of standards for on-board transponders

Name	Range	Data rate
IEEE 802.11a (WLAN)	300 m	54 Mb/s
DSRC @ 5.9GHz	Up to 1 km	54 Mb/s
IEEE 802.16 (WiMAX)	10 km	1-100 Mb/s

One of the tools will be the use of Dedicated Short-Range Communications (DSRC), which provide communications between the vehicle and the environment in specific locations. This will allow the implantation of systems such as Electronic Fee Collection (EFC) that should operate at a pan-European level (Figure 4-11).

Figure 4-11: EFC scenario

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DSRC are reserved for data-only systems, and include both the Road Side Units (RSUs) and the On Board Units (OBUs) with transceivers and transponders. They operate in the 5,725 MHz to 5,875 MHz Industrial, Scientific and Medical (ISM) band. The DSRC standards specify the frequencies of operation and the bandwidth of the systems that have to be respected in the design, and have thus an influence on the antenna performance. In Europe, some additional frequency bands can be defined at a national level. Nowadays, the existing DSRC systems existing in Europe are not fully compatible, so that further standardisation is required.

In the case of tolling systems, the European Commission has issued a Directive on Electronic Fee Collection (2004/52/EC) to introduce the European Electronic Toll Service (EETS). These systems could be used not only for road tolls, but also for other applications such as paying fees for tunnels, ferries or parking lots.

It will be mandatory that such systems be compatible with each other, based on open and public standards and use at least one of the following technologies:

- Satellite positioning
- Mobile communications (GSM and GPRS standards)
- 5.8 GHz microwave technologies (DSRC)

4.4.5 Other applications

The number of wireless applications that can be implemented on board of a car is almost infinite. In this section, a small sample of short range applications is given. They rely on the communications standards listed in Table 4-9.

Table 4-9: Possible standards for short range links.

Name	Range	Data rate
IEEE 802.11a (WLAN)	300 m	54 Mb/s
Bluetooth	100 m	1 Mb/s
IEEE 802.15.3c	0.1-10 m	1-10 Gb/s

4.4.5.1 Control systems and keyless entry

Automotive wireless systems are continued to develop. They include applications such as the ubiquitous remote keyless entry (RKE, Figure 4-12), to more sophisticated systems such as tire pressure monitoring Figure 4-13 or passive keyless entry (PKE). The challenge for antenna designers reside in integrating antennas that are at the same time small in size, cost-effective and highly efficient.

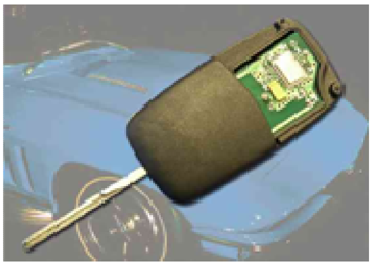

Figure 4-12: Remote, passive keyless entry (Source: IMST)

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Figure 4-13: Tire pressure monitoring system (Source: IMST)

These systems rely on RFID techniques, and make use of unlicensed ISM bands. The antennas for both sides of the communications link, namely the reader and the tag, have to be carefully designed. As low-frequency signals are used, in principle very large antennas for transmission and reception are required, which complicates their integration into the car and the mobile device.

In some cases, PKE systems use bi-directional links operating in two distinct frequency bands: 125 kHz for receiving data and UHF (315, 433, 868, or 915 MHz) for transmitting data. The communication range is typically reduced to less than 3m, due to the non-propagating nature of the 125 kHz signal. The problem is increased, as the position of the tag is completely random, and it can be in the close vicinity of other metallic objects. To increase the reliability of the system, three orthogonally placed antennas can be used in the lower frequency band, so that the transponder can pick up the base-station signal at any given direction. The working area of these antennas and their basic system design are shown in Figure 4-14.

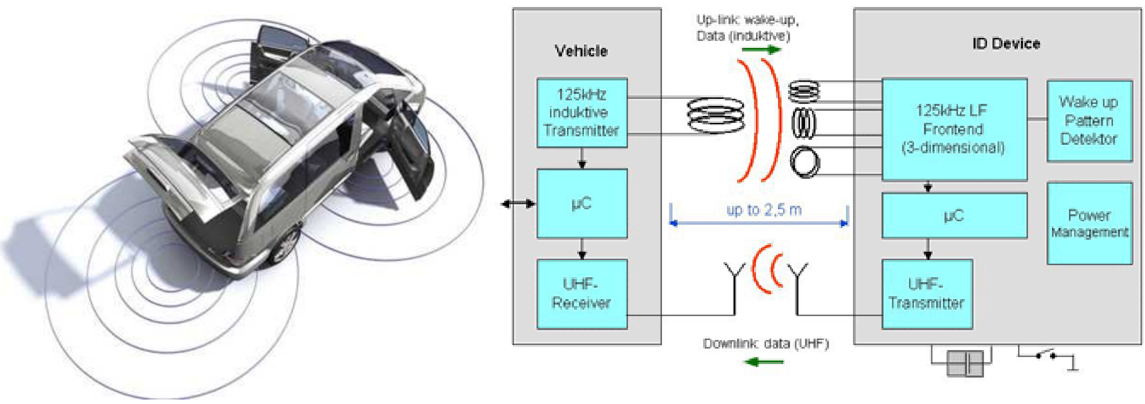

Figure 4-14: Antenna working areas and system design (Source : NXP Semiconductors)

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4.4.5.2 Bluetooth systems

Hands-free kits (HFK) and in-vehicle hands-free systems have been widely used in automotive environments for many years. Most Bluetooth devices require antennas that radiate in a spherical way, so they can connect in any direction. Yet designers have to consider variables such as available space, cost, and the effect of the surrounding components. Large signal path changes can be expected if the mobile device that is connected to the Bluetooth system is placed in the vicinity of metallic objects, or its orientation changes (for example, by a shift in the user's position).

4.4.5.3 60 GHz WLAN for on-board entertainment systems

Around 60 GHz there is a huge unlicensed ISM band, which could be used to implement high capacity WLAN systems for high-quality multimedia data streaming. The aim is to achieve data rates of up to 10 Gb/s. Although only short ranges can be covered, it would be possible to adapt such a system to the requirement of automotive on-board entertainment systems (Figure 4-15), thus eliminating cabling solutions and allowing for reduced weight, higher energy efficiency and less pollution.

These communications systems rely on the standard for mm-wave communications is being developed within Task Group IEEE 802.15.3c. Yet the high frequency poses a number of problems, linked to manufacturing tolerances and propagation issues.

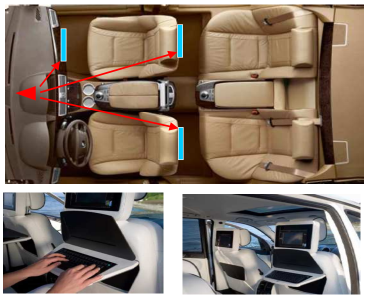

Figure 4-15: On-board WLAN scenario (Source: BMW)

In Table 4-10, an exemplary antenna requirement profile has been sketched, based on the experience gathered in the German funded project EASY-A.

Table 4-10: Example of requirements for60 GHz WLAN Antennas (source: EASY-A)

Parameter	**Single element**	***Array***
Gain	~4 dBi	*Tag: 4- 6 dBi* *Access point: 10-12 dBi*
Polarisation	Linear & Circular	*Linear & Circular*
Operating frequency & Bandwidth	58.320 GHz 60.480 GHz 62.640 GHz 64.800 GHz Operating bandwidth: 1.632 GHz	*58.320 GHz* *60.480 GHz* *62.640 GHz* *64.800 GHz* *Operating bandwidth: 1.632 GHz*
Matching	< -10 dB	*< -10 dB*
Element dimensions	$< \lambda/2$ (required for arrays, cancellation of grating lobes)	
Side lobe level		*Not relevant*
Scan range		*Fixed or ±45° from boresight*

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5. Expert group 3: Wideband antennas

5.1 General Remarks

As stated above in chapter 2 the number of services and the distribution of spectra increase increased significantly in the past and will further increase for example by V2V communications. Presently we have the service/frequency selective number of required antenna installation going up to 15 taking also the different spectra assignments in the different countries into account. As digital services require multiple antennas per service for MIMO and Diversity, the number of antennas could easily come up to 30-50. The reason is that digital services do below a certain S/N not just degrade, but loose the synchronisation completely. It is evident that there is no way to include 30 to 50 antennas on a car. The only solution is *Wideband Antennas*.

5.2 Wideband Antenna Needs up to 6GHz

5.2.1 Size and accommodation needs

When considering the placement of antennas in cars it becomes evident that “there is no place”, neither on limousines nor on cabrios. The best places of antennas are discussed earlier. Most of these places are because of car design criteria prohibited. This is again an argument for the integration of antennas in wideband antennas for multiple services. The size limitation accepted for wideband is presently ca. 10x6x3 cm^3 for roof mounting (fin-type) and approximately 1x5x5 cm^3 for semi-flat antennas with ground-plane for most other places for the integration, like mirrors, spoiler and so on. Only antennas in Windows may larger as they are µm flat. These antennas may have sizes up to 1 m in the rear and front window and up to 50 cm in the side widows. They require a definite ground-plane by other structures of the vehicle. These requirements are valid for any type of antenna, and to table it:

Table. 5-1 Size and accommodation needs for wideband automotive antennas

Wideband antenna type	**mounting places**	**size limitation**
fin-type	roof	10x6x3 cm^3
semi-flat with ground-plane	mirrors, spoiler and so on	1x5x5 cm^3
flat without groundplane	windows	Up to 1 m

5.2.2 Frequency coverage needs

The present frequency range for automotive antennas, excluding automotive radar is from 75 MHz to 6 GHz. This does not take into account some exotic frequencies for example for AM radio down at 0.15 MHz. The needs for antennas for the different services in the 75 MHz to 6 GHz frequency range can be roughly divided in:

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Table 5-2 Frequency needs for wideband automotive antennas

Service	frequency range
Broadcast Audio AM	0.153 MHz – 1.71 MHz
Broadcast Audio FM, DAB ..	76 MHz- 230 MHz
Broadcast Audio DAB	1452 MHz – 2345 MHz
TV terr.	47 MHz – 790 MHz
TV sat	2630 MHz – 2655 MHz
Navigation	1200 MHz- 1700 MHz
Communication (to BS)	790 MHz- 3600 MHz
Communication (V2V)	5700 MHz – 6000 MHz

Broadcast Audio AM does not require multiple antennas. In the following the same table like above is used for the evaluation of the needs for combining services in wideband antennas. Already here it ha to be taken into account that active (also transmitting) services have to be handled differently. In the reused table the bandwidth needs for wideband antenna possibilities are coloured.

Table 5-3 Wideband antenna coverage needs for wideband automotive antennas

Service	frequency range	Wideband ant. combining
Broadcast Audio AM	0.153 MHz – 1.71 MHz	
Broadcast Audio FM, DAB ..	76 MHz- 230 MHz	
Broadcast Audio DAB	1452 MHz – 2345 MHz	
TV terr.	47 MHz – 790 MHz	
TV sat	2630 MHz – 2655 MHz	
Navigation	1200 MHz- 1700 MHz	
Communication (to BS)	790 MHz- 3600 MHz	
Communication (V2V)	5700 MHz – 6000 MHz	

From the above table results that in an optimum case 8 wideband antennas need to be integrated into cars. For the following services multiple wideband antennas are needed for MIMO or Diversity:

Table 5-4 Needs for MIMO and Diversity formultiple wideband antennas for automotive applications

Service	frequency range	Wideband ant. combining
Broadcast Audio FM, DAB ..	76 MHz- 230 MHz	
Broadcast Audio DAB	1452 MHz – 2345 MHz	
TV terr.	47 MHz – 790 MHz	
Communication (to BS)	790 MHz- 3600 MHz	
Communication (V2V)	5700 MHz – 6000 MHz	

The other services not listed above do not need multiple wideband antennas.

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5.2.3 Coverage needs for wideband automotive antennas

For terrestrial application the coverage needs can be satisfied by an 360° azimuthal coverage and ±30° elevation coverage. For multiple antennas the different wideband antennas need to be uncorrelated. This de-correlation can be achieved as shown below

Table 5-5 Needs for decorrelation for multiple wideband antennas for automotive applications

Type of Diversity	Needs	remarks
Space	> lambda/2	corr.<0.4
Polarization	$\Delta\phi$>30°	for linear pol.
Coverage	AZ: 360°; EL: ±30°	in total

5.2.4 Needs for interference reduction

All passive systems are not so critical concerning the interference between different services as all systems meanwhile take care of this problem for example by extensive filtering or de-correlation. For the wideband antennas selected above, except for communication, filtering according to the intended frequencies is required in order to avoid out of band reception. This is especially critical for wideband antennas as they tend to gain and matching also at out of band frequencies. Typical examples are Ultra Wideband antennas, which may cover 1:10 bandwidth, which is only recommended for terrestrial TV. In addition it is recommended to integrate a wideband, low noise preamplifier with low intermodulation for the total covered band. This is because small wideband antennas suffer from lower gain, lower efficiency and worse matching compared to narrowband antennas.

5.3 Millimetre-wave Radar and Communications Antenna Needs

In this section we revisit the 77-81 GHz short range radar (SRR) and the 76-77 GHz long range radar (LRR) already addressed in Section **Errore. L'origine riferimento non è stata trovata.** adding the 63-64 GHz vehicle-to-vehicle (V2V) and vehicle-to-infrastructure or roadside (V2I) communication with the aim of combining these functions into fewer wideband antenna systems as proposed in the previous sections on the lower band antennas. We will not consider the 22-26.625 GHz temporary frequency designation for new SRR equipment as it will expire 1 July 2013 (and also is too far away from the other band**s).**

Table 5-1 summarises main characteristics for the two automotive antenna systems and the 63-64 GHz future communications system. Currently the only the 76-77 GHz LRR/ACC systems appear to be in an advanced level of development, but the deployment is mostly limited to high-end cars. It seems that 2nd generation systems in Europe often use dielectric lenses. An array is used to generate, e.g. four beams on receive and a single Tx beam within an angular range of about ±8° in azimuth (indicated by the narrow green ACC beam in Figure 5-1). A scanning beam is also possible, but then electronic scanning may be preferred to mechanical scanning to improve the reliability over the lifetime of the radar. Different EIRP requirement apply to fixed and to scanning beams. The ones listed in column 3 of Table 5-1 apply to fixed beams. The polarisation seems to be mostly linear (vertical), but it may be advantageous to use circular polarisation to reduce clutter in rain and tilted linear polarisation has been proposed to reduce interference between vehicles travelling in opposite directions. Newer LRR systems use digital beamforming on receive for the horizontal beamforming, possibly still combined with a lens or vertical subarrays with RF distribution for the beamforming in elevation. If lenses are used, it may be necessary to match the lens surfaces. In case of subarrays with RF distribution, a technology with low losses should be selected or developed. Integrated network technologies used at lower bands can have very high losses around 77 GHz 0. A challenge is to achieve a high angular resolution and accuracy – especially in multi-target scenarios **-** in the long range and

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adaptive antenna direction of arrival techniques are considered 0, 0. Initial ACC systems have adequate performance to provide comfort services as driver assistance. Future systems must have a higher reliability in order to provide safety services such as crash prevention or bicyclist and pedestrian protection. At same time the cost must be low – at least for mass-marked devices.

Table 5-1. Summary of 60-80 GHz system characteristics.

	77-81 GHz SRR	**76-77 GHz LRR**	**63-64 GHz V2V/V2I**
Comment	Measure (1) speed in CW Doppler mode, and (2) separation in WB mode	LRR systems which are not compatible with UWB SRR systems	Future high capacity DSRC, broadband access etc.
Typical gain	13-15 dBi	23 dBi	10-30 dBi
Range	Up to 30m	Up 150m	Up to 300m
Max average EIRP	-3 dBm/MHz	50 dBm (CW mode) 23.5 dBm (pulsed mode)	40 dBm proposed
Max peak EIRP	55 dBm	55 dBm	43 dBm proposed
Typical size [mm]		H=74,W=70, D=58	
Reference documents	CEPT ECC/(04)03 ETSI TR 102 263 ETSI EN 302 264	CEPT ECC/DEC(02)01 ETSI EN 301 091	CEPT ECC/DEC(02)01 ETSI TR 102 400

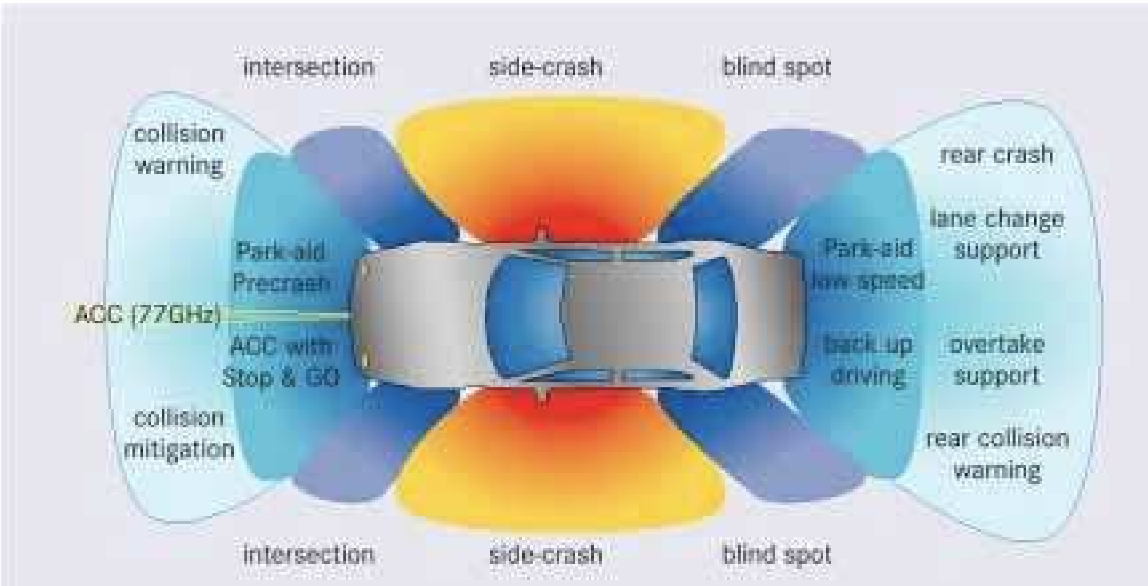

Figure 5-1. SRR and LRR functions relevant to road safety (ETSI TR 102 263).

The short range radar (SRR) has a CW Doppler mode capability to provide accurate speed measurement and a wideband capability to provide an accurate separation measurement (5-10 cm). The latter requires a bandwidth of about 4 GHz. Figure 5-1 shows the large number of services and beams that the SRR may provide in the vicinity of the car covering all azimuthal directions. It is anticipated that about 10 sensors may be required – either simple sensors just comprising one antenna element or larger sensors with some direction finding capability. Simple sensors without direction finding require that multiple sensors be used to localise targets. A range accuracy of 1.5cm is required to get a lateral accuracy of 20 cm with 1.5m sensor

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spacing. It is common practice to hide SRR sensors in electromagnetically transparent bumpers etc. typically coated by metallic paint. This is acceptable for current 24 GHz systems, but will have a big impact of future 79 GHz systems, e.g. 10 dB insertion loss and 5 dB noise figure degradation. However, some of this degradation may be recovered by reactive compensation as in the case of lens surfaces 0. This type of aperture cover is generally avoided for LRR systems. Compared to 24 GHz, the band 77-81 GHz offers several advantages 0:

1. one common technology platform for LRR and SRR easing combining of functions and integration
2. decreased dimensions and volume
3. increased Doppler sensitivity
4. higher angular resolution with moderate antenna aperture dimensions,

Less information is available for the 63-64 communication systems as most developments still go on the 5.9 GHz band.

5.4 Vehicular Satellite Terminals

It is expected that satellite vehicular terminals will continue to be used also as fill-in in areas where no other services are available, but probably the deployment of these systems will remain small. A line-of-sight to the satellite is required. Examples of existing vehicular terminals include:

1. Inmarsat BGAN terminal (L band) with tracking antenna.
2. Eutelsat EutelTRACs fleet management with various low-capacity services (35,000 terminals with tracking antenna, Ku band).
3. TVRO vehicular terminals (RVs and motor coaches) with tracking antenna (Ku band). A typical acquisition cost may be USD 1,000 and above. Several antenna systems have been developed, but do not appear to have been commercialised.

It is expected that also terminals compatible with Ka-band multimedia services will be developed.

Table 5-7 summarizes main characteristics for downlink (D/L) Ku-band Direct-to-Home (DTH) services and downlink and uplink (U/L) Ka-band interactive multimedia (Internet) services in Europe.

Table 5-7. Satellite DTH and multimedia applications in the Ku and Ka band.

Frequency bands	Applications
D/L: 10.7-11.7 & 12.5-12.75 GHz	Fixed Satellite Services (FSS) also used for Direct-to-Home (DTH) delivery in Europe. Polarisation is dual linear.
D/L: 11.7-12.5 GHz	Broadcast Satellite Services (BSS). Polarisation is dual circular, but dual linear is currently essentially exclusively used in Europe.
D/L: 17.7-20.2 GHz U/L 27.5-30.0 GHz	Multimedia two-way services with lower parts of the bands mainly used with gateways and higher parts of the bands mainly used with users. Polarisation is circular in USA. Polarisation was initially linear in Europe, but new systems like Eutelsat Ka-Sat and Avanti Hylas will use circular polarisation.

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5.5 References in chapter 5

[1] L. Pettersson, Shi Cheng, M. Salter, A. Rydberg, D. Platt, "Compact integrated slot array antennas for the 79 GHz automotive band", EuMC, Rome, Paper 12-4, 28 Sep-2 Oct 2009.

[2] M. Schneider, "Automotive radar - Status and trends", German Microwave Conf., Ulm, Paper 5.3, 5-7 Apr. 2005.

[3] R.H. Rasshofer, Y. Naab, "77 GHz long range radar systems status, ongoing developments and future challenges", EuRAD 2005, Paris, pp. 161-164, 6-7 Oct. 2005.

[4] F. Pfeiffer, E.M. Biebl, "Inductive compensation of high-permittivity coatings on automobile long-range radar radomes", IEEE Trans. Microwave Theory Techn., vol. MTT-57, pp. 2627-2632, Nov. 2009.

[5] H.-L. Bloecher, A. Sailer, G. Rollmann, J. Dickmann, "79 GHz UWB automotive short range radar - Spectrum allocation and technology trends", Advances in Radio Science, vol. 7, pp. 61-65, 2009.

5.6 Summary

Wideband antennas will definitely be required for future automotive wireless services. First we considered non-interactive services up to and including C band where wideband antennas – each providing multiple services – can drastically reduce the number of antennas to be integrated on a car. The automotive applications put a severe stress on the design of these antennas. Their design needs to fulfil the above derived requirements for an efficient application.

The 60-80 GHz bands for future automotive applications pose similar problems with high number of sensors required per vehicle and a potential to combine functions.

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6. Expert group 4 and 5: Array and smart antennas.

Smart car antenna needs review

Cooperative vehicle systems represent the marriage of the intelligent vehicle and the intelligent highway and are expected to enhance public safety and improve the mobility of the overall transportation system. All of them perform the called Intelligent Transportation System (ITS). A set of different standards can be used covering different kinds of system communications from satellite and terrestrial broadcast, GPS/Galileo, Wimax/2G/3G to closer communication systems: Wifi, DSRC, I2V, V2V, P2V and IR. However, not all the communication systems get advantages with the usage of smart antennas. In the following sections a summary of the standards and which information is needed for the application on smart antennas on cars is covered.

6.1 Specific V2V Standards

6.1.1 IEEE 802.11 P

This standard is an evolution of IEE802.11 (WiFi WLAN Solution). It is an amendment to be used in vehicular environment: roadway safety and emergency services.

The main radio characteristics are:

a) BW per channel of 10MHz

b) Bit Rate of 3, 4.5, 6, 9, 12, 18, 24, and 27 Mbps

c) The European frequency allocation has a band of 30 MHz from 5.875 to 5.905 GHz. This is the European Radiocommunication Office (ERO) [1] proposed for Intelligent Transportation Systems Radio Service (ITS) Aug 2008 but the ETSI EN 302 571 allocates it at 5.855 GHz to 5.925 GHz.

d) The USA allocation has a frequency band of 75 MHz at 5.850-5.925 GHz. It has been defined by the FCC for Intelligent Transportation Systems Radio Service (ITS-RS)

6.1.2 WAVE (Wireless Access in Vehicular Environments)

It has its own network and transport layer protocol called WAVE short message protocol (WSMP) evolved from IEEE 802.11p to support both vehicle-to-vehicle and vehicle-to-roadside communication, but the physical layer is the same of IEEE 802.11p.

6.1.3 DSRC (Dedicated Short Range Communication)

The target of this standard is:

a) Freight and fleet management,

b) Automatic vehicle identification,

c) Traffic control and parking management

In Europe the DSRC systems has a bandwidth of 10 MHz at 5.795-5.805 GHz proposing ETSI Standards downlink channels with a bit rate of 500 kbps and uplink channels with a rate of 250 kbps.

In USA DSRC services have been allocated at 5.9 GHz Band. However, it has been superseded by IEEE 801.11p.

The Japanese proposal for DSRC is collected at the standard ARIB STD-T55. The frequency bandwidth is at 5.8 GHz band with 1 Mbps of bit rate.

However, some millimetre Bandwidths for ITS&DSRC at 63& 64 MHz bands according to EN 302 571 and ISO/CD 21217 have been proposed too.

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6.1.4 Wireless broadband networks

Mobile Wimax (IEEE 802.16e) has been proposed for ITS services, but without a predefined bandwidth (<11 GHz). On the hand, South Korea authorities defined the Wibro (Wireless broadband) with a dedicated bandwidth of 100 MHz at 2.3 GHz.

6.1.5 CALM

CALM, Communication/continuous air-interface long and medium range, has been proposed by the ISO TC 204 WG 16 [2]. It is a framework intended to be used in packet-switched networks in mobile environments using different carriers, e.g., 2G, 3G,WiMAX, based on the internet protocol version 6 (IPv6), that is to say, CALM-M5 to incorporate the WAVE profile or CALM-IR to incorporate an infrared profile.

6.2 Non Specific V2V Standars

6.2.1 NGH

Next Generation Handheld (NGH) [3] system is needed to accompany digital switch over and convergence of fixed and mobile services as well as telecommunication services and what is more to facilitate the multimedia content consumption in an efficient, flexible and robust way.

MISO and SIMO (diversity reception) will provide a significant gain compared to SISO systems, but taken in consideration that T2 is already MISO-capable, and SH is strongly suggesting SIMO implementation, NGH needs to go further, and offer MIMO as the big step ahead.

NGH will be available over 5 MHz, 6MHz, 7 and 8 MHz bandwidth over the classical VHF and UHF TV broadcasting band:

- Band III: 174 MHz - 220 MHz (VHF)
- Bands IV and V: 470 MHz - 861 MHz

6.2.2 LTE

LTE (Long Term Evolution) is the standard that describes the evolution of the air interface for cellular mobile communication systems called usually 4th generation (4G), from the networks known as 3G. LTE is a set of enhancements to the Universal Mobile Telecommunications System (UMTS) which will be introduced in 3rd Generation Partnership Project (3GPP) Release 8.

Release 8's air interface, E-UTRA (Evolved UTRAN) uses OFDMA for the downlink and Single Carrier FDMA (SC-FDMA) for the uplink and employs MIMO with up to four antennas per station. LTE supports both FDD and TDD mode. While FDD makes use of paired spectra for UL and DL transmission separated by a duplex frequency gap, TDD is alternating using the same spectral resources used for UL and DL, separated by guard time.

The operating bands and channel bandwidth of LTE can be found in [4]. It has been summarized here.

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Table 6-1 Operating bands and bandwidths applied to the E-UTRAN

E-UTRAN Operating Band		Bandwidth	Region
Uplink	Downlink		
1920 MHz to 1980 MHz	2110 MHz to 2170 MHz	5, 10, 15, 20	Japan, Europe, Asia
1850 MHz to 1910 MHz	1930 MHz to 1990 MHz	1.4, 3, 5, 10, 15, 20	Canada, United States, Latin America
1710 MHz to 1785 MHz	1805 MHz to 1880 MHz	1.4, 3, 5, 10, 15, 20	Finland,' Hong Kong
1710 MHz to 1755 MHz	2110 MHz to 2155 MHz	1.4, 3, 5, 10, 15, 20	Canada, US, Latin America
824 MHz to 849 MHz	869 MHz to 894 MHz	1.4, 3, 5, 10	Canada, US, Australia
830 MHz to 840 MHz	875 MHz to 885 MHz	5, 10	Japan
2500 MHz to 2570 MHz	2620 MHz to 2690 MHz	5, 10, 15, 20	EU
880 MHz to 915 MHz	925 MHz to 960 MHz	1.4, 3, 5, 10	EU, Latin America
1749.9 MHz to 1784.9 MHz	1844.9 MHz to 1879.9 MHz	5, 10, 15, 20	Canada, US, Japan
1710 MHz to 1770 MHz	2110 MHz to 2170 MHz	5, 10, 15, 20	Brazil, Uruguay, Ecuador, Peru
1427.9 MHz to 1452.9 MHz	1475.9 MHz to 1500.9 MHz	5, 10, 15, 20	Japan (Softbank, KDDI, DoCoMo)
698 MHz to 716 MHz	728 MHz to 746 MHz	1.4, 3, 5, 10	
777 MHz to 787 MHz	746 MHz to 756 MHz	1.4, 3, 5, 10	
788 MHz to 798 MHz	758 MHz to 768 MHz	1.4, 3, 5, 10	
704 MHz to 716 MHz	734 MHz to 746 MHz	1.4, 3, 5, 10	
1900 MHz to 1920 MHz		5, 10, 15, 20	
2010 MHz to 2025 MHz		5, 10, 15	
1850 MHz to 1910 MHz		1.4, 3, 5, 10, 15, 20	
1930 MHz to 1990 MHz		1.4, 3, 5, 10, 15, 20	
1910 MHz to 1930 MHz		5, 10, 15, 20	
2570 MHz to 2620 MHz		5, 10	EU
1880 MHz to 1920 MHz		5, 10, 15, 20	
2300 MHz to 2400 MHz		10, 15, 20	China

6.3 References in chapter 6

[1] ERO web page: http://www.ero.dk/
[2] CALM web page: http://www.isotc204wg16.org/
[3] TM-H NGH Study mission report (Final) TM 4026r1. .06.2008. Digital Video Broadcasting.
[4] 3GPP TS 36.101 (Release 8.4.0)

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