



Technical Report

**Electromagnetic compatibility
and Radio spectrum Matters (ERM);
System Reference document (SRdoc);
Surveillance Radar equipment for helicopter application
operating in the 76 GHz to 79 GHz frequency range**

Reference

DTR/ERM-TGSRR-64

Keywords

aeronautical, radar, regulation, SRDoc

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Foreword

This Technical Report (TR) has been produced by ETSI Technical Committee Electromagnetic compatibility and Radio spectrum Matters (ERM).

Executive summary

The helicopter's unique hover and vertical take-off/landing capabilities make it ideally suited for transport in difficult access areas, take-off and land in confined areas (Figure 1) and perform hoisting operations (Figure 2). In these frequently encountered and demanding mission elements the pilot faces an increase in workload when scanning for obstacles and monitoring helicopter state. Especially in degraded visual conditions and unknown or confined areas, there is an imminent danger of collision with all kinds of obstacles, which continues to be among the top causes of civil helicopter accidents.



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Figure 1: Operations in confined areas



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Figure 2: Hoisting operations close to obstacles

The present document describes the heliborne application of 76 GHz to 79 GHz radar technology, in a near environment obstacle warning system. The application here used the benefit that automotive radar made the technology available but the technical parameters and sensor architecture for helicopter are different. The intended function of this system is to detect and inform the flight crew of obstacles in the direct vicinity of the helicopter environment. The surround coverage of the radar system will aid the crew in the obstacle detection task while manoeuvring at low airspeeds typically close to the ground. The system will help and improve the probability of detection of obstacles thereby increasing situational awareness and flight safety. It will reduce pilot's workload and can save time in critical flight phases, which is important especially for safety of life services.

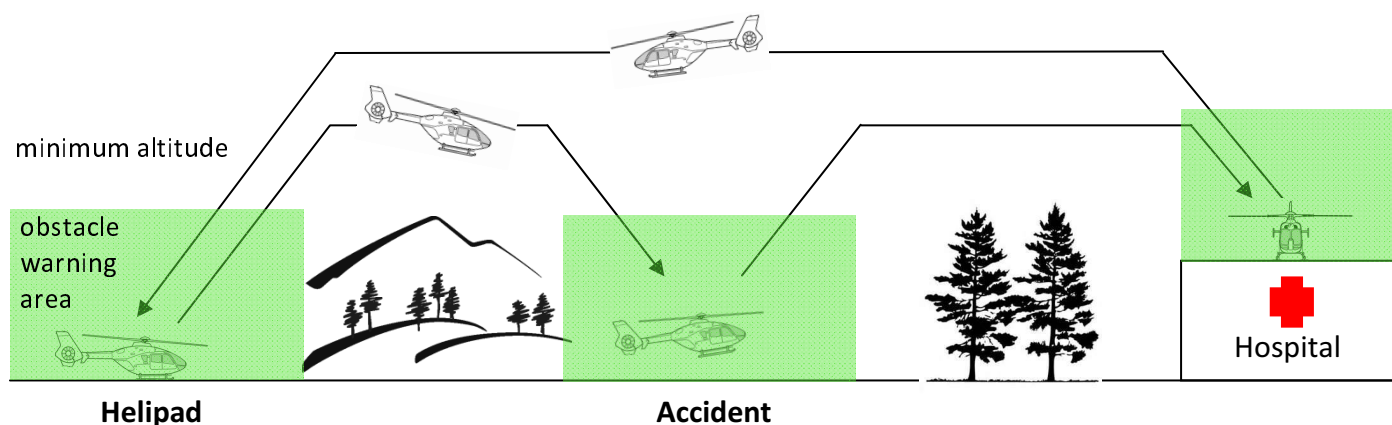


Figure 3: Typical operational profile for helicopter emergency medical service

Figure 3 shows a typical HEMS (helicopter emergency medical service) mission. The helicopter takes off from the helipad/airfield using the obstacle warning system until it rises out of the obstacle scene. After arriving at the accident site, the helicopter descends to the landing zone and picks up the person injured. During landing, hover and take-off, the obstacle warning system inform the flight crew of obstacles in the direct vicinity of the helicopter environment. The helicopter flies in cruise altitude to the hospital. During landing and take-off at the hospital, the flight crew again is informed of obstacle by the obstacle warning system. The system will be switched off during cruise flight back to the helicopters air base but will be active during the landing phase at the air base.

Minimum flying altitudes and off-field landing are regulated for each state.

Examples of regulation:

- Germany:
 - Landing outside of airfield (off-field landing) is only allowed after permission from authority. Exceptions are e.g. emergency landing and helicopter emergency medical service.
 - Minimum altitude is 300 m (1 000 feet) above residential area, production plants, gatherings and accident sites above the highest obstacle in an area of 600 m. For all other areas it is 150 m (500 feet) above ground and water.

For cross-country flights, a minimum altitude of 600 m (2 000 feet) is applicable.
- France:
 - Landing outside of airfield (off-field landing) is only allowed after permission from authority. Exceptions are e.g. emergency landing and helicopter emergency medical service.
 - Minimum altitude is 300 m (1 000 feet) above residential area, production plants, gatherings and accident sites. For all other areas it is 150 m (500 feet) above ground and water.

The Size, Weight and Power (SWaP) characteristics of 76 GHz to 79 GHz sensors make them ideally suited for use on smaller H/C types typically being used by civil operators. Due to the short wavelength and high bandwidth the precise measurement (in range and doppler) enables an accurate and reliable detection of those obstacles posing a threat to safe helicopter operations. The fact, that the automotive radar technology is proven and readily available makes it the only affordable sensor technology for a short-term market entry for this novel kind of application.

The aim is to enable the usage of already existing technology available e.g. in the automotive area for helicopter applications.

In the introduction of ERC Recommendation 70-03 [i.10], the following is stated:

"The CEPT has considered the use of SRD devices on board aircraft and it has concluded that, from the CEPT regulatory perspective, such use is allowed under the same conditions provided in the relevant Annex of Recommendation 70-03. For aviation safety aspects, the CEPT is not the right body to address this matter which remains the responsibility of aircraft manufacturers or aircraft owners who should consult with the relevant national or regional aviation bodies before the installation and use of such devices on board aircraft."

Introduction

The present document has been developed to support the co-operation between ETSI and the Electronic Communications Committee (ECC) of the European Conference of Post and Telecommunications Administrations (CEPT).

1 Scope

The present document describes the radar based surveillance applications in the 76 GHz to 79 GHz frequency range for a helicopter obstacle warning system. The 76 GHz RTTT Standard EN 301 091 [i.5] and the 77 GHz to 81 GHz RTTT Standard EN 302 264 [i.8], could be used as a baseline to defines the technical characteristics and test methods for this new radar equipment operating in the 76 GHz to 79 GHz range.

It includes in particular:

- Market information.
- Technical information (including expected sharing and compatibility issues).
- Regulatory issues.

2 References

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the reference document (including any amendments) applies.

Referenced documents which are not found to be publicly available in the expected location might be found at <http://docbox.etsi.org/Reference>.

NOTE: While any hyperlinks included in this clause were valid at the time of publication, ETSI cannot guarantee their long term validity.

2.1 Normative references

The following referenced documents are necessary for the application of the present document.

Not applicable.

2.2 Informative references

The following referenced documents are not necessary for the application of the present document but they assist the user with regard to a particular subject area.

- [i.1] EASA: "Annual Safety Review 2010", 2011.
- [i.2] ITU Radio Regulations (Edition of 2012).
- [i.3] ERC Report 25: "The European table of frequency allocations and utilisations in the frequency range 9 kHz to 3000 GHz".
- [i.4] CEPT/ERC/Recommendation 74-01: "Unwanted Emissions in the Spurious Domain".
- [i.5] ETSI EN 301 091 (Parts 1 and 2): "Electromagnetic compatibility and Radio spectrum Matters (ERM); Short Range Devices; Road Transport and Traffic Telematics (RTTT); Radar equipment operating in the 76 GHz to 77 GHz range".
- [i.6] Commission Implementing Decision 2011/829/EU of 8 December 2011 amending Decision 2006/771/EC on harmonization of the radio spectrum for use by short-range devices.
- [i.7] Commission Decision 2004/545/EC of 8 July 2004 on the harmonization of radio spectrum in the 79 GHz range for the use of automotive short-range radar equipment in the Community.

- [i.8] ETSI EN 302 264 (Parts 1 and 2): "Electromagnetic compatibility and Radio spectrum Matters (ERM); Short Range Devices; Road Transport and Traffic Telematics (RTTT); Short Range Radar equipment operating in the 77 GHz to 81 GHz band".
- [i.9] ECC/DEC/(04)03 of 19 March 2004 on the frequency band 77 - 81 GHz to be designated for the use of Automotive Short Range Radars.
- [i.10] CEPT/ERC REC 70-03: "Relating to the Use of Short Range Devices (SRD)".

3 Abbreviations

For the purposes of the present document, the following abbreviations apply:

e.i.r.p.	equivalent isotropically radiated power
EASA	European Aviation Safety Agency
EESS	Earth Exploration Satellite Service
EUT	Equipment Under Test
FMCW	Frequency Modulated Continuous Wave
FPGA	Field Programmable Gated Array
H/C	Helicopter
HEMS	Helicopter Emergency Medical Services
ISM	Industrial, Scientific and Medical
LPR	Level Probing Radar
MIMO	Multiple Input Multiple Output
MMIC	Monolithic Microwave Integrated Circuit
PDCF	Power Density Correction Factor
RBW	Resolution Bandwidth
RCS	Radar Cross Section
RF	Radio Frequency
RTTT	Road Transport and Traffic Telematics
SRD	Short Range Devices
SRR	Short Range Radar
TLPR	Tank Level Probing Radar
UWB	Ultra-Wideband
VLBI	Very Long Baseline Interferometry

4 Comments on the System Reference Document

No comments raised by ETSI members.

5 Presentation of the system or technology

The proposed system concept consists of multiple radar sensors distributed around the helicopter fuselage to detect obstacles entering a certain protective volume around the helicopter. The surround coverage of this Heliborne Obstacle Warning system will aid the crew in the obstacle detection task while manoeuvring at low airspeeds typically close to the ground. The system reduces the risk of collision with objects by an early detection of obstacles and will therefore improve safety for aircrew, passengers and persons on the ground. The system is developed to perform adequately even in degraded visual conditions in which the pilot's ability to visually detect obstacles might otherwise be severely compromised.

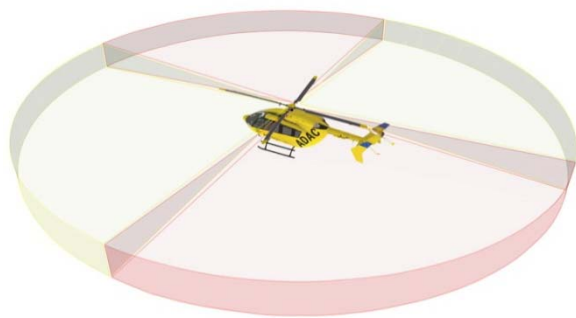
Depending on the required coverage, the field-of-view of the individual sensors, the installation location and the number of sensors to be integrated might vary.

The obstacle warning function can be decomposed in the following subfunctions:

- The Detection Subfunction for the perception of the environment as used by automotive radar technology operating in the range 76 GHz to 79 GHz.

- After subsequent processing the obstacle information can be presented to the flight crew.

In an example implementation the sensors are integrated below the main rotor head in a distributed manner such as to cover a larger horizontal field-of-view (Figures 4 and 5). In this orientation the Heliborne Obstacle Warning System is aimed at providing obstacle warning for obstacles that enter the main rotor plane. Typical use cases therefore involve hovering flight as well as manoeuvring at low airspeeds.



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Figure 4: E.g. sensor coverage (360° configuration)



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Figure 5: Landing in confined area

For a small helicopter type as depicted above, typically 4 sensors need to be integrated to cover the full 360° horizontal field-of-view.

As described earlier, the operational benefit of this system is in the initial or final phases of flight in which the helicopter manoeuvres in ground vicinity at low airspeeds. It is in those flight phases in which there is an increased risk of collision with all kinds of obstacles. The system will be used in environment with obstacles in the vicinity of the helicopter, only. It will be switched off if the helicopter leaves this environment. This will be defined in the flight manual. The effective detection range of the sensor system is prescribed by the velocity at which the helicopter approaches the environment as well as the minimum warning time needed for the pilot to assess the situation and initiate evasive manoeuvres. When considering only hovering and low-air-speed manoeuvring phases of flight (e.g. landing, hoisting operations, taxiing), the required detection range is limited to 250 m which is similar to detection range of automotive radars for which the 77 GHz technology has been developed. The required transmit power as described in the 76 GHz to 77 GHz regulation (refer to Recommendation 70-03 Annex 5, Frequency Band c [i.10]) is sufficient.

However, in the 77 GHz to 81 GHz regulation (refer to Recommendation 70-03 [i.10], Annex 5, Frequency Band e) the obstacle warning sensor will exceed the transmit power as it is not sufficient to detect all relevant obstacles within the required 250 m detection range.

The performance of the system is defined by the probability of detection within the detection range of those obstacles that typically pose a threat to helicopter operations in hover or at low airspeeds. Frequently encountered obstacles of particular danger are for instance suspended wires (e.g. overhead power lines, guy wires), poles, fences, trees, buildings, etc.

The Heliborne Obstacle Warning System is designed to inform the flight crew about the presence and location of obstacles. In a first implementation the system is an aid to the pilot with the pilot being responsible to visually verify the obstacle indications given by the system. The output of the system has to be interpreted as an indication and will improve the probability of detection of obstacles by the pilot.

The certification of the obstacle warning system will require a certification which is under the responsibility of respective certification authorities (e.g. EASA) and is not discussed in the present document.

Table 1: Technical parameters of the obstacle warning system




Technical Parameter of the obstacle warning system (example)	
Frequency Range	76 GHz to 79 GHz
Range of Sensor	250 m
Peak Power (e.i.r.p.)	40 dBm/50 MHz
Mean power spectral density (e.i.r.p.)	32 dBm/MHz
Bandwidth for 76 GHz to 77 GHz	800 MHz
Bandwidth for 76 GHz to 79 GHz	100 MHz with typical center frequencies of 76,05 GHz, 77,5 GHz and 78,95 GHz
Operational cycle of transmitter	50 ms, within this time the transmitter is active for 6 to 14 ms


Table 2: Technical parameters of the scenario

Technical Parameter of the scenario	
Field of View coverage	Full coverage
Typical minimum RCS of the objects detected	-10 dB/m ²
Typical number of helicopter operating in the scene	One helicopter, for specific scenarios like large scale operations of Emergency Medical Services or Police Services, several helicopter can be in the scene

The following table gives an overview of the different mission types that will have a direct benefit of the proposed system in various mission elements. It is obvious, that the proposed Heliborne Obstacle Warning System can offer valuable support to the flight crew in a wide range of missions in a wide range of operating environments. Not only does the flight crew benefit from the increase in flight safety, also passengers, victims to be rescued and people on the ground have a direct benefit of safer helicopter operations.

Table 3: Mission types

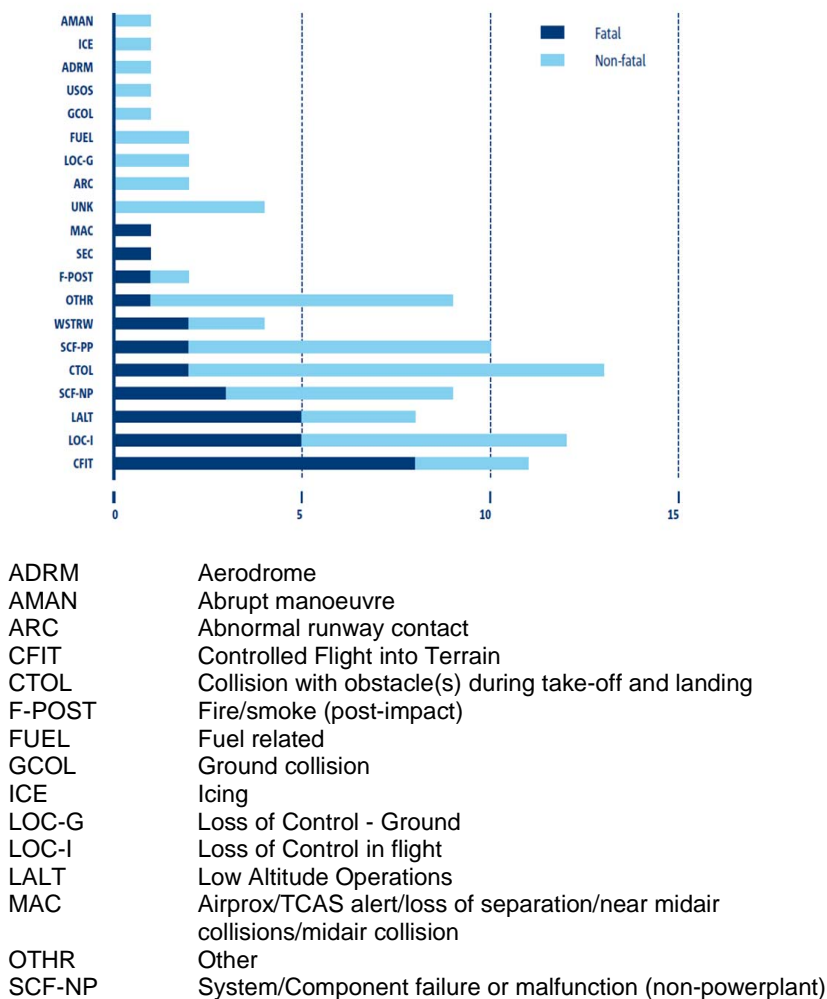
MISSION	MISSION ELEMENTS
<p>HEMS - Helicopter Emergency Medical Services</p>  <p>© Eurocopter/Photo Patrick PENNA</p> <p>Figure 6</p>	<ul style="list-style-type: none"> • Off-field landings in confined areas or complex obstacle environments. Typically primary rescue mission, transport of medical personnel, equipment and victims directly from the scene (e.g. accident, disaster relief) • Hoisting operations close to obstacles (e.g. mountain rescue close to rock formations) • Landing at terrain slopes • Operations in degraded visual conditions
<p>Offshore Operations</p>  <p>© Eurocopter/Photo Jérôme DEULIN</p> <p>Figure 7</p>	<ul style="list-style-type: none"> • Landing at ship deck or oil rigs • Wind park maintenance. Hoisting operations of maintenance personnel • Search and Rescue operations (hover and hoisting operations close to ship structure)
<p>Utility & Transport</p>  <p>© Eurocopter/Photo Christophe GUIBBAUD</p> <p>Figure 8</p>	<ul style="list-style-type: none"> • Forestry and logging (sling load operations) • Firefighting (sling load operations with water buckets) • Power line inspection • Gas pipe inspection <p>NOTE: The picture shows a low level operation.</p>

MISSION	MISSION ELEMENTS
<p>Private / Commercial Transport Use</p>  <p>© Eurocopter/Photo Anthony PECCHI</p> <p>Figure 9</p>	<ul style="list-style-type: none"> • VIP flights • Sightseeing • Transfer flights

6 Market information

6.1 Accidents

Figure 10 depicts a resent EASA (European Aviation Safety Agency) statistic on the accident numbers per cause for civil commercial air transport in the period 2001 - 2010 [i.1].



SCF-PP	System/Component failure or malfunction (powerplant)
SEC	Security related
UNK	Unknown or undetermined
USOS	Undershoot/overshoot
WSTRW	Windshear or thunderstorm

Figure 10: Accident categories for fatal and non-fatal accidents for commercial helicopters (2001 - 2010)

The category with the highest number of fatalities assigned is 'Controlled Flight into Terrain' (CFIT). When ignoring the categories concerned with 'loss of control in flight' (LOC-I) and 'system component failure' (SCF-NP), two categories related to obstacle collisions can be seen to take up the 3rd and 5th place. The category 'low altitude operations' (LALT) covers accidents with terrain or objects while intentionally flying close to the surface but excluding take-off and landing phases of flight. The category CTOL comprises the collision with obstacles during take-off and landing. Although the higher number of fatalities can be attributed to the higher speeds in cruise flight, collisions with obstacles during landing and take-off are clearly the main cause for helicopter commercial air transport accidents in general.

Contributing to the above statistics are challenges typical for commercial operations such as Helicopter Emergency Medical Services (HEMS). HEMS missions provide medical assistance in situations where either a traditional ambulance cannot reach the scene easily or quickly enough, or the patient needs to be transported over a distance or terrain that makes air transportation the most practical transport. Primary rescue missions in which patients or victims need to be transported from the scene of an accident to the hospital often involve landings in unknown, unprepared environments are part of the daily routine. Additional stress related to the urgency of the situation or deteriorating weather conditions compromises safety even further. These Safety-of-Life services will greatly benefit from the system described herein.

The aforementioned statistics once more reveal the need for a system which supports the pilot or crew in the obstacle detection task. For this purpose, various systems have been developed using a wide range of active sensing technologies. The majority of systems, however, come at a high cost often combined with a large physical size and power consumption. These systems are therefore deployed on military platforms. The system described in the present document realises a miniaturised, low-cost obstacle warning system specifically for civil operators.

Due to the missing awareness of the direct environment around the helicopter (especially to the rear side), the risk of overlooking an obstacle and possible obstacle strike is increased. Especially in situations in which pilot workload is already increased when for instance flying in degraded weather conditions, confined area or under high operational pressure, etc.). Statistics reported an accident rate of 8,7 per 100 000 flight hours in 2007 where controlled flight into terrain and collision with obstacles during take-off and landing claim a considerable share.

6.2 Market Potential

For 2008, it was estimated that approximately 6800 helicopters were registered in Europe for civil use. Thereof about 2500 helicopters are equipment with turbine engine. No reliable flight hour data is available for all registered helicopters across Europe. However, for the year 2008 a total of 1,7 million flight hours and 4.7 million landings was estimated for turbine powered helicopter, involved in civil use, registered in Europe [i.1].

The main criterion for a market launch of the system is its economical operation in daily helicopter flight. Only a system acquiring benefit to the operator will be installed and operated. The usage of available technology is therefore mandatory to allow success to the system in the near future.

Market size estimation for the obstacle warning system is:

- 10 % equipped in the first 5 years after market entry.
- 50 % equipped in the years 5 to 10 after market entry.
- 80 % equipped in the years 10 to 15 after market entry.

Since the sensors which are planned to be used for helicopters are already available for automotive radars synergy effects can be expected.

7 Technical information

7.1 Detailed technical description

The sensor unit consists in the example as shown in Figure 11, of an RF-Frontend with typically two transmitters and a 16 channel receiver with integrated baseband-signal conditioning. The Transmitter consists of a highly integrated 77 GHz SiGe-MMIC with signal-generator and up to 4 transmit-amplifiers. A top level diagram of the radar unit is given in Figure 11.

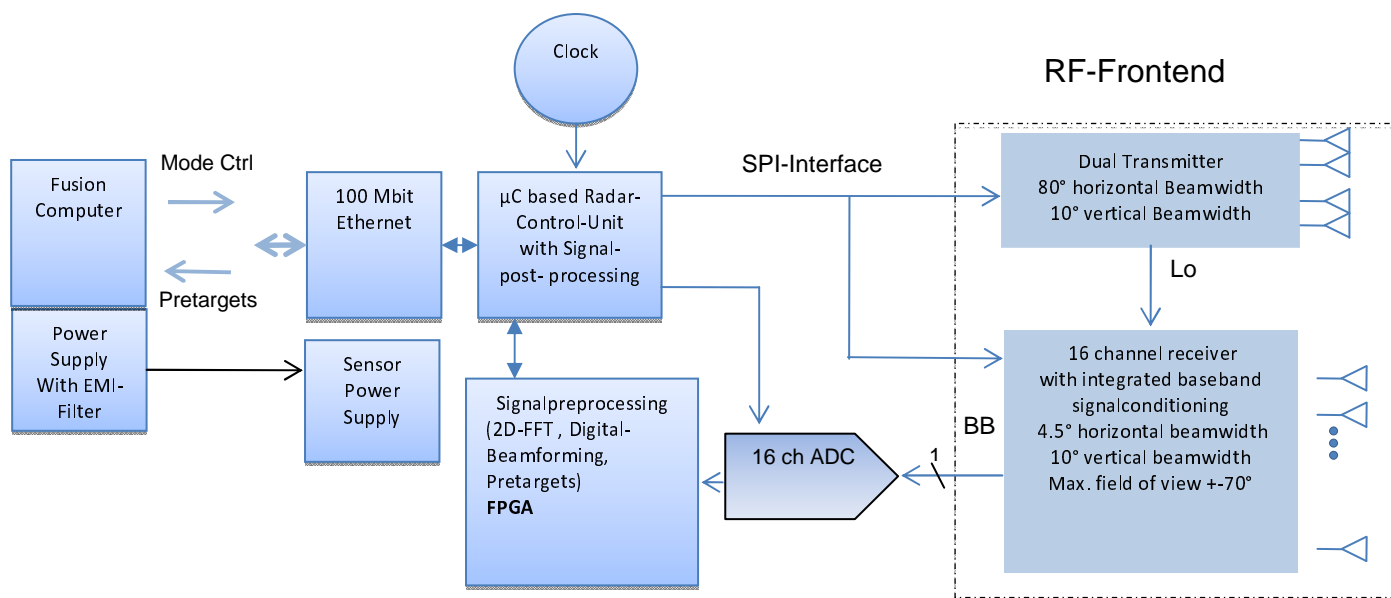


Figure 11: Top Level diagram of the radar sensor unit

The receiver-part consists of several SiGe-MMICs each with typically 4 receive-channel, forming a 16 channel receiver. A functional block diagram of the RF-Frontend is given in Figure 12.

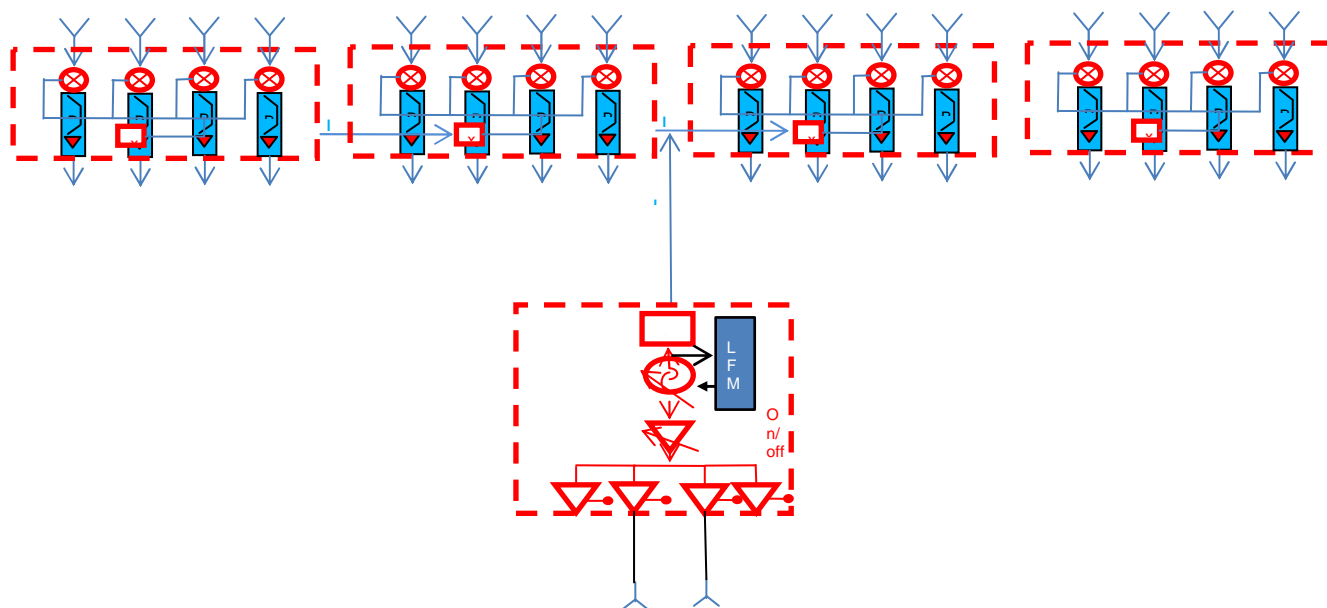


Figure 12: Functional block diagram of the RF-Frontend

The Transmitter has an integrated signal generator, which creates a fast ramp FMCW signal which will be sent sequentially by one of the two transmitters. The transmitter waveform as well as the receiver-data-acquisition is steered by a microcontroller via SPI-Interface. On the receiver site, each channel is connected to a single antenna-column with a wide horizontal and a narrow vertical beam. The signals of the receivers are sampled and pre-processed using the massive parallel signal processing capability of an FPGA. The signal processing is providing information about range and velocity of the detected objects. In the horizontal plane, the output of the receivers is combined using digital beam forming techniques. This allows a digital scan in the horizontal plane from -70° up to $+70^\circ$. By the use of two transmitters the beam can be additionally sharpened in the horizontal plane with MIMO techniques.

NOTE: The described sensor concept is not comparable with the architecture of an automotive radar sensor.

7.2 Technical parameters and implications on spectrum

7.2.1 Status of technical parameters

7.2.1.1 Current ITU and European Common Allocations

Current allocation of the candidate bands in the ITU Radio Regulations [i.2] is included in Table 1, together with actual usage within the CEPT.

Table 4: ITU Allocations and actual usage within CEPT

Frequency band	ITU allocations in Region 1	Actual usage of the band at national level within CEPT	Actual usage of adjacent bands at national level within CEPT
76 GHz to 77,5 GHz	RADIO ASTRONOMY RADIOLOCATION Amateur-Satellite Amateur Space Research (space-to-Earth)	Amateur, Amateur-satellite, SRR, Radiolocation (civil) Radiodetermination applications (Within the band 75 GHz to 85 GHz for TLPR and LPR applications) Railway applications (Obstruction/vehicle detection at level crossings) Radio astronomy (primary service) (Continuum and spectral line observations) RTTT (Within the band 76 GHz to 77 GHz Radar. Road Transport and Traffic Telematic) (SRD application)	Amateur, Fixed, Space research (VLBI), Amateur-satellite, Radiodetermination applications (Within the band 75 GHz to 85 GHz for TLPR and LPR applications)
77,5 GHz to 78 GHz	AMATEUR-SATELLITE AMATEUR Radio Astronomy Space Research (space-to-Earth)	SRR Radio astronomy (Continuum and spectral line observations) Radiodetermination applications (Within the band 75 GHz to 85 GHz for TLPR and LPR applications)	
78 GHz to 79 GHz	RADIOLOCATION Amateur Amateur-Satellite Radio Astronomy Space Research (space-to-Earth)	SRR Radio astronomy (Continuum and spectral line observations) Radiodetermination applications (Within the band 75 GHz to 85 GHz for TLPR and LPR applications) Defence systems Radiolocation (civil)	SRR Radio astronomy (Continuum and spectral line observations) Radiodetermination applications (Within the band 75 GHz to 85 GHz for TLPR and LPR applications) Defence systems Radiolocation (civil)

Current common allocation of the above bands in Europe is given in ERC Report 25 [i.3].

Current worldwide common allocation of the above bands is given in ITU Radio Regulations [i.2].

7.2.1.2 Sharing and compatibility studies (if any) already available

The ECC Report 56 considers the impact of automotive collision warning Short Range Radars (SRR) operating at 79 GHz on radiocommunication services with a primary allocation in the frequency range 77 GHz to 81 GHz. It does not address the impact of radiocommunication services on SRR receivers; as the latter are expected to operate on a non-interference non-protected basis.

The following 3 radiocommunication services have been considered:

- Radiolocation Service.
- Radio Astronomy Service (that is the primary service).

- Radio Amateur and Amateur Satellite Services.

The ECC Report 56 could be considered as a basis for compatibility studies.

7.2.1.3 Sharing and compatibility issues still to be considered

Airborne applications have not been considered up to now. The ECC Report 56 could be considered as a basis for compatibility studies.

For the helicopter radar systems it needs to be studied under which conditions (height above ground, speed, mitigation techniques) these helicopter applications can be used and what will be the influence on the services and applications already operations in the band 76 GHz to 77 GHz, as well as for 76 GHz to 79 GHz:

- Radiolocation Service.
- Radio Astronomy Service (that is the primary service).
- Radio Amateur and Amateur Satellite Services.
- Earth Exploration Satellite Service (EESS).
- And intra SRD studies (helicopter versus automotive, helicopter versus fixed road infrastructure and helicopter versus (T)LPR).

7.2.2 Transmitter parameters

7.2.2.1 Transmitter Output Power / Radiated Power

NOTE: The sensor is operated in two modes. Both modes use the same power level.

The transmitter is using a highly linear fast ramp FMCW-modulation with a ramp-duration of less than 50 microseconds. The two transmitters are operated in an alternating way. During one transmit-receive-cycle, multiple ramps are transmitted. Following the transmit-receive-cycle, the acquired signals are processed. During this time transmitter and receiver are switched off, resulting in a duty-cycle of less than 50 %. Figure 12 shows a typical timing diagram. The two transmitters are activated sequentially. Each of them transmits a fast ramp FMCW-Signal with 128 ramps. After 6,6 ms transmitter and receiver are switched off for the following signal processing time of typically 30 ms.

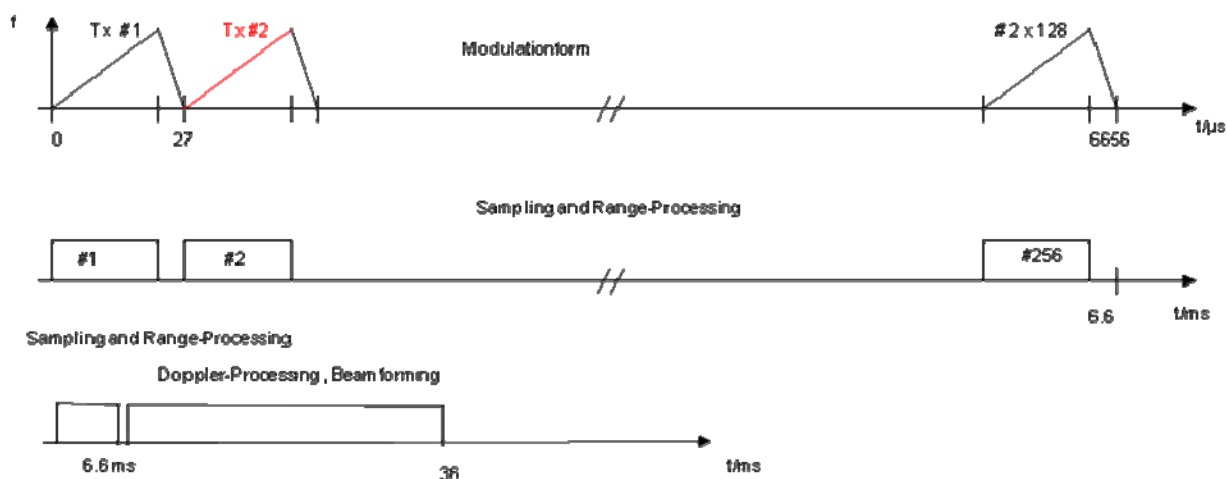


Figure 13: Typical timing Diagram of the sensor

For the frequency band 76 GHz to 77 GHz, the following limits for transmitted power are applicable according to EN 301 091-1 [i.5] (Class 1).

Table 5: 76 GHz to 77 GHz, Limits with fixed beam antenna

	Class 1 (systems others than pulsed Doppler radar)	Class 2 (pulsed Doppler radar only)
Mean Power (e.i.r.p.)	50 dBm	23,5 dBm
Peak Power (e.i.r.p.)	55 dBm	55 dBm
NOTE: Refer to EN 301 091-1 [i.5], clause 7.2.3.1, table 1.		

For the frequency band 77 GHz to 81 GHz, the following limits for broadband maximum radiated average power spectral density (e.i.r.p.) are applicable according to EN 302 264-1 [i.8].

Table 6: Limits for broadband maximum radiated average power spectral density (e.i.r.p.) in the frequency band from 77 GHz to 81 GHz

Frequency in GHz	77 GHz to 81 GHz
Maximum radiated average power spectral density (e.i.r.p.) [dBm/MHz] of the EUT	-3 dBm/MHz
NOTE: Refer to EN 302 264-1 [i.8], clause 7.2.3.1, table 1.	

For the frequency band 77 GHz to 81 GHz, the following limits for maximum transmitted peak power (e.i.r.p.) are applicable according to EN 302 264-1 [i.8].

Table 7: Limits for maximum transmitted peak power (e.i.r.p.) in the 77 GHz to 81 GHz band

Frequency in GHz	77 GHz to 81 GHz
Peak Power (e.i.r.p.) measured in 50 MHz bandwidth (dBm)	55
NOTE: Refer to EN 302 264-1 [i.8], clause 7.1.3.3, table 2.	

The applicable limits for the transmitted power between 76 GHz and 77 GHz are above the limits given in ERC/REC 70-03 [i.10], annex 5 and are above the limits between 77 GHz and 81 GHz given in ECC/DEC(04)03 [i.9]. The required values are given in Table 8.

The mean power will be measured according the test procedure described in EN 302 264-1 [i.8]. The peak power can also be measured as described in EN 302 264-1 [i.8] with the following restriction.

For unpulsed modulation schemes (like e.g. FMCW radar) the PDCF (Power Density Correction Factor) will not be applied because the peak power reading is correct for any RBW between 50 MHz to 1 MHz.

Table 8: Overview of transmitter radiated power

	Present Regulation		Radar Device for Helicopter Application
		FMCW/Class1	
Frequency	77 GHz to 81 GHz	76 GHz to 77 GHz	76 GHz to 79 GHz
Mean power spectral density (e.i.r.p.)	-3 dBm/MHz	20 dBm/MHz (see note)	32 dBm/MHz
Peak power (e.i.r.p.)	55 dBm/50 MHz	55 dBm	55 dBm
Operating Distance	30 m	150 m	250 m
NOTE: Assumption of 1 GHz bandwidth.			

7.2.2.1a Antenna Characteristics

The maximum antenna gains will be 18 dBi.

Add typical antenna gain.

The horizontal half power beamwidth is less than 80 degree, without sidelobes as shown in Figure 14.

The vertical half power beamwidth is less than 10 degree with sidelobes below -15 dBc as shown in Figure 15.

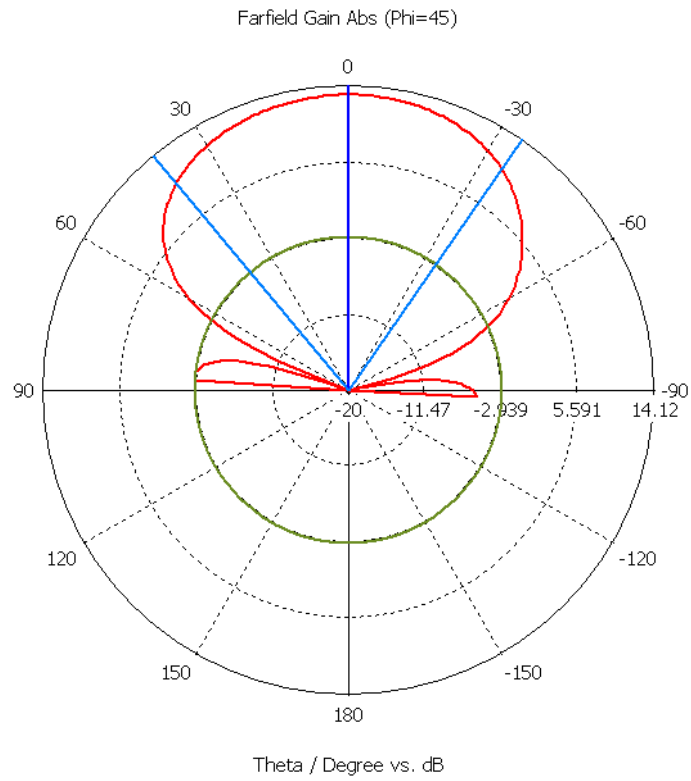


Figure 14: Typical horizontal antenna diagram of the transmit-antenna and of a single receive-antenna

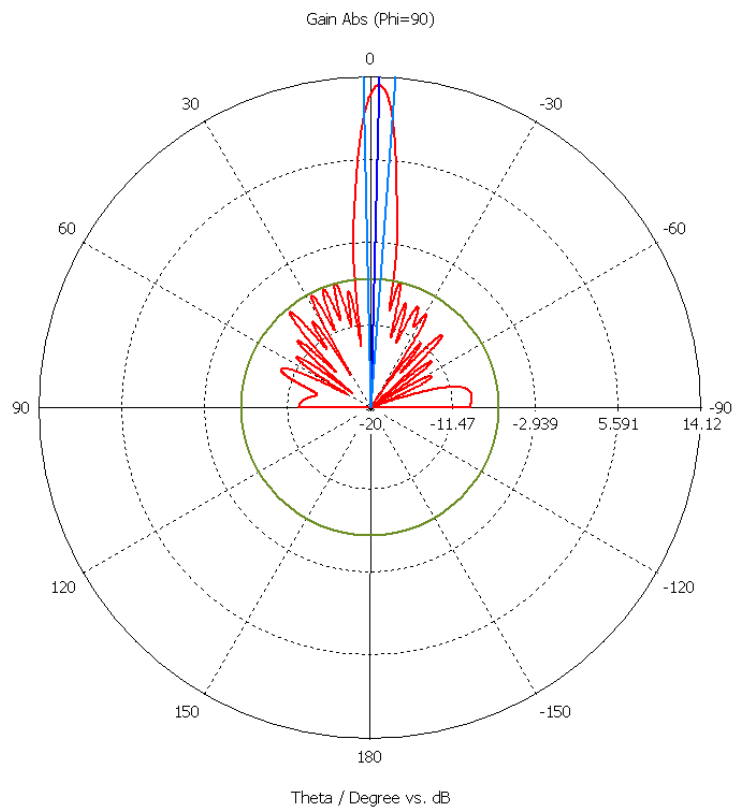


Figure 15: Typical vertical Antenna diagram of the transmit-antenna and the receive-antenna

7.2.2.2 Operating Frequency

The permitted range of operating frequencies for intentional emissions will be from 76 GHz to 79 GHz.

7.2.2.3 Bandwidth

The sensor will be operated for coverage of the main rotor plane in the frequency band from 76 GHz to 77 GHz with a maximum modulation bandwidth of 800 MHz. The broad bandwidth is necessary for high range resolution at distances up to 40 m which allows precision information to the pilots of the helicopter.

For coverage below the main rotor plane, not only horizontal but also vertical beam steering is required. The sensor is modulated with a bandwidth of typically 100 MHz at different center frequencies, e.g. typically 76,05 GHz, 77,5 GHz and 78,95 GHz. The different center frequencies are necessary to provide additional beam steering in vertical direction.

7.2.2.4 Unwanted emissions

For consideration of the sensor working in the frequency range of 76 GHz to 79 GHz, the following out of band emission limits are applicable, see Table 9.

Table 9: Limits of out of band emissions 76 GHz to 79 GHz

Frequency range	Limit values for out of band emissions
73,5 GHz to 76 GHz	0 dBm/MHz
79 GHz to 79,5 GHz	0 dBm/MHz

The out of band emissions outside the 76 GHz to 77 GHz band will not exceed the values shown in Table 10 if only the band 76 GHz to 77 GHz is considered for the application.

Table 10: Limits of out of band emissions 76 GHz to 77 GHz

Frequency	Maximum mean power emissions
73,5 GHz to 76 GHz	0 dBm/MHz
77 GHz to 79,5 GHz	0 dBm/MHz

The spurious emissions will not exceed the values given in Table 11, in accordance to CEPT/ERC/Rec. 74-01 [i.4].

Table 11: Limits of spurious emissions

Frequency range (MHz)	Limit values for spurious emissions (e.i.r.p.)
47 MHz to 74 MHz	-54 dBm/100 kHz
87,5 MHz to 118 MHz	-54 dBm/100 kHz
174 MHz to 230 MHz	-54 dBm/100 kHz
470 MHz to 862 MHz	-54 dBm/100 kHz
otherwise in band 30 MHz to 1 GHz	-36 dBm/100 kHz
1 GHz to 160 GHz	-30 dBm/1 MHz

7.2.3 Receiver parameters

The homodyne Radar Sensor converts the RF-Signal directly into the baseband without any IF-Frequency.

The total receiver bandwidth is less than 10 MHz. The input-stage of the receiver is an active mixer with a noise of typically 15 dB. By combining and integrating multiple channels, the receiver can detect signals below -120 dBm. The channel to channel isolation is more than 20 dB.

7.2.4 Channel access parameters

As described in clause 7.2.2.1 the transmitter and receiver are powered on during less than 50 % of the operational cycle.

The operational cycle of transmitter is about 50 ms. Within this time, the transmitter is active for 6 ms to 14 ms.

7.3 Information on relevant standard(s)

A relevant standard does not exist. EN 301 091 [i.5] and EN 302 264 [i.8] could be the basis for a future standard for the helicopter application.

8 Radio spectrum request and justification

The request is to allocate the following for the helicopter radar application.

Table 12: requested radar characteristic

Frequency	76 GHz to 79 GHz
Mean power spectral density (e.i.r.p.)	32 dBm/MHz
Peak power (e.i.r.p.)	40 dBm/50 MHz

The 76 GHz to 77 GHz band has been chosen as sensor platform in order to realize the Heliborne Obstacle Warning System. Nevertheless from a technical point of view an operation of the system in the 79 GHz band would be possible, as well.

The available technology advantages are high range resolution, low weight and size, simplified and robust technical design suitable for helicopter application, good penetration performance compared to optical systems through environmental conditions like fog, rain, dust and snow. It is available at an attractive cost which provides the chance of a significant market penetration of this system resulting in increase of safety of helicopter operation.

76 GHz to 79 GHz radar technology is still available as a mature, robust and cost efficient platform for the sensor development. Moreover, only sensors operating in the millimeter waveband (W-band) are able to reach adequate dimensions and weights, with respect to given sensor performance parameters (in particular the angular resolution, which is directly dependent on the aperture dimensions). This required sensor performance is related to the objective of an obstacle warning system to inform the pilot of even small obstacles like suspended wires which are one of the most dangerous threats for helicopters.

In addition, the 60 GHz and 122 GHz bands as potential alternative bands for Heliradar operation were discussed within TGSRR, but considered to be not appropriate.

In the 60 GHz and 122 GHz band no mature RF components for radar sensors are available. RF components at 60 GHz are focused on communication applications. At 122 GHz only components on research level exists. The regulation does not provide the necessary transmit power to detect small objects (like suspended wires). Furthermore qualified and mature components are commercially not available.

Table 13 gives a comparison of other radar allocations and the proposed applications.

Table 13: Radar performance overview and evolution of systems (automotive and non-automotive allocations)

Frequency range (see note 1)	Narrowband 24 GHz	24 GHz/26 GHz UWB	76 GHz	79 GHz	122 GHz ISM
Sensor performance for proposed applications (summary of all three parameters / resolutions) (see notes 2, 3 and 4)	0	+	++	+++	+++
ΔV : Velocity Axis $\Delta \phi$: Angle Axis ΔR : Range Axis					

Frequency range (see note 1)	Narrowband 24 GHz	24 GHz/26 GHz UWB	76 GHz	79 GHz	122 GHz ISM
Bandwidth	200 MHz	> 2 GHz	1 GHz	4 GHz	1 GHz
Regulated output power	++	0	++	+	
Radar Cross Section influence (cooperative contribution)	+	+	++	++	+++
Technology available	++	++	++	++	+ technology 0 for sensor realization
NOTE 1: Other frequency ranges below 24 GHz were not taken into account, because of possible/reachable sensor performance for the proposed applications.					
NOTE 2: The smaller the cubic, the better the radar performance.					
NOTE 3: Doppler resolution of object distance is RF frequency dependent, Higher RF frequency enables better Doppler resolution.					
NOTE 4: For a given aperture, the resolution increases with frequency. Angular resolution is directly related to antenna aperture.					

So based on actual information in table Table 13, it is possible to conclude in general for all applications in the present document that:

- 76 GHz to 79 GHz sensors have a factor 3 to 5 times better object separation by distance compared to 24 GHz narrow band solutions due to higher useable bandwidth of 1 000 MHz vs. typical available bandwidth of 200 MHz for 24 GHz narrow band sensors.
- 76 GHz to 79 GHz sensors have a factor 3 times better accuracy in measurement of relative velocity compared to 200 MHz narrowband solutions due to better Doppler resolution at higher carrier frequency.
- 76 GHz to 79 GHz sensors have a factor 1/3 smaller size of antenna structure compared to 24 GHz solutions at equal field of view (opening angle/detection range) due to necessary antenna aperture size.
- With higher frequencies it is possible to use the better RCS factor of a target/object.

$$\text{With e.g. } RCS = \frac{4 * \pi * a^4}{3 * \lambda^2};$$

and a = dimension of the target/object, in this case radar corner reflector, $\lambda = \frac{c_0}{f}$.

9 Regulations

9.1 Current regulations

NOTE: Refer also to clause 7.2.1.1.

Currently, the European regulatory framework is available for ground based vehicle, tank level probing radar and infrastructure applications only, and does not include similar helicopter radar applications, where the 76 GHz to 77 GHz band is covered under:

- 2011/829/EU: Commission Implementing Decision of 8 December 2011 amending Decision 2006/771/EC on harmonisation of the radio spectrum for use by short-range devices [i.6].

and the 77 GHz to 79 GHz band under:

- 2004/545/EC: Commission Decision of 8 July 2004 on the harmonisation of radio spectrum in the 79 GHz range for the use of automotive short-range radar equipment in the Community [i.7].

9.2 Proposed regulation and justification

Airborne 7XGHz are currently not regulated. It needs to be analyzed if this can be covered in REC 70-03 as SRD or if this airborne application needs to be regulated under the relevant airborne radio regulations.

It is proposed, that CEPT considers, based on the already existing regulatory requirements for radar applications in the frequency range 76 GHz to 79 GHz, what steps would be necessary to allow a harmonisation for helicopter radar applications across the CEPT region.

Since the helicopter radar applications are intended to use the same technology as automotive radar applications for which regulatory requirements already exist, a revision of these regulatory requirements to include helicopters would appear to be an appropriate regulatory instrument. This would allow the highest degree of harmonisation across the CEPT region and would give easy and prompt access to the spectrum. If this approach will not be possible the developing of a new ECC Decision would seem to be an appropriate alternative.

9.3 Proposed ETSI actions

Based on the proposal given by CEPT it is proposed, that ETSI will draft a corresponding ETSI Standard.

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History

Document history		
V1.1.1	January 2014	Publication